Book of abstracts

An overview of marine research in Belgium anno 2009

10th VLIZ Young Scientists' Day
Special edition at the occasion of 10 years VLIZ

VLIZ

Thermae Palace, Oostende
27 November 2009

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Vlaams Instituut voor de Zee
Flanders Marine Institute

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PREFACE

This is the 'Book of Abstracts' of the 10th edition of the annual VLIZ Young Scientists' Day, a one day event that was organized on 27 November, 2009 in Thermae Palace Hotel, Oostende to mark the 10th anniversary of the Flanders Marine Institute.

When we invited the marine science community to contribute to a poster session and competition, we had the ambition to illustrate the diversity, quality and relevance of marine and coastal sciences in Belgium to an audience of scientists, funding agencies, policy makers and journalists.

With an exhibition of more than 150 posters, I think it is fair to say that we have succeeded. Marine and coastal scientists from all Flemish universities, associations and scientific institutes – and representing all marine science disciplines – have contributed. We also welcome many contributions from private companies, administrations, the Belgian French-speaking universities, and Dutch research institutes. Furthermore, the abstracts of the applicants and laureates of the 'VLIZ aanmoedigingsprijzen mariene wetenschappen 2009' and 'Annual VLIZ North Sea Award 2009' are also included in this volume.

This book therefore provides a beautiful and comprehensive snapshot of the state-of-the-art of marine scientific research in Flanders in 2009.

Thirty abstracts have been selected for a plenary oral presentation. Today, the relevance and quality of these short 'pitching' presentations will be evaluated by a professional jury of science communicators and journalists. The challenge for the young scientists is to present their research in an exciting way and to 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.

Oostende, 27 November 2009

Dr Jan Mees
Director VLIZ

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ANNUAL VLIZ THESIS AWARDS MARINE SCIENCES 2009

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 2009 winners of the Annual VLIZ Thesis Award Marine Sciences are:

DENNIS DE RYCK

Onderzoekseenheid Algemene Plantkunde en Natuurbeheer (APNA),
Vrije Universiteit Brussel

for the thesis entitled:

Verspreiden en vestigen: experimenten over processen van verpreiding en vestiging van hydrochore mangrovepropagulen
Moving and settling: experiments on the dispersal and establishment of hydrochorous propagules

&

THOMAS VERLEYE

Onderzoekseenheid Paleontologie, Vakgroep Geologie en Bodemkunde,
Universiteit Gent

for the thesis entitled:

Het Holocene paleomilieu van de zuidwestelijke Zwarte Zee: een reconstructie aan de hand van dinoflagellatencysten en andere palynomorfen
The Holocene palaeoenvironment of the southwestern Black Sea: a reconstruction based on dinoflagellate cysts and other palynomorphs

VERSPREIDEN EN VESTIGEN: EXPERIMENTEN OVER PROCESSEN VAN VERPREIDING EN VESTIGING VAN HYDROCHORE MANGROVE-PROPAGULEN

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Mangrovebossen vormen een divers ecosysteem in de zone tussen land en zee, met als basiseenheid de facultatief halofyte mangroveboom. Doordat het leven in zout water een hoge fysiologische stress met zich meebrengt, zoals het minder beschikaar zijn van het levensnoodzakelijke water in deze omgeving, hebben mangrovebomen zich moeten aanpassen. Naast aanpassingen zoals bijvoorbeeld luchtwortels en zoutklieren hebben verschillende mangrovesoorten vivipare propagulen geëvolueerd als mechanisme om zich te verspreiden via water (Tomlinson, 1994). Viviparie is een type van zaadkieming, waarbij er geen dormante fase is (stop in embryonale groei) zoals bij de meeste andere zaadplanten. Het embryo groeit hierdoor uit tot een 'kleine boom' (zonder wortels en bladeren), die nog steeds aan de ouderlijke boom hangt. Zodra deze 'kleine boom' dan loskomt van de ouderlijke boom heeft hij de mogelijkheid om zeer snel wortel te schieten en blaadjes te ontwikkelen.

In de laatste decennia werd het brede publiek steeds vaker geconfronteerd met de problematiek omtrent de stijgende bedreiging van ecosystemen overheen de wereld. Dit leidt vaak tot degradatie van vele ecosystemen door overexploitatie en vervuiling. De lokale bevolking, die afhankelijk is van lokale producten voor inkomen en voeding is de dupe van deze degradatie door de afname van broodnodige hulpbronnen. Het mangrovewoud bevindt zich in deze situatie als uiterst gevoelig ecosysteem onder enorme anthropogene druk. Doordat deze modderige, dense wouden vaak gezien worden als 'wastelands' worden grote delen ontbost en/of omgevormd in functie van stedelijke of landbouwontwikkeling. Mangrovebomen kunnen zich echter niet vegetatief voortplanten en zijn dus enkel aangewezen op zaadverspreiding om zich te regenereren en gebieden te (her)koloniseren. Kennis omtrent deze verspreidingsdynamiek is daardoor uitermate belangrijk om regeneratie van deze wouden te begrijpen en geschikte behoudsplannen op te stellen. Alhoewel de hydrochorie van mangrove propagulen reeds lange tijd gekend is, werd er tot nu toe maar weinig onderzoek gedaan naar het verspreidingsproces en zijn bepalende factoren.

Deze studie is een onderdeel van een groter framework van studies op mangrove-structuur, -functionaliteit en -dynamiek. Het algemene doel van deze studies is om de invloed van biotische en abiotische factoren op het mangrove ecosysteem te begrijpen. Het begrijpen van deze invloeden is een fundamenteel doel, maar is tegelijkertijd ook bedoeld om bij te dragen tot of het verbeteren van rehabilitatie en duurzaam management van de mangrove ecosystemen.
In mijn thesis onderzochten we de verspreidingsdynamiek, wortelgroei en anatomische structuur van mangrove zaden (propagulen). Het doel van deze studie is om informatie te verzamelen over de verspreidingsdynamiek van mangrove zaden (propagulen), om een bijdrage te leveren aan de huidige leemte in kennis betreffende het moment tussen het loskomen van de propagule (van de ouderlijke boom) en vestiging na een zekere verspreidingsperiode via water (hydrochorie). We beogen hiermee een bijdrage te leveren tot een beter begrip van het rehabilitatiesucces van mangroven, mangrove verspreiding (langsheen het intergetijdegebied) en zonatiepatronen.
Mangrovebomen, die hun propagulen normaliter verspreiden via water, hebben een complex verspreidingspatroon dat afhankelijk is van tal van verwoven factoren, zoals saliniteitsgradiënten, bodemstabiliteit en inundatie door getijden. Inzichten in deze differentiële propaguleverspreiding van mangrovesoorten is van fundamenteel belang om de soortenverspreiding van mangroven te begrijpen op zowel een lokale als een globale schaal. Op een lokale schaal gaat propaguleverspreiding een rol spelen in het onstaan van zonatiepatronen die in verschillende mangrovegebieden worden geobserveerd. Ook op een globale schaal is het de verspreiding van propagulen die kan bijdragen tot het verklaren van de latitudinale grenzen en de genetische structuur van de mangrovewouden.

We bestuderen deze verspreidingsdynamiek d.m.v. een 'tracking experiment'. Hierbij laten we met verf gemerkte propagulen van twee mangrovesoorten (*Ceriops tagal* en *Rhizophora mucronata*) los in verschillende vegetatie-assemblages, waarna hun verspreiding gedurende enkele weken wordt gevolgd. De experimentele setup werd zo eenvoudig mogelijk gehouden om, op zijn minst

gedeeltelijk, de complexiteit van de verspreidingsdynamiek te ontleden. We vonden significante verschillen tussen de gekozen plots, waarbij:

- propagulen die losgelaten werden in de meest landwaartse en zeewaartse plots verspreiden vaak over grote afstanden[1];
- propagulen losgelaten in het dense midden van het mangrovewoud (hoge worteldichtheid en modderig substraat) verspreiden over korte afstanden en ondervonden hoge predatie door krabben.

Alhoewel de meeste propagulen verspreidden in een landwaartse richting of evenwijdig aan de kustlijn, werd er geen eenduidige verspreidingsrichting geobserveerd. Dit toont het belang van de locale topografie aan bij verspreiding, daar het de richting van de getijdenstromingen beïnvloedt en dus ook onrechtstreeks de verspreidingsrichting van propagulen.

Ons baserend op de resultaten uit het 'tracking experiment' en op experimenten, waarbij we de snelheid van *C. tagal* propagulen nagingen tegenover *R. mucronata* propagulen in een getijdenstroming, kunnen we besluiten dat *C. tagal* propagulen snellere verspreiders zijn en meer predatie ondervinden door verschillen in hun morfologie (vb. grootte) en anatomische eigenschappen (vb. dichtheid van de propagule en breedte van zijn cuticulum).

De hypothese die resulteerde uit een vorige studie (De Ryck *et al.*, 2007) en stelde dat de verminderde drijfkracht van uitgedroogde propagulen veroorzaakt werd door het krimpen van luchtholtes in het aërenchyma, werd verworpen. Door de anatomie van propagulen te bestuderen ontdekten we dat het de parenchyma cellen zijn die krimpen door vochtverlies en niet de luchtkamers.

Door de lage overlevingskansen van *C. tagal* en *R. mucronata* propagulen (door bv. predatie en uitdroging), eventueel gekoppeld aan uiteindelijk vrij geringe geschiktheid voor lange-afstandsverspreiding, vroegen we ons af of het wel nuttig is om een dergelijke grote energie-investering te doen als de mangroveboom in de zeer grote propagulen (die dan beperkter moeten zijn in aantal), een als het ware falende K-strategie. Om dit na te gaan bedachten we een experiment om te gaan kijken of deze groene propagulen eventueel de energiebehoefte naar de ouderlijke boom kunnen verminderen d.m.v. autonome fotosynthese. Nadat we *C. tagal* propagulen in een (kledings)stof wikkelden, dat de lichtintensiteit ongeveer 24 maal verminderde, vergeleken we de verschillen in lengtegroei tussen 'in stof gewikkelde' en normale propagulen. Een significant verminderde groei bij 'in stof gewikkelde' propagulen werd waargenomen, wat onze hypothese i.v.m. autonome fotosynthetische activiteit ondersteunt.

Als conclusie kunnen we zeggen dat 'tracking experimenten' een groot potentieel hebben om de verspreidingsdynamiek in het veld bloot te leggen, als een adequaat aantal propagulen wordt teruggevonden en over een voldoende grote perimeter[2] kan gezocht worden. Een mogelijke opschaling van 'tracking experiment' resultaten kan bewerkstelligd worden door deze in te voeren in voorspellende modellen (predictieve/dynamische modellen) (Di Nitto *et al.*, 2008), wat echter de complexiteit vergroot en de nauwkeurigheid doet dalen.

Verder observeerden we dat propaguleverspreiding sterk gelinkt is aan de lokale topografie (doordat deze de getijdenstromingen en diepte van het zeewater bepaalt) en dat predatie door krabben en obstructie door stelt-, knie- en dense 'potlood'-wortels belangrijke factoren zijn die de verspreidingsafstand van propagulen sterk reduceren. Alhoewel *C. tagal* propagulen het meest gepredateerd werden, lijken deze te beschikken over eigenschappen (e.g. lagere weefseldichtheid) die geschikter zijn voor lange afstandsverspreiding dan deze van R. mucronata propagulen.

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[1] Om een idee te geven van wat we bedoelen met grote afstanden: de landwaartse plots (>50m tot verschillende honderden meters) en de zeewaartse plots (>50m mogelijk tot verschillende kilometers).

[2] Voldoende grote perimeter: een vooropgestelde perimeter waarin gezocht wordt, die groot genoeg is om de meeste verspeidende propagulen te omvatten, maar niet zo groot is dat men over propagulen begint te kijken tijdens het zoeken.

HET HOLOCENE PALEOMILIEU VAN DE ZUIDWESTELIJKE ZWARTE ZEE: EEN RECONSTRUCTIE AAN DE HAND VAN DINOFLAGELLATENCYSTEN EN ANDERE PALYNOMORFEN

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Opmerking: Ouderdommen in abstract zijn niet gecalibreerd, in de Masterscriptie wordt wel naar gecalibreerde ouderdommen verwezen! Deze aanpassing werd in acht genomen wegens problemen met het reservoireffect in de Zwarte Zee (Marret et al.*, 2009). Voor verdere informatie aangaande de dateringen van de aangewende kern wordt verwezen naar Lamy* et al. *(2006) en Kwiecien* et al. *(2008).*

Tijdens het Holoceen werd de Zwarte Zee, oorspronkelijk een zoet/brakwatermeer, gekenmerkt door een opvallende saliniteitstoename. Dit was het gevolg van de herverbinding met de Middellandse Zee via de Straat van Bosporus, de Marmara Zee en de Dardanellenstraat (*Marmara Sea Gateway*). Het aantal studies betreffende deze herverbinding steeg exponentieel na de publicatie van de zogenaamde '*Noah's Flood Hypothesis'* door Ryan *et al.* (1997). Deze studie veronderstelde een catastrofale heropvulling van de Zwarte Zee met zout water, resulterend in een snelle stijging van zowel de saliniteit als de waterspiegel (Ryan and Pitman, 1998). Deze hypothese werd weerlegd door de '*Outflow Hypothesis*' geïntroduceerd door Aksu *et al.* (2002), welke een uitstroom van zoet/brak water veronderstelde van de Zwarte Zee naar de Marmara Zee voordat het globale zeeniveau de Bosporus sill-diepte bereikte. Deze hypothese veronderstelt een geleidelijke saliniteitstoename en een langzame zeespiegelstijging (na de herverbinding) gelijk met deze van de oceanen.

De door ons aangewende proxy, teneinde een beter zicht te krijgen op de herverbinding tussen de Zwarte Zee met de Marmara Zee, zijn dinoflagellatencysten. Dinoflagellaten zijn ééncellige organismen met een grootteorde tussen de 15 en 200 µm. Onder de planktonische dinoflagellaten komen enerzijds meroplanktonische (planktonisch actief haploïd stadium, diploïd stadium hoofdzakelijk als cyste) en anderzijds holoplanktonische soorten (in beide stadia planktonisch actief) voor. Het cystestadium vertegenwoordigt meestal een rustperiode, vandaar de term *resting cyst* of hypnozygote. Dinoflagellatencysten zijn gekend als belangrijke paleomilieu-indicatoren, en verschaffen informatie over saliniteit-, temperatuur- en productiviteitsvariaties. Deze veranderingen komen tot uiting in wijzigingen van de cystenassemblages en door morfologische aanpassingen van bepaalde species (vb. *Lingulodinium machaerophorum, Operculodinium centrocarpum*). Deze species vertonen immers een variabele uitsteeksellengte als reactie op een wijzigende saliniteit/temperatuur ratio (Mertens *et al.*, 2009), waarbij lage saliniteitswaarden resulteren in korte uitsteeksels of uitsteeksels met bolvormige uiteinden (Lewis and Hallett, 1997). Bij een constante temperatuur (saliniteit) is men in staat saliniteit (temperatuur) te reconstrueren gebaseerd op uitsteeksellengte variaties. Daar de saliniteitswijzigingen in de Zwarte Zee tijdens het Holoceen van een ongeziene grootteorde zijn kunnen we stellen dat de uitsteeksellengtes hier voornamelijk variaties in saliniteit zullen weerspiegelen.

Het voornaamste doel van deze studie was het bepalen van het tijdstip en het tempo van de herverbinding tussen de Zwarte Zee en de Marmara Zee. Hiervoor werd kern GeoB 7625-2 (41°26.7'N; 31°04.0'E) aangewend. Deze kern is aangeboord op zo'n 50 km ten noordoosten van de monding van de Sakarya rivier en ~150 km ten oosten van de Bosporusstraat. Het diepte-ouderdom model van kern GeoB 7625-2 is gebaseerd op een visuele correlatie tussen de ^{14}C-AMS gedateerde nabijgelegen kernen GeoB 7622-2 (0-624 cm; correlatie gebaseerd op lamina) en MD04-2760 (624-725 cm; correlatie gebaseerd op Calcium record). Tussen de top van de kern (0.52 ka BP) en 622 cm (7.42 ka BP) werd de kern bemonsterd met een resolutie van ~200 jaar. Het dieper gedeelte van de kern (tot 680 cm; 10.74 ka BP) werd bemonsterd met een variabele resolutie, rekeninghoudend met het belang van bepaalde tijdsintervallen teneinde een eenduidige conclusie te formuleren.

Vijf belangrijke opeenvolgende dinoflagellatencysten zones konden onderscheiden worden waarbij de overgang tussen Zone 1 en 2 te wijten is aan een sterke saliniteitsverandering. Zone 1 komt voor van de basis van de kern tot 8.08 ka BP en wordt gekenmerkt door de dominantie van de stenohaline zoet- tot brakwatertaxa *Pyxidinopsis psilata* en *Spiniferites cruciformis*. Gebaseerd op

de huidige voorkomens van beide species schatten we dat de saliniteit van de oppervlaktewateren een waarde tussen 7 en 12 psu vertoonde vóór 8.08 ka BP. De afname van *Pyxidinopsis psilata* doorheen Zone 1 wordt gecompenseerd door een toename van *Spiniferites cruciformis* en is mogelijks te wijten aan opwarming tijdens dit tijdsinterval. Het eerste voorkomen van de euryhaline species *Operculodinium centrocarpum* en *Spiniferites* spp. (exclusief *Spiniferites cruciformis*) op 8.25 ka BP is hoogstwaarschijnlijk gerelateerd aan de initiële herverbinding met de Marmara Zee. Tussen 8.08 en 7.97 ka BP vond een sterke afname plaats van zoet/brakwater species van 60% naar 5% van de totale dinoflagellatencysten assemblage. Dit duidt op een duidelijke verandering in het milieu. De korte uitsteeksellengtes van zowel de *Spiniferites* species als *Lingulodinium machaerophorum* wijzen op een lage saliniteit rond deze tijd.

Een vergelijking met de kern M02-45 (Marret *et al*., 2009), ten westen van de Bosporus, duidt op een diachronisme in de verzilting van de Zwarte Zee. De verzilting van de regio rond de monding van de Sakarya rivier blijkt zo'n 600 jaar eerder te zijn gebeurd in vergelijking met de regio ten westen van de Bosporus (althans op de ondiepe shelf). Dit impliceert dat er geen catastrofale intrusie van marien water in de Zwarte Zee heeft plaatsgevonden. De reden voor de vroegere verzilting te oosten van de Bosporus, samen met de kortere overgangsperiode van zoet/brak water naar meer saline waters in vergelijking met de regio te westen van de zee-engte, kan te wijten zijn aan de oostwaarts stromende zoute waterpluim vanuit de Bosporusstraat. Deze saline waters beïnvloeden zo rechtstreeks ons studiegebied. Een niet-catastrofale herverbinding wordt tevens bekrachtigd door de geleidelijke toename van de uitsteekssellengtes van *Lingulodinium machaerophorum* tussen 8.25 en 4.12 ka BP.

Tijdens het Holoceen worden de hoogste relatieve abundanties van *Lingulodinium machaerophorum* waargenomen tijdens periodes met lage rivierinput, terwijl het omgekeerde geldt voor *Spiniferites* spp. en cysten van *Pentapharsodinium dalei*. Deze laatsten zijn in vergelijking met andere cysten vaak slecht bewaard, wat zou kunnen wijzen op transport van de shelfgebieden tijdens perioden met een hoger rivierdebiet. De hogere cystenconcentraties tijdens periodes van lagere rivierinput zijn niet hoofdzakelijk het resultaat van een hogere productiviteit maar kunnen tevens het resultaat zijn van een lagere terrigene input. Door het anoxische milieu, welke leidt tot een betere preservatie (o.a. Toth en Lerman, 1977; Reimers en Suess, 1983; Emerson, 1985), kan een lagere sedimentatiesnelheid leiden tot een vertekende toename van de cystenconcentratie, en dus mogelijks verkeerdelijk geïnterpreteerd worden als een verandering in productiviteit.

Verder heeft deze studie geen duidelijk verband aangetoond tussen de saliniteitsvariaties in ons studiegebied en veranderingen in de debieten van de Sakarya rivier (*clay layer frequency* curve; Lamy *et al*., 2006). Dit impliceert dat de veranderingen in saliniteit onder andere het resultaat zijn van oceanografische veranderingen zoals de niet constante doorstroom van zout water van de Marmara Zee naar de Zwarte Zee. Tevens kan de saliniteit beïnvloed worden door veranderingen in de totale input van zoetwater in de Zwarte Zee door regenval (gerelateerd met NAO/AO cycli) en grote stromen zoals de Donau, Dnjepr en Dnjestr. We dienen hier echter tevens te vermelden dat de *clay layer frequency* curve, welke de terrigene input voorstelt, tevens beïnvloed kan zijn door tektonische activiteit zoals aardbevingen en landverschuivingen.

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ANNUAL VLIZ NORTH SEA AWARD – 2009

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 aeas 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 2009 is awarded to:

MIEKE MATHYS

Renard Centre of Marine Geology, Department Geology and Soil Science, UGent

for her scientific contribution entitled:

THE QUATERNARY GEOLOGICAL EVOLUTION OF THE BELGIAN CONTINENTAL SHELF, SOUTHERN NORTH SEA

THE QUATERNARY GEOLOGICAL EVOLUTION OF THE BELGIAN CONTINENTAL SHELF, SOUTHERN NORTH SEA

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Introduction

Since the end of the 70's and beginning of the 80's, the Quaternary cover of Belgian Continental shelf (BCS) has been intensively surveyed in the framework of several national and international projects. This resulted in one of the densest regional seismic grids of the world. These high-resolution reflection seismic profiles are available in the data files of the Renard Centre of Marine Geology (RCMG). In addition, an extensive series of cores and core descriptions have been acquired over the years and are stored in the repository of the Geological Survey of Belgium (GSB). Previous analyses of these datasets, however, focused mostly on a single sandbank or a distinct sub-area of the BCS. For each of the sandbanks and sub-areas a new, local stratigraphy and interpretation was proposed in these studies. So, notwithstanding the amount of information available, the data were never processed or interpreted in an integrated, coherent and BCS-wide way. With respect to the Quaternary deposits, the BCS had thus remained one of the last unmapped and unknown areas of Belgium.
One of the key reasons for this is that the Quaternary cover on the BCS is very patchy and discontinuous, mostly shaped into isolated sandbanks by past and modern tidal currents. It has a maximum thickness of only 45 m, and is on average even less than 10 m thick. This thin, fragmented record has made it so difficult to produce a coherent reconstruction of the Quaternary evolution of the BCS, especially at times when only analogue data were available.
So, in the present digital era, the main goal of the presented study was to archive, integrate and (re-interpret all existing datasets – seismics as well as cores – in order to develop for the very first time a common stratigraphy for the Quaternary deposits on the BCS and a genetic model for the Quaternary geological evolution of the area.

Development of a Quaternary evolutionary model

In order to be able to correlate the complex Quaternary structure of one sandbank to another, the old, paper seismic recordings had to be translated into a digital format. Almost 30 years after their acquisition, more than 4000 km of high-resolution seismic profiles were scanned, converted into digital 'SEG-Y' format, and integrated with 1300 km of modern, digitally acquired seismic data, and with more than 600 core descriptions.

Seven seismic units were identified in the Quaternary deposits on the BCS. They are bounded by erosional unconformities. After calibration of the seismic characteristics with the core data, these seismic units could be assigned a lithological meaning and be interpreted in terms of depositional environment. The erosional surfaces represent important phases in the Quaternary sea-level evolution or changes in the sedimentary dynamics in response to it.
A valley incised in the Paleogene subsurface offshore Oostende, i.e. the Ostend Valley, is filled with three seismic units (U1-U2-U3). They represent three successive phases in the transgressive estuarine infilling during a relative sea-level rise. The infill is truncated at the sea bed by a ravinement surface formed by shoreface erosion and marine planation during marine transgression. On top of this regional erosional surface lies a fourth seismic unit (U4) representing tidal-flat deposits, which developed behind a coastal barrier in a back-barrier environment. On top of this unit, separated by another erosional surface, lies a fifth seismic unit (U5), which represents three parallel storm-generated sand ridges. A sixth seismic unit (U6) is interpreted as nearshore deposits consisting of reworked material of former tidal-flat deposits. The seventh, uppermost seismic unit (U7) represents mainly the recent tidal sandbanks and inter-sandbank swale sediments.

As no unreworked datable material was recognised in the available cores, it has thus far not been possible to obtain reliable absolute ages for these seismic units. The time of incision and the age range of the Ostend Valley fill had to be inferred from indirect evidence, such as the depositional depth of the seismic units and the marine transgressive surface in comparison with known relative sea-level curves (Denys and Baeteman, 1995, Siddall *et al.*, 2006). The connection to the Flemish Valley on land gave a maximum age for the Ostend Valley time of incision. For reconstructing the

Holocene evolution of the BCS, the link was made with the evolutionary history of the western Coastal Plain (Baeteman, 1999; Baeteman and Declercq, 2002; Baeteman, 2004, 2005ab). Holocene geological and archaeological reconstructions of Zeeland (The Netherlands) (Vos and van Heeringen, 1997) and historical coastline reconstructions of the Western Scheldt area (Coornaert, 1989; Augustyn, 1995; Termote, 2006) have also been taken into account. All these clues have been put together as in a giant jigsaw puzzle, to come to a comprehensive model for the Quaternary history of the BCS, which is presented in paleo-reconstructions.

The Quaternary geological evolution of the BCS

The Pleistocene evolution

Saalian glaciation

During the maximum ice-sheet extent of the Saalian glaciation (MIS6; 200-130 ka ago) a large, proglacial ice lake formed between the Scandinavian and British ice in the central North Sea area, and a ridge north of the Dover Strait (Gibbard, 2007). The Rhine-Meuse system entered this proglacial lake that reached heights similar to the present mean sea-level (Busschers *et al.*, 2007), and formed a delta close to the present-day Dutch coastline. During the following deglaciation, at the end of the MIS6 ice age, the proglacial lake breached the ridge north of the Dover Strait and drained. With dropping base level, the Meuse deeply incised in the former proglacial Rhine-Meuse braidplain and sought its way south, towards the Dover Strait, forming the Offshore Platform and Offshore scarp on its way, i.e. prominent morphological features in the Top-Paleogene surface of the BCS. Most likely also the rivers of the Flemish Valley formed a delta entering the Saalian proglacial lake. In reaction to the dropping base level, these rivers started incising as well, moulding the eastern Coastal Valley and the Ostend Valley. When the meltwater outflow diminished, and only the deeper Axial Channel was still occupied as main drainage path, a small stream in the Ostend Valley extended towards the Axial Channel cutting through the former Meuse valley flank.

Eemian interglacial

During the Eemian (MIS5e; 130-110 ka ago) sea-level rise, the sea invaded the earlier incised valleys, which evolved into estuaries. Soon, the Ostend Valley evolved into a typically funnel-shaped tide-dominated estuary, consisting of an outer estuary, middle estuary and fluvial-tidal transition zone according to the model of Dalrymple and Choi (2007). Three seismic units (U1-U2-U3) represent the estuarine infilling of the Ostend Valley. They represent each time a more seaward section of the estuary, indicative of a landward migration of the estuarine environment. With rising sea level, the estuary continuously migrated further upstream the eastern Coastal Valley, which forms the connection between the Flemish and Ostend Valley. In the process of transgression, landward and laterally migrating tidal channels, coupled with wave action, eroded part of the more landward facies, and left tidal ravinement surfaces in between the seismic units.

Meanwhile, also the coastline migrated landward, and the upper surface of the estuarine infillings became truncated at the seabed by a ravinement surface formed by shoreface erosion and marine planation during marine transgression. By the time the Eemian relative sea level reached its maximum height, comparable to the present-day level, the coastline was situated 7 km inland of the present-day shoreline (near Brugge). In the Flemish Valley, the marine influence reached as far as 40 km inland into the low-lying tributaries (De Moor *et al.*, 1996), turning a large part of the Flemish Valley into an estuarine embayment. In both the eastern Coastal Plain and Flemish Valley, the final phase in the Eemian succession is represented by the development of exposed (open marine) tidal flats.

Weichselian glaciation

At the beginning of the Weichselian period (MIS 5d-5a; 110-75 ka ago)), sea level lowered due to ice-mass expansion, and soon the North Sea floor became dry land. In our regions the climate became relatively cold, but with a very high humidity (Verbruggen *et al.*, 1991), which induced an intense and deep fluvial incision, as no permafrost was established yet. In the Flemish Valley, the Eemian sediments were largely removed. In the former Ostend Valley area, the river incised down to -21 m MLLWS. During the Early Pleniglacial (MIS4; 75-60 ka ago), characterised by a very cold and humid periglacial climate, the thalwegs evolved into braided river systems. This continued during the milder Middle Pleniglacial (MIS3; 60-25 ka ago). During the Late Pleniglacial (MIS2; 25-10 ka ago), the climate evolved to very cold and dry circumstances with very restricted vegetation. Aeolian action took over and earlier deposited fluvial sediments were blown into cover sand ridges, gradually damming the Flemish Valley. The whole northward oriented braided drainage system of the Flemish Valley was forced to branch off eastward, along the Lower-Scheldt (De Moor and Van De Velde, 1995). Since then, the Ostend Valley was no longer connected to the Flemish Valley.

Holocene evolution

Initial flooding of the southern North Sea and formation of a coastal barrier

During most of the Weichselian, the North Sea was dry land, but around 12,500 cal BP rising sea water entered the southern part of the North Sea again. Coastward sediment transport could not keep pace with the rapid rise in sea level and the relict landscape drowned rapidly (van der Molen and van Dijck, 2000). Microtidal conditions prevailed in most of the Southern Bight. In this early Holocene period, most likely an exposed tidal-flat environment developed in the Southern Bight. As groundwater level rose with sea level, the tidally flooded area was fringed by freshwater marshes in which peat accumulated, known as basal peat (Baeteman, 2004).

Around 9500 cal BP, the North Sea was already sufficient in size to produce waves at its eastern shores capable of building a protective barrier behind which a complex of estuaries and tidal basins could develop (Beets and van der Spek, 2000; van der Molen and van Dijck, 2000), represented in seismic unit U4. Sand to fill the back-barrier basins was derived from the shoreface adjacent to the tidal inlets and from the ebb-tidal deltas. As insufficient sediment was supplied to the shoreface to compensate for this sediment loss, the shoreline was forced to recede (Beets and van der Spek, 2000), while eroding the underlying deposits and previous back-barrier sediments.

Formation of storm-generated ridges from the transgressive sand sheet

Several metres of sand covered the ravinement surface cut by the barrier retreat process, i.e. the Holocene transgressive sand sheet. From this sandy layer storm-generated or shoreface-connected ridges formed erosively under influence of storm and tidal forces which left a deep imprint in the U4 surface. On the basis of morphological evidence, the Goote and Akkaertbank most likely represent former shoreface-connected ridges, represented by seismic unit U7. Their position with respect to former coastlines suggests that these banks started forming around 9500 and 8900 cal BP, respectively. Shortly later, around 8400 cal BP at a more nearshore position, the sand ridges recognised in seismic unit U5 started developing. With further rising relative sea level, the ridges became detached, but continued growing upwards. On the basis of the preserved dimensions of the ridges, it is suggested that the most nearshore ridge developed until about 7000 cal BP.

Coastal barrier stabilisation around 7500 cal BP

Since the start of the flooding of the Southern North Sea, substantial volumes of sand were eroded from the bottom and transported toward the coast by the tidal asymmetry, aided by wave suspension (van der Molen and van Dijck, 2000; van der Molen and de Swart, 2001). Around 7500 cal BP, the rate of relative sea-level rise decreased resulting in a sand surplus and consequently in the upsilting of the back-barrier tidal basins and the onset of stabilisation of the coastal barrier and closing of the tidal inlets (Baeteman and Declercq, 2002). The retreating shoreline reached in the western Coastal Plain its maximal landward position and the barrier stabilised about 3 km inland of the present-day coastline (Baeteman, 2005a). Note that the barrier retreated more or less parallel with its former position, keeping a straight coastline, but with an angle to the present-day coastline, which caused the seemingly more landward position of the barrier in the western Coastal Plain. The upsilting of the back-barrier basins resulted in the evolution of salt marsh vegetation into reed growth (fresh water marsh), and consequently in peat accumulation (Baeteman,1999; Baeteman, 2004).

Changing hydrodynamics and formation of tidal sandbanks around 7000 cal BP

With further rising sea level, the tidal and current amplitudes kept increasing until 7000 cal BP. The larger water depths allowed the tide to propagate closer to the shore, changing the shoreward net sand-transport pattern from before 7000 cal BP to a pattern of along-shore transport. The sand supply to the coast decreased, which was enhanced by a decrease in the suspension of sand by wind waves as the sea became deeper (van der Molen and van Dijck, 2000). The decrease in the rate of relative sea-level rise after 7500 cal BP (Denys and Baeteman, 1995), could compensate the reduced sediment supply, resulting in the sand surplus and consequently in the silting up of the tidal basins as mentioned above (Baeteman, 1999, 2004).

From 7000 cal BP the tidal system became comparable to the present one (van der Molen and van Dijck, 2000). Most likely from this period onwards, when the outer and middle sand ridges of U5 reached their maximum preserved heights, the tidal sandbanks of the Flemish and Hinder Banks (represented by seismic unit U7) started to develop on top of these sand ridges. The Flemish and Hinder Banks formed simultaneously, as a response of the sea bed to a suitable hydraulic regime, and are not formed diachronously, as a response to shoreface retreat due to sea-level rise. Most of the material of which the U7 banks are built up, originates from local erosion of underlying sediments, which can be deduced from the often erosional character of the base of the banks and the presence of deeply incised swales in between them.

Coastal barrier progradation from 6800-5000 cal BP

Between 6800 and 6000 cal BP, the relative sea-level rise lost its driving force (Baeteman and Declercq, 2002; Baeteman, 2005a). The relative sea-level rise decreased, so that even the reduced

sediment supply exceeded the created accommodation space, inducing the coastal barrier to prograde. In spite of a second slow-down in the relative sea-level rise, around 5500 cal BP, the barrier did not continue prograding, but stabilised. At that time in the west, the barrier had extended seaward of the modern coastline. In the east, the barrier had migrated seaward over the previous developed nearshore storm-generated ridge. The sediment deficiency responsible for the stabilisation of the barrier is due to a further reduction in sediment supply from offshore to the shoreface. The formation of the tidal sandbanks since 7000 cal BP might have played a role in this.
Meanwhile, since 6400 cal BP, periods of peat growth lasted longer and the lateral extension of freshwater marshes became more widespread (Baeteman and Declercq, 2002; Baeteman, 2008). Between 5500 and 4500 cal BP, almost the entire coastal plain had changed into a freshwater marsh with peat accumulation, the so-called surface peat (Baeteman, 1999; Beets and van der Spek, 2000).

Renewed expansion of the tidal environment and barrier retreat from 2800 cal BP to 1200 cal BP (750 AD)
After 2000-3000 years of uninterrupted peat growth (Baeteman and Declercq, 2002; Baeteman, 2008), a tidal system was again installed in the back-barrier area. This was not the result of a sea-level rise, since the sea level still rose with the same strongly reduced trend as during the peat growth. Re-entrance of the tidal system was probably induced by the cleaning of older channels due to an increased rainfall related to a climatic change around 2800 cal BP (Baeteman, 2005b). Due to compaction of the peat and collapse of the channel banks, a lowering of the ground level occurred, which induced an increase of the tidal prism of the tidal channels and consequently, deep vertical incision. Part of the sediment needed to fill the deep incised channels came from the eroding shoreface, which resulted in a landward migration of the coastline.
Around1400-1200 cal BP (550-750 AD), the newly formed channels came in infilling phase, and the major part of the plain evolved again in a supra-tidal environment. As sediment was no longer needed for the further infilling of the remaining tidal channels, the barrier retreat slowed down or even stopped, and did not retreat much further. When the receding barrier stabilised, the shoreline coincided with the present-day coastline in the west, but in the east the coastline was still located at about 10 km from the present coastline, forming the seaward boundary of the island 'Wulpen'.

Human induced barrier retreat in early 15th century
The final phase of the barrier retreat up to the present-day coastline, was a consequence of human intervention. Mismanagement of the dunes, dikes and embankments led to the inundation of the isle of Wulpen and losses of large areas of Zeeland during the storm surges in the early 15th century. This caused irreversible hydrographical changes in the mouth of the Western Scheldt. Due to these changes in the hydraulic regime and the consequently stronger tidal currents near the entrance of the widened Western Scheldt, the original – natural – and storm-induced shoreface ravinement surface was deepened, until an equilibrium was reached under the new hydraulic regime. This did not happen though until the middle of the 16th century, as it was then still possible to trace the contours of the drowned island (Augustyn, 1995), while the equilibrium surface adjusting to the renewed hydrographic situation reached a depth of -12 m before it was covered with sediments. So at least after the middle of the 16th century, the eroded, high-organic muddy sediments (of former back-barrier deposits) could settle, alternated with sandy storm layers, i.e. seismic unit U6.

Formation of the Coastal Banks
After the deposition of seismic unit U6, the Coastal Banks (seismic unit U7) started developing on top of it. On the basis of morphological evidence these banks represent shoreface-connected ridges. They developed simultaneously though, as a response of the sea bed to a suitable hydraulic regime of wave (storms) and tide, and not in relation to a retreating shoreline as the coastline had already reached the present-day position by the time they could form.

Conclusion
Despite the very thin and fragmented Quaternary record without any datable material, a comprehensive geological evolutionary model could be reconstructed for the entire Belgian Continental Shelf for the very first time. As the BCS appears more often in the news nowadays, on issues such as the construction of offshore windmill parks or requests for extending sand and gravel extractions permits, reliable knowledge of the nature and composition of the shallow subsurface of the BCS, which is closely related to its geological evolution, is truly indispensable. A thorough knowledge of the sedimentology, structure and evolution of the shallow subsurface is essential, not only for practical applications but also for biological and ecological investigations in the North Sea, as the seafloor forms a crucial part of the North Sea ecosystem. Finally, the knowledge of the development of former estuaries and the natural evolution of past coastlines can help to assess future coastline migrations in the light of further sea-level rise.

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ORAL & POSTER PRESENTATIONS

MULTI PROXY METHODS TO REDUCE THE SALINITY IMPACT ON TEMPERATURE PROXIES IN MARINE BIVALVES

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To get an insight of the human impact on the current global warming more information about climate past is needed. The reconstruction of seasonal variations in the paleo-environment is possible thanks to the bivalve shells that are commonly found back in archeological sites and that are sensitive environmental recorders. To do these reconstructions we look to the chemical composition of a shell along its growth axis. When a certain element or isotope can be related to an environmental parameter it is called a proxy for that parameter. Many elements and isotopes have been proposed as potential temperature proxy. But the same problem is showing up over and over again: a certain element shows a good linear correlation with temperature, but at the moment that the intrinsic variation has to be explained, the incorporation of the proxy seems to be much more complex than assumed in the first instance.

We suggest reconstructing temperature based on multi proxy models since we expect these models to be more robust. The robustness of the multi proxy models is a result of the fact that the variations in one temperature proxy due to e.g. salinity can be canceled out by observing the variation in other proxies due to the same environmental variable.

In our poster we present four multi proxy methods. We compared one *linear multiple regression method* with three non-linear methods: two of the three nonlinear regression methods explored in this poster make use of the assumption that the proxies are close to a one-dimensional manifold. One of the two is an *intuitive approach*, the other is a new system identification approach, *Weight Determination by Manifold Learning* (WDMR), and based on *manifold learning*. The third approach, *Support Vector Regression* (SVR), does not rely on an assumption of a manifold in the proxy space. The four methods are validated on shell data of Scheldt estuarine environment using high resolution measurements of Mg, Mn, Ba, Sr and Pb on a LA-ICP-MS. The site specificity is tested for all methods using shell-data from four different sites along the Scheldt. Time specificity is checked by reconstructing the temperature corresponding to a shell that grew in another year.

Best reconstructions are obtained by the WDMR-method, although it is clear that performance of the reconstructions is strongly influenced by the data preprocessing. Depending on the proxy-combination and the data multiplication the reconstruction performance of the model varies between a mean absolute error of 0.5° C to 2° C.

SOIL MACROINVERTEBRATE COMMUNITY DEVELOPMENT IN THE FIRST CRT

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Densely populated and industrialized, the Schelde Estuary (Belgium) has been highly impacted for a long time. Embankment, navigation, toxicant and habitats reduction have severely modified the integrity of the estuary. Embankment engendering tidal compression has led to a drastic reduction in tidal flats and other shallow habitats, and the remaining ones undergo a severe physical stress. However, some large projects aiming at restoring wetlands and estuarine habitats are ongoing. So far, among several restoration techniques, CRT (Controlled Reduced Tide area) was proved to be the sole for restoring an integral neap / spring tide cycle. It consists in a former agricultural polder reclaimed for estuarine habitats compensation. By extending the river flood bed, CRT's give rise to new habitats which are expected to compensate for the loss and degradation of river habitats.

The 'Lippenbroek project' is an interdisciplinary research focusing on different aspects of these newly-created zones. As part of this project, a three-year monitoring was conducted on macroinvertebrate community development, each season from April 2006 to February 2008; an additional sampling was realized in July 2009. Four sites were selected prior to tidal characteristics: three ones on the flooding gradient (high, medium and low elevation), and one characterized by the water permanency but also exposed to the tide (tidal pool). Samples were extracted with a core from the top-soil to fifteen centimetres depth. Concurrently, three reference habitats in river were monitored according to the same framework: high marsh, reed bed and tidal flat.

Community pattern in the reference habitats exhibited a simple opposition between high marsh and both reed bed and tidal flat. These habitats were found to be still characterized by species-poor communities, more than ten years after a first sampling. Despite an improvement of the water quality in the Schelde Estuary over this period, other abiotic parameters were hypothesized to be responsible for the lack of taxa recovering. In the CRT, a rapid extirpation of the terrestrial fauna happened during the first months, interactively with the flooding frequency. In low elevation, the deposition of fresh and fine sediments gave rise to the settlement of an estuarine fauna in less than 6 months. The second year, the community development was still ongoing with an increase in densities and a taxa enrichment. In high elevation, terrestrial features persisted without significant species turnover. In July 2009, changes appeared only in top-soil with an expansion of Gastropoda at all elevations. The tidal pool was rapidly colonized by an aquatic fauna, still enriched in Chironomidae in July 2009.

Globally, macroinvertebrate communities in the newly-created tidal flats in the CRT appeared to contrast the most with the reference ones, with a more diversified fauna and higher densities in Tubificidae. However, high CRT elevation kept taxa richer than high riverine marsh. Intermediate CRT elevation, without riverine counterpart, experienced the development of an impoverished and stress-tolerant fauna.

Designed for restoring a progressive tidal gradient, the newly-created CRT habitats were found to be more physically suitable than river references for recovering the pool of macroinvertebrate functions.

OPTIMIZATION OF THE LAY-OUT OF A FARM OF WAVE DRAGON WAVE ENERGY CONVERTERS IN THE NORTH SEA

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Wave energy is a renewable energy source that has the potential to contribute significantly to our renewable energy supply. In the last decade many concepts for wave power conversion have intensively been studied and developed, a.o. the Wave Dragon Wave Energy Converter (WD-WEC) (Kofoed *et al.*, 2006). The WD-WEC is a floating offshore converter of the overtopping type. Two wave reflectors focus the incident waves towards a ramp. The focussed waves run up the ramp and overtop in a basin above mean sea level. Power is produced when the stored water drains back to the sea through hydro turbines. The considered WD-WEC has a rated power of 2MW in a 12kW.m^{-1} wave climate. As the rated power of a single device is relatively small, several WD-WECs need to be installed in a geometric configuration or in a 'farm'.

WD-WECs in a farm are partly absorbing and partly redistributing the incident wave power. As a result a wake behind each WD-WEC is created. The power absorbed by each individual WD-WEC in a farm is affected by the wakes of its neighbouring WD-WECs. The wake effects in a farm and consequently the power absorbed by a farm, depend on the wave climate and on the lay-out of the farm. The farm lay-out does not only affect the amount of absorbed power but also modifies the cost of the farm. Mainly the cost of the electrical cables between the WECs in a farm is affected by the farm lay-out. The costs of installation, operation and maintenance are to a lesser degree dependent on the farm lay-out.

In this study, the lay-out of a farm of WD-WECs is optimized to decrease the cost per produced kWh. Therefore the power production of two different farm lay-outs of WD-WECs with a rated power of 198 MW (99 WD-WECs arranged (i) in a single line and (ii) in a staggered grid) in a near shore North Sea wave climate, has been assessed numerically using the time-dependent mild-slope equation model MILDwave, developed at Ghent University (Beels *et al.*, 2006). Furthermore, for each lay-out an optimal (low cost) submarine cable network has been designed.

The results, as presented in this poster, indicate that the investment cost of the submarine cable network is only a fraction of the total investment cost of the farm. Hence, when designing the lay-out of a farm of WD-WECs, mainly maximum power production should be aimed at. A single line of WD-WECs results in the highest power production and lowest cost of energy. On the other hand this lay-out requires a wide sea area.
The installation of a line of WD-WECs in front of a farm of wind turbines may be beneficial. In that case the WD-WECs may be connected to the transformer platform of the wind farm, which reduces the grid connection cost. Furthermore, the WD-WECs reduce the wave height in their lee, which makes maintenance of the farm of wind turbines easier and cheaper.

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SAND DYNAMICS IN COASTAL DUNES AND ITS ECO-EVOLUTIONARY FEEDBACKS ON ARTHROPOD SPECIES PERSISTENCE

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In coastal dunes, aeolic dynamics (e.g. severe sand displacements) comprise an essential geomorphological process that retains the landscape into its dynamic phase (Provoost, 2004), i.e. characterised by absence of soil development and extreme microclimatological conditions with high summer temperatures. Aeolic disturbance originates primary from natural sand displacement in blond dunes, but also secondary through anthropogenic disturbance, i.e. by trampling of recreants and large herbivores. These processes at the local scale are tightly linked to landscape processes that relate to the overall openness of the dune landscape. In order to understand which species benefit from sand dynamics and how landscape processes interact with local processes, we performed both mechanistic and correlative research to detect bottlenecks for species persistence within the process of changing disturbance dynamics at different spatial levels (see selected references below) using arthropods as a model. At larger spatial scales, shifts in species composition in relation to decreasing sand dynamics are more pronounced in dynamic landscapes and species from dynamic sites are more vulnerable and more prone to extinction than their counterparts from stabilised fragments because of specific life history adaptations. Maintenance of sand dynamics at a landscape level rather than at a local level appears to be of primordial importance for species conservation. At the local scales, secondary sand dynamics through the action of recreation appeared to be much more beneficial than those created by cattle trampling. We finally demonstrated that the loss of sand dynamics may induce evolutionary changes in dispersal, with subsequently cascading effects on species persistence.

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MONITORING WETLANDS ALONG THE WESTERN-GREEK BIRD MIGRATION ROUTE: AMVRAKIKOS GULF (GREECE)

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The west coast of Greece is an important migration route for African-Eurasian migratory water birds, as it is part of the Black Sea/ Mediterranean flyway (Davidson and Stroud, 2004; Lagring, 2008). The wetlands along this coast are important stopover sites during birds' migration between their wintering and breeding sites (Newton, 2008). Labour- and cost-effective methods are needed to monitor these wetlands (Bazigou, 2007). The hypothesis at the basis of this research is that loss and/or deterioration of number, area and quality of wetlands along the west coast of Greece can result in a lack of suitable stopover sites for migratory birds.

The use of remote sensing methods for mapping bird migration habitat along the west coast of Greece and for temporal monitoring of changes in these habitats was investigated, while the methodology used and the results were meant to form a baseline for future research in this field and in this area.

The Amvrakikos Gulf, a wetland complex along the west coast of Greece, was selected as study area. It is a Ramsar site and an Important Bird Area (IBA) (Zalidis and Mantzavelas, 1995). Landsat TM (1989) and ETM+ (2000) images and ASTER VNIR images (2002 and 2004) were compared and screened for obvious changes over a time period of 15 years (1989-2004). A classification scheme was developed based on the MedWet classification system (Farinha *et al.*, 1996). Adaptations to this scheme in order to fit our research objectives were made, following the information retrieved from the satellite images. Each image was classified (pixel-based classification) separately in ERDAS IMAGINE, followed by a pixel-to-pixel comparison. An unsupervised ISODATA (Iterative Self-Organizing Data Analysis) classification was performed and followed by signature editing, supervised classification and an accuracy assessment of the classification. The post-classification comparison was done with a raster GIS-based matrix analysis (ERDAS, Inc, 1999). FRAGSTATS was used to investigate change in the degree of fragmentation of bird migration habitat (McGarigal *et al.*, 2002).

The results showed that Landsat and ASTER VNIR satellite images can be used to trace small wetlands of approximately 0.5ha. These images can be used to monitor changes in area of important water bird migration habitat, marshes and mudflats. From 1989 to 2004 there has been a decrease in this class of 32%. 25% of the marshes and mudflats changed to water surface and 7% changed to vegetation. The degree of fragmentation increased from 1989 to 2004.
In conclusion, there has still been a decrease in quality of bird migration habitat since 1989. The materials and methods used in this research are proposed as helpful tools for the investigation of wetlands. The use of Landsat and ASTER satellite images could be helpful for policy makers and managers, as they can easily recognize and detect changes of wetlands and so evaluate the efficiency of protection and management schemes that each country, and in our case Greece, applies to its wetlands. They are easily accessible, reliable and low cost, though research is needed to improve ecological resolution (further characterization of biotopes and habitat types).

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BIOTIC AND ABIOTIC FACTORS INFLUENCING THE MANGROVE VEGETATION OF GAOQIANG (GUANGDONG, CHINA): A FIRST APPROACH

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The present ongoing MSc study is carried out in south-western China, in a mangrove managed by the Zhanjiang Mangrove National Natural Reserve (ZMNNR). The ZMNNR covers approximately 20,000ha of naturally established mangrove forest, mangrove plantations, inter-tidal sand and mud flats, river channels and streams. The reserve has been classified in 2002 as a wetland of national importance by the Ramsar Convention for its biodiversity, for the goods and services provided to the population and also as a bird refuge of great importance. However, this area is still relatively unknown, and not much phytosociological studies were carried out there. The mangrove we are studying is located in the County of Lianjiang: an enclave in the Beibu Gulf, at 4.5km to the south-west of the town of Gaoqiao. The Gaoqiao mangrove is the most important wetland area managed by the ZMNNR. The aim of this study is to understand and analyse the structure of the vegetation in terms of floristic diversity, biomass, density and height of the trees based on nine transects with a total of 210 sampled points. The structure of the vegetation will be determined with beta diversity index, biomass, height and basal area of trees for each of the sampling point. Then we will apply a multivariate analysis (ordination, cluster and statistical analysis) to find which of the selected environmental factors can explain the most part of the vegetation. Each analysis will be done for two phytosociological methods: a plot-based method and a plot-less method. We will test the relationship between these sampling methods to find an appropriate compromise between accuracy and time spent on it. Other observations were also made in this newly studied mangrove. New researches will be done soon on the parasitism of mangrove trees by barnacles and caterpillars, on the invasion of exotic introduced species, on fishing impact, aquaculture and rice culture, on the climate impacts and on the importance of the rivers network on the vegetation structure and dynamics.

RESEARCH STRATEGY AND EQUIPMENT TO CONTINUOUSLY STUDY FLYING BIRDS IN WIND FARMS IN THE BELGIAN PART OF THE NORTH SEA

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The effects of offshore wind farms on birds are still uncertain at this time. Therefore it remains a necessity to study the impact of newly built wind farms on the flight movements of local and migrating birds. The biggest concern is the mortality risk due to collisions with the offshore constructions because this elevates the normal mortality rate of species (Johnson *et al.*, 2002). At this time, three wind farms are granted a permit in the Belgian part of the North Sea. Two of them are currently under construction. To assess the possible impacts on birds an intensive monitoring is being conducted by the Institute of Nature and Forest Research (INBO) based on visual counts and collision models.

The research goals of the long term monitoring are (1) to study the avoidance behaviour of birds in the vicinity of the wind farms; (2) to quantify the flux of flight movements on site and (3) to assess the number of collision victims and the impact of this mortality on the NW-European population of the concerned species.

In a preliminary study MUMM assessed the possibilities and usefulness of an Automated Radar System (ARS) as an addition to the monitoring that is conducted by INBO and to set up a continuous monitoring. The different ARS that are commercially available are similar and work in a dual radar configuration. This means they have both a horizontal and a vertical antenna. The horizontal surveillance radar scans in the horizontal plane providing x-y data 360 degrees around the research site and shows the spatial distribution of the birds. The vertical antenna scans in the vertical plane providing y-z data from the ground level to a minimum altitude of 1.5 km. This gives insight in the bird fluxes and altitudes in the wind farm area. In the future vertical radar flux data will be used as input for existing collision models as part of a collaboration between MUMM and INBO. This will give a more reliable estimation of the number of collision victims than the results that are currently being calculated based on visual flux counts.

When using radar out at sea, better quality data is to be obtained using a platform based set up, rather than a ship based set up (Walls *et al.*, 2009). So, the offshore high voltage stations seem to be the most appropriate locations for mounting the ARS. Before a platform is installed at sea the ARS will be installed and tested at an onshore location. This will give the ability to spend time with the system, which is not always possible offshore, and to get acquainted with the data.

An ARS seems fit for the research purpose. In compliance with European legislation a public call for tender was published and the received quotations were evaluated on several criteria. The best suited ARS within the limits of the allocated budget will be purchased so the research can start in 2010. To be continued!

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Also see abstracts of related projects further in this publication:

Coates *et al.*; Degraer *et al.*; Di Marcantonio M.; Haelters J.; Kerckhof *et al.*; Reubens *et al.*; Vandendriessche *et al.*

DOES MACROFAUNA AFFECT THE BENTHIC PROCESSING OF A SETTLING PHYTOPLANKTON BLOOM?

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Macrofauna-induced particle mixing (bioturbation) and solute transfer (bio-irrigation) contribute extensively to ecosystem functioning in areas where physical disturbance is low. Oxygen and organic matter are transported deeper into the sediment, thereby probably providing favorable niches for the lower parts of the food web and thus stimulating mineralization. Whether macrobenthos facilitates uptake of fresh organic matter by e.g. bacteria and nematodes through niche establishment or rather deprives them from food sources, is so far not clear. In this in vitro experiment, we investigated the influence of the ecosystem engineers *Lanice conchilega* (bio-irrigator) and *Abra alba* (bioturbator) compared to regular physical disturbance events on bacterial and meiofaunal dynamics after a simulated phytoplankton bloom. The uptake of ^{13}C labeled diatoms will be traced down the food web based on stable isotope and fatty acid analysis. Next to this, the vertical dimension of the meiofaunal response was taken into account.

First results on nematode counts indicate that the different functional traits of the macrobenthos vs. regular physical disturbance induce contrasting nematode profiles: nematodes receiving the physical sediment disturbance regime shift to the stratum just below this intensive mixing, whereas they stay around the bioturbated area in the *A. alba* treatments; the bio-irrigating polychaete *L. conchilega* on the other hand, seems to facilitate nematodes to dwell deeper strata of the sediment.

The labelled algae will be distributed differently according to the mixing intensity in each treatment and the results on its uptake and mineralisation by macrofauna, nematodes and bacteria will generate a better understanding of the role of macrofauna in the functioning of the sea floor ecosystem.

STEROLS AND THEIR $\delta^{13}C$ SIGNATURE IN SUSPENDED PARTICLES IN THE SOUTHERN OCEAN WATER COLUMN

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Improving our understanding about the functioning of the biological carbon pump is necessary for a proper assessment of the ocean's CO_2 sequestration capacity. The biological pump efficiency depends on the phytoplankton community structure and its activity in the upper mixed layer as well as on the composition and activity of zooplankton and prokaryotes consuming the sinking flux of organic matter. The relative importance of different microbial and zooplankton components, as well as the variable composition of the C-export flux in the water column can be resolved by studying the occurrence and spatial variability (depth and latitude) of specific compounds or biomarkers in suspended matter. During the BONUS-GOODHOPE Southern Ocean expedition (Feb.-Mar. 2008; R/V *Marion Dufresne*), particulate organic matter was sampled along the Greenwich Meridian using large volume in-situ filtration systems. Five stations were selected on the basis of their zonal characteristics: S1 (36°S, 13°E) and S2 (42°S, 8°E) in the Subtropical Zone, S3 (47°S, 4°E) in the Subantarctic Zone, S4 (51°S,°E) in the Polar Front Zone and S5 (57°S, 0°E) in the Weddell Gyre (Antarctic Zone). For surface waters, two size fractions were separated ($Ø_1$ > 53 µm and 53 > $Ø_2$ >1 µm), while from the mesopelagic layer to the deep ocean we sampled the 53 > Ø >1 µm particles. Here we present sterols which were extracted following the modified Bligh and Dyer method, separated from glycolipids and polar lipids using silica gel as a function of their polarity and sylilated prior to GC-MS (compound identification) and GC-c-IRMS (carbon isotopic composition and relative quantification) analyses. We discuss the variability of sterol concentrations and their carbon isotopic composition with depth and in the different oceanic regions defined by the major fronts.

DOES THE FREE ION ACTIVITY MODEL APPLY TO ESTUARINE AND MARINE ENVIRONMENTS? A CASE STUDY FOR CD, CS, MN AND ZN IN THE EUROPEAN SEA BASS, *DICENTRARCHUS LABRAX* (L.)

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The Free-Ion Activity Model (FIAM) states that the primary metal form available for uptake is the free ionic form. Apart from some exceptions, this appears to be true for a range of freshwater compositions and freshwater organisms. However, for marine and estuarine organisms observations are not so straightforward and physiological adaptation to different salinities may play a key role. The aim of this study was to determine whether the FIAM was applicable for the uptake of four trace metals in a wide range of salinities going from 1ppt to 35ppt. European sea bass (*Dicentrarchus labrax*, L.), which are euryhaline marine and estuarine teleosts, were acclimated to hypo-, iso- and hyperosmotic media and for each of the acclimation conditions the uptake rate constants of Cd, Cs, Mn and Zn were determined simultaneously by means of their corresponding radio-tracers ^{109}Cd, ^{137}Cs, ^{54}Mn and ^{65}Zn. Uptake rate constants of Cd, Mn and Zn dropped approximately 23, 7 and 8 times, respectively, when salinity was raised from 1ppt to 35ppt. Although such a decrease is predicted by the FIAM, several deviations were observed for sea bass. Even more, Cs uptake did not significantly differ between the lowest and highest salinity. Besides the chemical composition of the environment, differences in fish physiology between hypo- and hyperosmotic conditions seemingly also influence metal uptake rates. Therefore, we postulate that fish physiology can be a crucial factor in determining metal uptake in this marine euryhaline species.

COUPLING OF A NEW IN-SITU MEASUREMENT TECHNIQUE WITH A NEW MODELLING APPROACH FOR THE DETERMINATION OF THE EFFECTIVE SETTLING VELOCITY OF FLOCCULATING SEDIMENTS IN ESTUARIES

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This research project is funded by Research Foundation Flanders (FWO-Vlaanderen) and led by VUB partnered with other three Flemish universities (KULeuven, UGent and UA) and two Flemish institutions, Flanders Hydraulics Research (WL) and Flanders Marine Institute (VLIZ). It is a four-year project involving field measurements with an innovative in-situ system, comparative laboratory experiments in a water tank and the development of a new modelling approach. Estuarine particles are largely flocculated and their size and density may vary significantly over time scales of minutes. Knowledge of flocculation and accurate in-situ measurements of floc are essential for understanding particle aggregation mechanisms and the resulting settling velocity and the entire sediment transport process. One of the most crucial parameters, which remains an unresolved problem known to the hydraulic research domain, is the determination of in-situ settling velocity and related floc properties as well as particle-turbulence interactions. This research is aimed to develop a new and reliable system for the in-situ real-time measurement of particle movement along with simultaneous measurement of turbulence and size and shape of settling particles; to use the aforementioned new measurement system to investigate in-situ particle settling velocity and particle-turbulence interaction on meso-scale in the laboratory experiments and on macro-scale in the Scheldt Estuary; and to bridge the gap between the measurements and the simulation and prediction of flocculation by numerical models. This involves feed-back from the model to the interpretation of the measurements with the new system. Consequently the complementary nature of this project will lead to the characterisation of the relation between flow and particle-turbulence interactions, and to the development of a new modelling approach for the determination of the effective settling velocity of flocculating sediments in estuaries.

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OCCURRENCE OF MICROPLASTICS IN THE BELGIAN COASTAL ZONE

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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 keeps rising and the buildup of these materials in our environment has become problematic.

Under influence of UV-light and mechanical forces, plastics also tend to break down into smaller particles in the size range of 1mm and smaller. While no clear adverse effects of these so-called microplastics on marine organisms have been reported, they have been detected in the water column and sediments at high concentrations. Moreover, uptake of these particles has been observed in mussels, sea cucumbers, barnacles and other organisms, and as plastics have a high affinity for hydrophobic chemicals there is a risk of pollutant transfer from ingested microplastics to the food chain.

This poster presents the results of a study in which microplastic concentrations in sediments of Belgian beaches, harbours and the Belgian seafloor were determined. The results revealed high concentrations of plastic fibres, spherules and grains in sediments of all these areas. Moreover, despite international efforts to reduce the amount of marine litter, the analysis of sediment cores taken on the beaches suggests that microplastic concentrations are increasing with time.

USE OF MULTI-BIOMARKER EXPERIMENTS WITH CAGED MUSSELS FOR RISK ASSESSMENT OF MARINE POLLUTANTS

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For many years, biomarkers have been used to detect physiological, cellular or molecular changes in organisms exposed to contaminants. Biomarkers are known to respond rapidly to general stress and/or the presence of specific pollutants and may therefore be a rapid and cost-effective alternative to the more time-consuming and labour intensive population studies. However, biomarker results are rarely linked to changes occurring at higher levels of organization.

In an attempt to address this shortcoming, the INRAM project conducted multi-biomarker experiments with caged mussels which were carried out in the coastal harbours of Oostende (one station at Oostende marine) and Zeebrugge (one station at Zeebrugge marina and one in the outer harbour). The mussels were simultaneously exposed to the harbour waters for six weeks after which the responses of the following biomarkers were determined: cellular energy allocation (CEA), 7-ethoxyresorufin-0-deethylase (EROD) and lysosomal membrane stability (LMS). All mussels used for this experiment originated from a non-polluted site in the Eastern Scheldt. Mussels exposed at this site were used to obtain control values.

The biomarker results indicate a strong influence of pollution at all stations in the harbours. Compared to the controls, lysosomal stability was significantly lower in both marinas but no effect was detected in mussels exposed in the outer harbour station of Zeebrugge. CEA values were lower at all harbour stations. EROD showed the highest response at the marina of Oostende and the outer harbour of Zeebrugge. Chemical analysis of mussel tissue and passive samplers is currently performed and will be used to explain these observations. Additionally, the results will be discussed in the light of an earlier long term cage experiment in which multiple biometric parameters were monitored in mussels exposed at the same stations.

INTEGRATED RISK ASSESSMENT AND MONITORING OF MICRO-POLLUTANTS IN THE BELGIAN COASTAL ZONE

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Hazardous substances end up in the marine environment through riverine inputs (including harbours), direct discharges and/or atmospheric deposition. As such, marine systems are the ultimate repository for a cocktail of persistent chemicals. Organisms living in these ecosystems are thus exposed to a range of substances which have the potential to cause adverse effects which may lead to population and community level changes.

The INRAM project is an integrated project funded by the Belgian Science Policy aimed at assessing the risks of micropollutants occurring in the Belgian coastal zone. The transfer of micropollutants of three Belgian coastal harbours and the Scheldt Estuary to coastal waters, and their contribution to contamination and/or pollution is examined. The underlying objective of the INRAM project is to develop a novel, multidisciplinary methodology – based on a suite of chemical, biological and ecological measurements - to evaluate the health of marine ecosystems. This poster will present the approach and – along with multiple other posters presented at this conference – the main results of the INRAM project that are available at present.

OCCURRENCE AND EFFECTS OF PHARMACEUTICALS IN THE BELGIAN COASTAL ZONE

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For freshwater ecosystems, a considerable number of studies have reported detectable levels of common pharmaceuticals. For the marine environment, however, only a limited number of studies are available. While concentrations of pharmaceuticals in the marine environment are generally thought to be lower than in freshwater, potential effects cannot be excluded since these substances are designed to exert a well-defined effect at low doses.

In this study, which is part of the INRAM project aimed at developing an integrated impact assessment and monitoring strategy for the Belgian coastal zone, environmental concentrations of 15 pharmaceuticals were determined in Belgian marine waters. Ecotoxicological data have been generated for a number of the most frequently observed compounds, using the marine diatom *Phaeodactylum tricornutum* (72h growth inhibition test) and the Pacific oyster *Crassostrea gigas* (24h larval development test) as test species.

Of the 15 pharmaceuticals analyzed, nine were frequently detected. The highest concentrations were found for salicylic acid (855ng/L, Oostende harbour), carbamazepine (119ng/L, Oostende harbour) and atenolol (88ng/L, Oostende harbour). Based on the ecotoxicological test results and the environmental monitoring data, an initial risk characterisation was performed. This exercise indicated that individual substances do not pose a substantial risk to marine life in the Belgian coastal zone. However, the potential risks of mixtures and long term effects still need to be established.

MONITORING THE IMPACT OF OFFSHORE WIND FARMS ON THE SOFT-SEDIMENT MACROBENTHOS

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As part of the environmental permit granted to C-Power and Belwind the baseline monitoring programme on the soft-sediment macrobenthos was initiated in 2005. Since then, macrobenthos has been sampled and analysed on the C-Power and Belwind concession areas (Thornton Bank and Bligh Bank, respectively), together with carefully selected reference stations on the Goote Bank, Bligh Bank and the Thornton Bank.

The baseline studies (Year-0) of the Thornton Bank and the Bligh Bank were carried out both during the autumn and spring of 2005 and 2008, respectively. In total, 76 sample sites were investigated for the baseline study of the Thornton Bank and 78 for the Bligh Bank. Both studies expressed higher macrobenthic densities during autumn (max. 1300ind.m^{-2} in 2005 and 3500ind.m^{-2} in 2008) in comparison to spring (max. 1100ind.m^{-2} in 2005 and 900ind.m^{-2} in 2008). The species richness on all sampling locations was rather low with a maximum of 15 species/0.1m² in 2005 and 26 species/0.1m² in 2008. *Nephtys cirrosa* was detected as the most dominant species over all the sampling locations. Therefore, the macrobenthic community of the several sandbanks investigated either belonged to the *Nephtys cirrosa* community or the transitional community between the *Nephtys cirrosa* and the *Ophelia limacina – Glycera lapidum* community. Furthermore, the sediments mainly consisted of medium sand (350-500µm) with a low mud content (max. 10%) and low organic material percentages (max. 1%).

During the autumn of 2008 the impact of the first six windmills built on the Thornton Bank (Year-1) was assessed. In this first year after implementation no large-scale impacts on the macrobenthos were detected while seasonal and annual variations in densities, species richness, biomass, productivity and community composition appeared to be more important. However, a continuation of the baseline monitoring is necessary to determine long-term effects and successive recovery of the soft-sediment macrobenthos.

Currently, the Year-2 situation of the Thornton Bank and the Year-1 situation of the Bligh Bank are being analysed. Slight modifications in sampling locations were carried out to attain samples in closer vicinity to the first six windmills and to hopefully determine more small-scale impacts on the macrobenthos.

In the near future, targeted monitoring will be applied to create a greater understanding of the source of wind farm impacts on the soft-sediment macrobenthos. Consequently, small-scale experiments will be carried out to gain more insight in the organic enrichment and the changing currents around wind mills together with their possible effects on the soft-sediment macrobenthos.

Also see abstracts of related projects further in this publication:

Brabant *et al.*; Degraer *et al.*; Di Marcantonio M.; Haelters J.; Kerckhof *et al.*; Reubens *et al.*; Vandendriessche *et al.*

AGONISTIC SOUNDS IN CLOWNFISHES (AMPHIPRIONINI, POMACENTRIDAE): SOUND PRODUCTION MECHANISM AND POTENTIAL ROLE IN THE GROUP HIERARCHY

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Currently, more than 50 fish families include species with the ability to emit sounds. The majority of acoustic signals are used for communication in different behavioural contexts such as aggressive behaviour (territorial defence, agonistic interactions) or reproductive activities (mate identification and choice, courtship).

The damselfishes (family Pomacentridae) are prolific callers that produce a wide variety of sounds in different kinds of behavioural contexts. Within this family, clownfishes are well known because of their amazing association with sea anemones that host them. Due to this symbiotic relationship, these fishes are highly territorial and they notably produce agonistic sounds to defend their territory.

Although clownfish sounds were recorded as early as 1930, the mechanism of sound production has remained obscure for a long time. However, it has been demonstrated recently that they produce agonistic sounds using a jaw teeth snapping due to a fast mouth closing. It appears that an unusual ligament was responsible for the rapid mouth closing. This ligament joins the hyoid bar to the internal part of the mandible. Acting as a cord, it forces the mandible to turn around its articulation during the lowering of the anterior part of the branchial basket, forcing the mouth to close.

At present, this mechanism has highlighted the onset of the sound but has not explained yet which structure is responsible for the sound modulation. Interestingly, some acoustic features such as dominant frequency and pulse duration are highly related to fish size. The more fish size increases, the more sound duration increases and the more dominant frequency decreases. Such variations are linked to a morphological constraint. The existent relationship between fish size and swimbladder size also implies that the swimbladder is involved in the sound production by acting as a resonant chamber.

Additionally, the fact that pulse duration and dominant frequency are morphologically determined signals related to fish size could be of significant importance in clownfishes. In this context, smaller individuals produce shorter duration and higher frequency sounds than larger individuals. Both sonic features are signals conveying information related to the size of the emitter. These fishes live in social groups within which there is a size-based dominance hierarchy. In such a system, agonistic interactions are usual and play an important role in social organization by maintaining size differences between individuals adjacent in rank. Sounds are known to be associated with agonistic interactions. Acoustic signals might thus help to understand one of the mechanisms that carry the clue for individual recognition within the group hierarchy.

HOW DO PERSISTENT ORGANIC POLLUTANTS BEHAVE IN COLD-BLOODED NON-HIBERNATING FISH?

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It is well known that persistent organic pollutants (POPs) accumulate and usually remain immobilized in fatty tissues of warm-blooded and even cold-blooded hibernating organisms. The partitioning behavior of these chemicals in cold-blooded non-hibernating organisms is much less clear and hardly known although undoubtedly crucial in understanding the mechanisms behind biological effects of contaminants and their respective risk assessments.

This gap in knowledge was taken onboard in this study on partitioning of important pollutants and other variables in the liver of dab (*Limanda limanda*), sampled in the Belgian part of the North Sea in distinct seasons. The liver tissue is the main fat storage matrix in dab and was therefore chosen. The determinants were the liver fat and multiple congeners of chlorinated POPs: 7 dioxins, 10 dibenzofurans and biphenyls, including 4 planars and 8 mono-orthos, and is a continuation of previous work on the seasonal partitioning of long-term monitored indicator biphenyls. Other measured variables were, in the first place, the bottom water temperature amongst others.

The seasonal temperature conditions have a profound impact on the fat matrix with approx. 2.5-fold concentration differences between March and August/September. The use of fat reserves in winter is a logic and recurrent metabolic necessity and, surprisingly, all measured POPs exhibited exactly the same patterns and ratios and that is a net observation. Since the persistence of these chemicals prevents biotransformation, the most plausible explanation for the distributional behavior is that approx. 60% of the accumulated liver contaminant burdens recirculate yearly. A clear-cut conclusion is that the seasonal influences on the liver fat contents mobilize these chemicals in and out of the liver and that concentration in the remaining fat during elimination does not take place. The big question is: where do these chemicals go to? Storage in other compartments of dab is unlikely because of the low fat concentrations in those tissues that might well exhibit similar seasonal patterns as the liver fat tissue.

In terms of toxicological equivalents, the results show that the chemicals can be ranked in order of toxicological importance: planar biphenyls > dibenzofurans > dioxins > mono-ortho biphenyls.
Very interesting and promising is that sampling and analyses on a more frequent basis (e.g. on a weekly basis) would allow quantification of released and accumulated POPs. These fluxes may be assumed active **doses of exposure**, distinguished from the bulk of the contaminants. The data would allow the design of a dynamic model on **the mechanistic roles of chlorinated POPs**, providing a better understanding and interpretation of their biological actions and the biomarkers that are recommended in risk assessments. The model would also clearly demonstrate the periods with highest release and accumulation rates during which organisms might be most vulnerable.
The conclusive message is that (1) a large part of the bulk of accumulated chlorinated POPs in fat tissues of cold-blooded fish is being recirculated during the year, and (2) the presented concept might provide **the** approach needed to tackle questions and complex interactions in the field that compromise a reliable risk assessment.

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ECOLOGICAL PROCESSES AND CONSERVATION OF THE MANGROVE: A REVIEW AT THE CANANÉIA REGION, SÃO PAULO STATE, BRAZIL

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Wetlands, including mangroves, perform several functions, besides generating products and services, which have a fundamental importance for the human society. It is possible to manage mangrove areas, making use of opportunities for recreation, tourism, fishing, education and research, without the need of a considerable manipulation of the system. Such management can be done for instance while preserving the flow of material and nutrients that sustain ecosystem production and while maintaining control of the quality of the water. The study of physiographic types could be of help in the comprehension of the large variability of structural development, as a result of the response of mangrove plant species to the innumerous abiotic components that interact in this environment. With the aim of improving the understanding of mangrove vegetation structure dynamics and to help the management of the Cananéia region, located in the South coast of the São Paulo State (25°S), data from the 1980's to present on the structural development of mangrove forests of different physiographic types, were analyzed. The **fringe forests** studied in the region presented a predominance of *Rhizophora mangle* and high structural development due to the high inundation frequency, in stable sites, where there are no important sedimentary processes. On the other hand, fringe forests, located in progradation areas with low tidal energy, were dominated by *Laguncularia racemosa* with low structural development. As a rule, the **riverine forests** are dominated by *R. mangle*, with a high structural development in function of the high inundation frequency and a continuous flow of fresh water, this permitting a larger input of nutrients, oxygen and dissipation of noxious substances from the sediment. **Riverine forests**, located in progradation areas with high river energy, were dominated by *R. mangle* with low structural development and were associated to the smooth cordgrass *Spartina alterniflora.* The **basin forests** were also seen to be dominated by *R. mangle,* presenting, however, reduced structural development in function of the low inundation frequency, a predominantly sandy sediment and low salinity. However, some areas showed to be well developed due to the structural characteristics of the dominant arboreal mangrove species (*Avicennia schaueriana*). The results presented here indicate that variations in the quality and intensity of forcing functions are infinite, the structural variability being limited by the plasticity of the species involved and their capacity to adjust themselves to the environment in which they develop. The main objective of management should be limited to the protection of those processes which act upon the system, and the control of the fulfillment of services. Studies of the different physiographic types, dynamics, zonation patterns, and responses to abiotic characteristics are essential to help to define conservation policies for the mangroves in the Cananéia region.

PROSPECTIVE SAND EXTRACTION ON THE HINDERBANKEN: MONITORING STRATEGY FOR FUTURE IMPACT ASSESSMENT

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The exploitation of sand on the Belgian Continental Shelf (BCS) started in 1976 and increased rapidly from 29,000m³ to a current annual extraction of > 1,800,000m³. In 2004, three zones were (re)defined as sand extraction zones, while part of the Hinderbanken sandbank complex was assigned as exploration zone IV, mainly based on the assumption that gravel and coarse sand are present in high amounts in that area.

To describe the biological characteristics in exploration zone IV prior to extraction, a base line study was performed between 2005 and 2008 for three ecosystem components, namely macrobenthos, epibenthos and demersal fish. The Hinderbanken complex is a typical sandbank-gully system with a high variability in depth ranging from 10m to > 35m. This is reflected in the fact that the overall species community for the three ecosystem components in the Hinderbanken area is mainly structured by depth, i.e. the position of the samples in the gullies versus on top of the banks. Overall, gully samples were significantly more diverse and had significantly higher densities compared to bank samples. Therefore, it is recommended to avoid future extraction in the gullies. Furthermore, it would be ideal to allocate a reference zone within exploration zone IV, where extraction is prohibited, to allow for a sound impact assessment of potential sand and gravel extraction in the area.

The baseline study also showed that the sediment of exploration zone IV mainly consists of coarse sand (300-450µm), with the exception of some zones where a high percentage of mud or large cobbles and gravel are found. However, the zones with large cobbles and gravel are rather limited. Still, the coarse sand is of main interest to the Flemish Region for beach replenishment. Based on a seismic survey carried out by RCMG in 2009, several zones can be assigned as potential extraction zones with suitable coarse sand (300-420µm). Based on this geological study and the biological recommendations, two zones on top of the banks seem to have the largest potential for sand extraction. As there is a high need for this coarse sand, which is not found in other extraction zones, a Before-After Control-Impact (BACI) design for macrobenthos, epibenthos and demersal fish in the considered zones is set up, starting in Autumn 2009. This will enable us to accurately assess the potential future impact of sand extraction in these zones.

WAVE ENERGY ABSORPTION BY POINT ABSORBER ARRAYS

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Huge amounts of unexploited energy are available in the ocean waves. The purpose of wave energy converters is to extract this energy and convert it into electrical energy. Point absorbers are wave energy converters with small horizontal dimensions. They oscillate in the ocean waves according to one or more degrees of freedom. By damping their motion, electricity is produced. In order to extract a considerable amount of power, point absorbers are intended to be installed in arrays. Some devices are even composed of several, interacting point absorbers, integrated in one unit. The design and optimization of multiple, closely spaced point absorbers is studied in more detail.

Several theoretical models exist to predict the behaviour of closely spaced point absorbers. The most well-known are the 'point absorber approximation' [Budal, 1977; Evans, 1980; Falnes, 1980] and the 'plane wave approximation' [Simon, 1982; McIver and Evans, 1984]. These theories are based on assumptions which are generally not fulfilled for closely spaced point absorbers. Hence, with current computer capacity, Boundary Element Methods (BEM) are becoming more important to investigate the performance of array configurations of point absorbers [Ricci *et al.*, 2007; Taghipour *et al.*, 2008].

In the presented study, the behaviour of closely spaced heaving point absorbers has been investigated in unidirectional irregular waves. Constraints are implemented imposing limits to the buoy motion and control forces. An array of 12 buoys in a staggered grid layout is considered. The power absorption of the array is optimized in three different ways. Firstly, the optimal parameters of a single body are applied to the array. This appeared to be not an efficient optimization strategy. Secondly, diagonal optimization has been applied. With this method, all buoys have the same control parameters, but they are optimized for the array. In the third method, the buoys get individually optimized control parameters. This strategy clearly outperforms the other methods. The presented model can be used to estimate power absorption values at specific locations. An estimation of the yearly absorbed energy at the Westhinder area has been made.

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STUDY OF CHEMICAL AND MICROBIAL FACTORS AFFECTING THE CORROSION IN BALLAST TANKS ON BOARD OF MERCHANT NAVY VESSELS

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In 2008, the Antwerp Maritime Academy together with the University of Antwerp started a BOF project aiming to establish the driving forces behind corrosion in ballast tanks of merchant navy vessels.

During a period of two years, the researchers did *in situ* inspections in more than 100 ballast tanks. The tank condition was compared with international accepted standards. These standards were too complex to allow statistical interpretation. An own index was developed, quantifying corrosion with only one figure. Pictures of the tank structure and samples of mud and rust were taken. These samples were then chemically and microbiologically analysed at the University of Antwerp.

The methodology of the research technique was published in the October and November numbers of 'Materials Performance', a NACE publication.

The project has reached the final phase where conclusions can be drawn. We were able to establish a general corrosion model showing the function between age and corrosion. A number of other correlations surfaced, such as the relation between corrosion and trading area, land of construction, ballast frequency, ship's type and coating type

Particularly interesting are the graphs concerning the effect of sacrificial anodes in relation to the ballast pattern.

Traditionally zinc anodes are considered as the best way to fight corrosion in ballast spaces after coating failure. We proved this thesis to be a myth for the majority of the tanks.

One of the results of this study will be a clear message to the ship-owners. The use of an improved coating system is to be preferred above the use of sacrificial anodes.

DIVERSITY AND LONG-TERM CHANGES IN THE BRYOZOAN FAUNA OF THE HINDER BANKS, BELGIUM

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The Hinder banks rise about 25m above the seafloor and are about 20km long. Gravel fields are located in the gullies between the sand banks. The sand banks are characterized by large transversal sand waves. In a transitional zone, patches of gravels are present between large sand waves. The gravel field along the south-eastern flank of the Westhinder bank once hosted large flat oyster banks, which were destroyed by oyster dredgers in 1873. Nevertheless the samples of Gustave Gilson taken between 1900 and 1910 still reveal a very rich biodiversity on the Hinder Banks. Due to increased trawling, Gilson recommended in 1921 to protect gravel habitats. After the First World War, direct impacts to offshore gravels increased subsequently to the introduction motorized bottom trawling. After the collapse of herring in 1960, beam trawling was used to catch flatfishes with increasingly powerful ships. Continuous disturbance of the bottom has a devastating impact on erect growing fauna. Erect growing bryozoans like *Flustra foliacea*, *Electra pilosa*, *Alcyonidium* sp., *Bugula flabellata* and *Vesicularia spinosa* used to be abundant in Gilson's time, nowadays erect colonies are rare. Only sheltered areas, where the beam trawl hops over the hill and can not reach the gravel zone, host more and larger specimens. Encrusting bryozoans e.g. *Schizomavella teresae*, *Membranipora tenuis*, *Conopeum reticulum*, *Aspidelectra melolontha* and *Electra pilosa* are now dominant on gravel. In 2005 the Hinder Banks were re-sampled with a 2m beam trawl (Houziaux *et al.*, 2008). Up to 21 bryozoan species were found on gravel locations, covering large parts of the substratum. Surprisingly, the greatest diversity of bryozoans occurs on empty shells on sandbanks with up to 71 species per location. This study revealed 31 species new for the Belgian fauna. A great amount of species that are typically reproducing at small colony size as an adaptation to short survival on small unstable substrata, are added to the Belgian list. *Escharella gilsoni* and *Escharoides bishopi* described from the Kwintenbank (De Blauwe, 2006) are found again and probably some other species new to science are discovered. The campaign shows that some species well known from the English Channel are protruding in the southern bight of the North Sea. The presence of *Distansescharella seguenzai*, *Puellina nana* and others show some resemblances with the fauna in the Rias in northern Spain. Thousands of shells in the Gilson collection still have to be screened to determine long-term changes in the bryozoan fauna on shell debris.

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METAL ACCUMULATION AND METALLOTHIONEIN INDUCTION IN THE SPOTTED DOGFISH *SCYLIORHINUS CANICULA*

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Metal toxicity has been studied extensively in teleost fish, but much less is known about the effect of metals on elasmobranchs. In a previous study, examining the effects of metals on an elasmobranch, silver appeared to be 10 times more toxic to Pacific spiny dogfish than to similarly sized marine teleosts and in fact, sensitivity approached that of freshwater teleosts. This sensitivity coincides with high Ag accumulation rates in gill and other tissues. As in teleosts, toxicity appeared to be related to osmoregulatory disturbance; however, in this elasmobranch, failure of the urea retention mechanism played an important role in the osmoregulatory disturbance. Cu, which usually exert similar effects as Ag, did not induce this high toxicity or the high accumulation rates.

Despite the fact that normal background levels for metals in the marine environment are low, the differences in response between marine teleosts and elasmobranchs are intriguing. Therefore, the goals of the present study were to determine which metals showed high accumulation rates in another elasmobranch, *Scyliorhinus canicula*. For this purpose, we exposed the dogfish to 0.1 and 1µM of Ag or to 10µM Cd, Cu, Ni or Pb for one week and measured metal accumulation, metallothionein induction, and parameters related to osmoregulation.

PLANT-SOIL FEEDBACK AS MECHANISM OF INVASION OF *CARPOBROTUS EDULIS* IN COASTAL DUNES

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The interaction between plant and soil is not unidirectional and depends to a great extent on feedback mechanisms between plants and their associated soil biota. Plant-soil feedbacks explain the success of certain exotic species in the introduced areas. *Carpobrotus edulis* is one of the most devastating species in Mediterranean and Atlantic coastal dunes in southern Europe. Although several aspects of its biology have been studied in relation to invasion, the occurrence of plant-soil feedbacks has been scarcely addressed. We tackled this key question and we studied the effect of plant-soil feedbacks on (i) the growth of *C. edulis* at different stages of the invasion and (ii) the growth and germination capacity of different species of the native community in Mediterranean coastal dunes.

The results obtained illustrate the importance of the plant-soil feedbacks to understand *C. edulis* invasion. The modification of the soil biota after invasion benefits not only *C. edulis'* subsequent growth but also it is detrimental for the growth of the native plant community.

INCORPORATING TRAIT DIVERSITY IN FOOD WEB MODELS FOR USE IN PREDICTIVE ECOLOGICAL RISK ASSESSMENT

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Monitored time series of plankton abundance in marine ecosystems demonstrate the large interspecies variability of biological traits such as maximal growth rate, dependence on available resources and degree of specialisation. Accounting for this trait diversity in predictive ecological risk assessment is difficult because the degree of physiological detail in state-of-the-art food web models is often too high to include more than 10 species. Here, a recently proposed modelling approach was implemented that minimizes physiological detail but maximizes the number of modelled species. Trait diversity was introduced by assigning random values to parameters that represent species' traits, yet within biologically realistic ranges. We demonstrate (1) that the population dynamics produced by such models compare well to observed phyto- and zooplankton dynamics; and (2) that stressor effects can be incorporated in such models to study stressor-induced effects in marine ecosystems on time scales of decades to centuries.

STRESSOR EFFECTS ON AQUATIC FOOD WEB FUNCTIONING: METHODOLOGY AND CASE STUDY

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The status of natural marine ecosystems and how they respond to and recover from exposure to stressors is often assessed by monitoring the population size of individual species using field surveys. Although this approach reveals which food web components are abundant, it provides little information on food web functioning. Here, we present a new approach that uses carbon budget estimation techniques to establish stressor effects on food web functioning from monitored population sizes. We applied this methodology to a data set from an enclosure experiment in which a single anthropogenic stressor, the insecticide cypermethrin, adversely affected the zooplankton community and provoked a phytoplankton bloom. Our model showed that protozoa benefited most from this bloom, i.e. they gradually shifted from 60-90% bactivory in the control to 60-90% planktivory at 3.6 µg L^{-1} cypermethrin. At this concentration, protozoa made up 50% of the copepod diet while in the control, copepods were strictly herbivorous. Network analysis revealed that the increasing dependence of food web functioning on one compartment (protozoa) rendered the food web less stable and thus more vulnerable for future disturbances. We conclude that our approach is an excellent tool to analyse the available monitoring data sets that contain the population size of individual species as a function of pollution gradients.

SEASONAL PCB BIOACCUMULATION IN AN ARCTIC MARINE ECOSYSTEM: A MODEL ANALYSIS

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Primary production, species' lipid contents and migration patterns in Arctic ecosystems are notoriously seasonal. Taking the southern Barents Sea as a study region and PCBs as model contaminants, we examined to what extent each of these factors induce season dependent bioaccumulation changes. Using quantitative data on the Barents Sea food web compartments, going from primary production to Atlantic cod stocks, we estimated season-specific carbon budgets and by inference also corresponding values for food ingestion and production of cod, capelin and herring. When combining these values with Arctic lipid dynamics into a dynamic bioaccumulation model, we predicted bioaccumulation factors (BAFs) that differed less than a factor 2 from measured BAFs in cod and capelin observed between 1998 and 2008. BAFs in all fish were 10 times lower in summer than in other seasons and this trend was mainly driven by lipid dynamics and not by seasonal changes in carbon uptake and production as those changes were negligible for fish. When using the derived carbon budgets to estimate trophic levels (TLs) using network analysis, trophic magnification factors (TMFs: increase in BAF per unit increase in TL) were highest for PCB 138 during spring (2.5 - 2.7) and lowest for PCB 52 in summer and autumn/winter (1.5 - 1.6). These seasonal differences were mainly driven by TL increases of fish in spring, relative to TLs in summer and autumn/winter. This underscores the importance of food web quantification for accurately assessing the transfer of organic contaminants in marine food webs.

COLD-WATER CORAL ECOSYSTEMS IN THE PENMARC'H AND GUILVINEC CANYONS (BAY OF BISCAY): DEEP-WATER *VERSUS* SHALLOW WATER SETTINGS

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In 1948, Le Danois reported for the first time the occurrence of "massifs coralliens" along the European Atlantic continental margin. Within the framework of the EC FP6 IP HERMES and ESF EuroDIVERSITY MiCROSYSTEMS projects, the R/V Belgica BiSCOSYSTEMS cruise was set out to rediscover these cold-water corals in the Penmarc'h and Guilvinec canyons along the Gascogne margin of the Bay of Biscay. During this cruise, an area of 560km^2 was studied using swath bathymetry (EM1002), high-resolution reflection seismic profiling, CTD casts, ROV observations and USBL-guided boxcoring.

Based on the multibeam data and the ROV video images, two different cold-water coral reef settings were distinguished. In water depths ranging from 260 to 350m, mini-mounds up to 5m high, covered by dead cold-water coral rubble, were observed. In between these mounds, an alternation of rippled and unrippled seabed with a patchy distribution of dropstones was observed. The second setting features both living and dead cold-water corals (predominantly *Madrepora oculata*) in water depths of 700 to 950m. At certain locations, they form dense coral fields with a diameter of about 10-60m, characterized by mostly dead coral graveyards and a few living ones. In this area also hard substrate with cracks, ridges, cliffs and oyster banks was noticed.

Both the shallow area with the mini mounds (SE flank of the Guilvinec canyon) and the living and dead corals in the deeper setting were sampled with boxcores. These boxcores were used to determine the different sedimentary facies and to identify coral species present on the site. For this purpose, grain size analysis and U/Th dating of coral fragments were established.

The cold-water corals from the deeper area occur in a density envelope (sigma-theta) of 27.35–27.55kg.m^{-3}, falling within the range of values which are considered to be a prerequisite for the development, growth and distribution of cold-water coral reefs along the northern Atlantic margin (Dullo *et al.*, 2008). The presented data prove for the very first time that this prerequisite is also valid for the Bay of Biscay. However, this does not explain the presence of the shallow mini mounds, for which another genetic model needs to be proposed.

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THE BACTERIAL STORAGE COMPOUND POLY-β-HYDROXYBUTYRATE (PHB) INCREASES GROWTH PERFORMANCE AND INTESTINAL MICROBIAL DIVERSITY IN EUROPEAN SEA BASS JUVENILES (*DICENTRARCHUS LABRAX)*

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Poly-β-hydroxybutyrate (PHB) is accumulated as a carbon and energy storage compound by a wide variety of bacteria. It has potential to be used as alternative anti-infective strategy for aquaculture rearing (Halet et al., 2007). However, its positive impact has until now only been reported for the aquaculture model organism *Artemia fransciscana*. In this research, the effects of (partially) replacing the feed of European sea bass juveniles with PHB were investigated in relation to the growth performance of the fish and the intestinal microbial community structure. During a 6 weeks trial period, the sea bass were fed 6 different PHB treatments: a non-fed treatment and a 0%, 2%, 5%, 10% and 100% substitution of the normal feed (w/w) by PHB. At weekly intervals, the wet weight of the fish in each treatment was determined in order to calculate the growth performance. Also, measurements of the intestinal pH were performed and samples of the gut microbial community were taken for molecular analysis using denaturing gradient gel electrophoresis (DGGE).
The fish treated with 0%, 2%, 5% and 10% PHB showed no significant difference in survival (ca. 90%). For the non-fed sea bass the survival decreased to 40%, while feeding with 100% PHB resulted in a survival of 75%. The latter observation indicated that the PHB was degraded and absorbed during gastrointestinal passage and that it could be used as an energy source for survival (Defoirdt *et al.*, 2007). A lower gut pH at higher dietary PHB levels suggested that the degradation of the PHB resulted in an increased production of (short chain fatty) acids in the gut.
The diets supplemented with 2% and 5% PHB resulted in a significantly increased gain of the average fish weight of 243% and 271%, respectively, relative to 216% in the 0% PHB treatment. A PHB level of 10% resulted in the lower weight gain of 209%. The fish in the un-fed treatment and the 100% PHB did not show an increase in weight, indicating that PHB could not be used as a source for growth.
Upon DGGE analysis of the intestinal bacterial community samples, cluster analysis showed a trend of larger changes in the bacterial community at higher dietary PHB levels after 42 days of feeding. Based on the DGGE band patterns, the range-weighted richness (Rr) was calculated. This parameter was used to describe the bacterial community with higher Rr values representing a higher bacterial richness (Marzorati et al., 2008). The Rr values of 53, 67, 89 and 41 calculated for the 0%, 2%, 5% and 10% PHB treatment, respectively, showed a highly similar trend to that of the fish growth performance. This finding indicated that the fish growth performance may have been closely related to the intestinal bacterial community richness and thus warrants further research on this type of host microbe interactions.

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LATIS: THE TOOL FOR FLOOD RISK CALCULATIONS IN FLANDERS

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In Flanders' recent history, flood events caused several times substantial damage to buildings and infrastructure. Those floods originated from small non navigable waters, small navigable rivers and even from the Scheldt, the Meuse or the North Sea (1953). Scientists predict that these flood events could even become more frequent and more dramatic in the future, as climate is changing and sea level is rising. In the past, the solution of Flemish water managers to prevent flooding was evacuating the water as fast as possible and heightening the dikes along the river banks, but experience showed that this was a far from ideal situation. Therefore, a new approach was proposed during the late 1990's. The focus was no longer on protecting against all floods and the highest water levels, but changed to avoidance of serious economic damage. This meant that for the evaluation of different protection scenarios, a new objective methodology was needed to assess the damage, caused by floods, in a quantitative way.

Therefore, Ghent University developed in cooperation with Flanders Hydraulics Research a risk-based methodology. This methodology defines flood risk as the product of the probability of a flood event and the damage caused by that event. The damage is a function of the water depth and the maximal damage, which is dependent on the land use of the flooded area and the socio-economic context. In a second phase, this methodology was implemented in a tailor-made GIS-based flood risk assessment tool called LATIS. This tool integrates a variety of land use information and socio-economic data with potential inundation maps to calculate the damage and risk of certain flooding events. In addition, LATIS is also able to calculate the casualties of a flood and the additional damage caused by high flow velocities. These high flow velocities cause collapse of buildings inducing much higher damage. Recently, a new module that specifically calculates the casualties and damage on the sea wall (which is a special situation because a lot of people and buildings are concentrated there) was also implemented in the software.

In the past years, LATIS was used for several studies in Flanders, varying from assessments of the impact of different climate change scenarios on flood risk (Willems *et al.*, 2009) to studies on coastal defence alternatives within the framework of the Integrated Masterplan for Flanders' Coastal Safety (Mertens *et al.*, 2008). In the near future, LATIS will continue to play an important role when Flanders will have to fulfil the requirements of the European Flood Directive (EU Commission, 2007).

Keywords: Flood risk, risk calculations, GIS, LATIS

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THE NATURAL FURANONE (*5Z*)-4-BROMO-5-(BROMOMETHYLENE)-3-BUTYL-2(*5H*)-FURANONE DISRUPTS QUORUM SENSING IN *VIBRIO HARVEYI* BY DECREASING THE DNA-BINDING ACTIVITY OF THE MASTER REGULATOR LUXR

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Our previous work showed that quorum sensing-disrupting furanones significantly increase the survival of brine shrimp infected with luminescent vibrios (Defoirdt *et al.*, 2006). This study aimed at getting a deeper insight in the molecular mechanism by which the natural furanone (*5Z*)-4-bromo-5-(bromomethylene)-3-butyl-2(*5H*)-furanone disrupts quorum sensing in *Vibrio harveyi*. Bioluminescence experiments with signal molecule receptor double mutants revealed that the furanone blocks all three channels of the *V. harveyi* quorum sensing system. In further experiments using mutants with mutations in the quorum sensing signal transduction pathway, the compound was found to block quorum sensing-regulated bioluminescence by interacting with a component located downstream of the Hfq protein.

Furthermore, reverse transcriptase realtime PCR with specific primers showed that there was no effect of the furanone on $luxR_{Vh}$ mRNA levels in wild type *V. harveyi* cells. In contrast, mobility shift assays showed that in the presence of the furanone, significantly lower levels of the $LuxR_{Vh}$ response regulator protein were able to bind to its target promoter sequences in wild type *V. harveyi*. Finally, tests with purified $LuxR_{Vh}$ protein also showed less shifts with furanone-treated $LuxR_{Vh}$, whereas the $LuxR_{Vh}$ concentration was found not to be altered by the furanone (as determined by SDS-PAGE). Therefore, our data indicate that the furanone blocks quorum sensing in *V. harveyi* by rendering the quorum sensing master regulator protein $LuxR_{Vh}$ unable to bind to the promoter sequences of quorum sensing-regulated genes.

The fact that the furanone affects the master regulator rather than selectively blocking one of the channels of the *V. harveyi* quorum sensing system is quite important with respect to possible practical applications since there seems to be a difference in the relative importance of the three channels for a successful infection of different hosts (Defoirdt *et al.*, 2005; Tinh *et al.*, 2007). Since the furanone blocks all three channels of the system at once by acting at the end of the quorum sensing signal transduction cascade, it will not be necessary to develop different furanone compounds to protect different hosts. In addition to this, human pathogens, including *Vibrio cholerae*, *Vibrio parahaemolyticus* and *Vibrio vulnificus*, have been shown before to contain $LuxR_{Vh}$ homologues (Milton, 2006).

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MONITORING THE IMPACT OF OFFSHORE WINDFARMS ON THE MARINE ENVIRONMENT: AN OBLIGATE MULTIDISCIPLINARY AND INTEGRATED PROGRAMME

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In 2004 the Belgian government assigned a zone for wind energy in the Belgian part of the North Sea. Since then two companies, C-Power and Belwind, were granted a permit to build and exploit a wind farm on the Thorntonbank and the Bligh Bank, respectively. The first wind turbines are up and running since 2009. A third company, Eldepasco, started the environmental permit procedure in 2009. The permit includes the obligation to assess the impact of the project on the marine environment. As such, the monitoring programme covers physical, biological and socio-economic aspects of the marine environment.

The Management Unit of the North Sea Mathematical Model (MUMM) coordinates the monitoring and cooperates with different institutions that have expertise in a specific domain: Research Institute for Nature and Forest (INBO; birds), Institute for Agricultural and Fisheries Research (ILVO; soft sediment epibenthos and fish), Ghent University's Marine Biology Section (soft sediment macrobenthos), Ghent University's Renard Centre of Marine Geology (underwater noise) and MUMM (sea mammals, hard substrate biofouling and fish, radar detection of seabirds, underwater noise, hydrodynamics and seascape).

In general, two parallel and complementary aspects can be distinguished within the monitoring programme. The baseline monitoring, generally following a Before/After-Control/Impact or BACI design, aims at the detection and quantification of the combined effect. The targeted monitoring aims at unraveling and hence understanding the underlying causes of a selected set of priority effects, such as bird collisions and altered (commercial) fish (re)productivity.
The multidisciplinary and integrative approach will lead to scientifically sound advices for possible mitigating measures for existing, but also future offshore wind mill farms in both Belgian waters and abroad.

Also see abstracts of related projects further in this publication:

Brabant *et al.*; Coates *et al.*; Di Marcantonio M.; Haelters J.; Kerckhof *et al.*; Reubens *et al.*; Vandendriessche *et al.*

THE COASTAL TEAM AT FLANDERS HYDRAULICS RESEARCH: MATCHING RESEARCH PRIORITIES AND CZM NEEDS FOR THE 21ST CENTURY

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The mission of the coastal team at Flanders Hydraulics Research is to deliver knowledge, expertise and advice on issues relevant to the sustainable development, exploitation and protection of the Belgian coast. In this framework, we provide science-based methodologies, modeling results and CZM (Coastal Zone Management) supporting tools. We develop our knowledge taking part in national and international research projects contributing to a better understanding of our coast and its context and essential when solutions to issues relevant to the Belgian coast need to be conceived at the regional scale.

Traditionally, CZM activities in Belgium focus on sustainable exploitation and on minimizing the effect of human intervention on natural systems. During the last 10 years, however, CZM problems need to be tackled from a new perspective. Climate change effects as rising sea levels or increased storminess make necessary modifying CZM practices and priorities. As a consequence, new synergies between research and arising needs need to be found. Researchers and experts have to work now on longer time and space scales and, at the same time, account for processes often occurring locally at small scales. This fact represents a new challenge, especially for the assessment of uncertainty of results and for the validation of the models that should now be based on long-term data including extreme events which in many cases have never been monitored.

In our search for a real synergy between research priorities and CZM needs, our team contributes not only to developing but also to transferring knowledge and expertise into suitable and reliable tools. We take advantage of the knowledge gained thanks to projects as SAFECOAST (2005-2008, INTERREG) for which we delivered a new methodology for coastal risk assessment in the North Sea. We study climate change impact on the Belgian coast in CLIMAR (2007-2011, BELSPO) which objective is developing a framework for the assessment of possible adaptation strategies in Belgium. With SUSCOD (2009-2013, INTERREG), practical attempt to facilitate direct knowledge transfer between experts and coastal managers, we will provide a reliable and user-friendly tool for impact assessment and risk awareness in Belgian coastal towns.

Most of the outcome of these activities is gathered into the Coastal Safety Plan for the Belgian Coast (2007-2010, Coastal Division of the Flemish Authorities) for which we provide tailor-made methodologies and results about coastal flooding impact and risk assessment.

It is clear that CZM priorities have shifted due to the need of anticipating possible climate change effects, but there are also other important CZM needs, as those related to the exploitation of resources. Investigating new aspects related to sediment management, as the impact of human action on the sediment budget (QUEST4D, 2007-2011, BELSPO) or exploring marine energy potential in Belgium (BOREAS, 2009-2011, BELSPO) are also part of our activities. Both sediment management and marine energy related issues are becoming more and more relevant for CZM. However to be able to fulfil old and new CZM needs, more work on understanding, quantifying and predicting fundamental driving processes is still necessary.

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MANAGING CULTURAL HERITAGE UNDER WATER

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The under water cultural heritage in Europe is very rich and in many places well preserved. Above this it is linked with the development of Europe: a history of seafaring, busy maritime routes and battles.

Many of these sites are under threat by looting and commercial development. For that reason the Machu project, sponsored by the Culture 2000 programme of the European Union, was set up from September 2006 until September 2009. The seven Machu-partners, situated in Belgium, Germany, Poland, Portugal, the Netherlands, Sweden and the United Kingdom aimed to find better ways for an effective management of this heritage.

Therefore a greater understanding of how sites are formed, changed and threatened is important.
As a tool for that purpose a web-based GIS application and an interactive website have been developed. These two applications will engender a greater public commitment to the protection of under water sites and must also be a critical tool for decision makers for the management of underwater sites.

The second tool developed is the sediment-erosion model by the University of Southampton. This model aims to understand the interaction between a ship wreck and the current and wave action and sediment input, without the need for extensive field monitoring. The model, using computers, is provided with basic data of coastlines, water depth, seabed characteristics and tidal information.

In Belgium the Flemish Heritage Institute (VIOE) picked out two study areas in order to determine the threats and gain archaeological information on wreck sites in this area. The areas are situated around the sandbank Buiten Ratel in the southwest (225 km²) and around the Vlakte van de Raan in the northeast (97 km²) of the territorial Sea and this because of the presence of valuable wreck sites. The areas contain 41 known wreck positions.
The information on these sites is gained by gathering existing information like multibeam images and side-scan sonar images. These data are completed by recent information by divers, by marine acoustic techniques and by analysing sediment samples.

On-site investigations were executed regarding the character and condition of numerous wreck sites. However most of the remains of the wrecks are covered in sediment, most of them are damaged by looting. Steel cables, dredges and pieces of metal witness these looting activities.
Processes such as degradation and sedimentation at certain wreck sites are measured through analysis of sediment samples. 18 samples from 4 wreck sites have been analyzed by means of grain size analysis by the Renard Centre of Marine Geology of the Ghent university (RCMG).
A clear difference is recognized in the grain size distribution for samples taken at the wreck compared to those taken off the wreck. Inside the wreck, sediments have a heterogeneous character and are characterized by a wide grain size distribution (less sorting). This proves the dynamic character of sedimentation and erosion on wreck sites.

The marine seismic imaging, also by the RCMG, is tested on two sites in the area: Buiten Ratel and 't Vliegend Hert and revealed the burial of parts of the wrecks.

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AN INTEGRATED IMPACT ASSESSMENT OF TRAMMEL NET AND BEAM TRAWL FISHERIES – PROJECT WAKO

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Belgian fisheries are dominated by beam trawls as fishing gear. Beam trawl fisheries have been much debated over their economic and ecological perspectives. Trammel net fishery might be a viable alternative, especially for the Belgian Part of the North Sea. It is a passive fishing method, implying less dependency on fuel and a higher economic potential. However, its environmental impact has not only limitedly been quantified, nor has it been evaluated in direct comparison with other fisheries. Up till today, it remains difficult to conclude in an objective way which type of fishing method is most sustainable for the marine ecosystem. Three research institutes (ILVO, INBO, RBINS/MUMM) and the University of Ghent have therefore initiated a multi-disciplinary research project concerning the environmental impact of trammel net and beam trawl fisheries in the Belgian Part of the North Sea. In a step-by-step process, the ecosystem effects of both fishing methods are being studied on the level of five structural ecosystem components: endofaunal and epifaunal invertebrates, fish, seabirds and marine mammals.

A first step in the process focused on the compilation of information, existing in literature and an investigation of the best practice for combining existing databases and studies in order to compare the effects of both fisheries. These efforts have resulted in the identification of numerous knowledge gaps (WAKO-I, 2006-2008). A second initiative has consequently been set up, WAKO-II, to fill out these gaps. The main objectives to be dealt with are:

- the quantification of the mortality or interaction of five ecosystem components (endofauna, epifauna, fish, seabirds and marine mammals), with beam trawl and trammel net fishery;
- a sensitivity assessment through which key species, sensitive to beam trawl and/or trammel net fishery, will be selected;
- a spatial and/or temporal distribution pattern of the selected, sensitive key species;
- the development of sensitivity maps for beam trawl and trammel net fisheries, based on the spatio-temporal distribution of key species and a comparison with the current fishing effort in the Belgian Part of the North Sea.

The integration of sensitivity maps and the best available information on fishing effort will enable us to spatially map the impact of the two most important Belgian fisheries. This could provide a baseline for the development of policies, leading to an appropriate environmental management and a coastal fisheries management for sustainable beam trawl and trammel net fisheries.

More information will become available throughout the project on www.ilvo.vlaanderen.be/wako.

MORTALITY OF FISH DISCARDS IN BEAM TRAWL FISHERIES

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The ecosystem-based approach of fisheries management implies that a fishery does not exceed the sustainability of the resource and that the impact on the natural ecosystem is limited. One important issue in this approach is fishing mortality, caused by discarding. The overall discarded bycatch discharged back into the North Sea of flatfish beam trawl fishery has been estimated to be 71-95% of the total weight landed. Discards are not only non-commercial species but also commercial species that are below minimum landing size or because of quota restrictions. Often fish discards will not survive the catching process. This discard mortality is responsible for a large source of uncertainty in estimates of fishing mortality and may hamper the sustainable use of marine recourses.

In this study the discard mortality of different commercial fish species has been investigated. Survival experiments were carried out onboard of the RV 'Belgica'. Sampling took place during fishing trip in November-December 2008, February 2009 and April 2009. A 4m beam trawl equipped with a chain mat was used for fishing and rigged as those in commercial circumstances. After hauling the catch we accommodated our specimens in survival tanks provided with a continuous flow of fresh sea water. The specimens were followed up for minimum 60 hours and the level of injury was determined. Next to the mortality rates of the discarded fish, different variables were measured to understand why discarded fish die. Mainly this is the result from interactions between animal and fishing gear. Therefore, catch variables and biological factors such as catch weight and species size were recorded and investigated for their significance on the mortality of discarded fish. Uncovering patterns for discard mortality are important to predict the discard mortality and evaluate new fishing methods designed to reduce or eliminate discards. Our field experiments will be the basis for an evaluation of discard mortality for fish species as sole (*Solea solea*), plaice (*Pleuronectes platessa*) and cod (*Gadus morhua*).

TRANSCRIPTOME AND EXOMETABOLOME ANALYSIS OF THE CELL SIZE-REGULATED SEXUAL REPRODUCTION IN DIATOMS

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Diatoms, the most species-rich group of unicellular eukaryotic algae, undergo a gradual cell size reduction during vegetative divisions, due to the rigidity of their silica cell wall, which consists of two valves typically overlapping one other like the two halves of a petri dish. During mitosis, a new valve is built inside each parental valve. Large vegetative cells are generated again by the special ability of small diatom cells to restitute their original cell size through sexual reproduction (auxosporulation). Remarkably, only cells under a certain cell size threshold are able to become sexualized.

Seminavis robusta has, in contrast to the sequenced diatom species, a well described life cycle in which sexual reproduction can be induced experimentally. As meiosis only occurs in cells below the sexual cell size threshold, differences in gene expression in large and small cells are expected, induced by a hitherto unknown cell size sensor once the critical threshold has been reached. This gene expression possibly results in the secretion of products to sense the presence of compatible mating partners, as small cells show directed movement towards small cells of the opposite mating type.

Here we demonstrate differential gene expression and metabolite excretion using cDNA-AFLP transcriptome analysis and UPLC-MS exometabolome analysis, respectively. Genes which show a significant differential expression pattern between large and small cells are selected and blasted against the available databases. The identified genes potentially involved in the cell size-induced sexual sensitivity are further explored with RT-qPCR for their expression in cultures of different cell sizes above, across and below the threshold. A sudden decrease or increase in gene expression when crossing the size threshold, could be demonstrated for a subset of the selected genes. On top of this, a pilot UPLC-MS experiment indicates that also some metabolites are excreted differentially in large and small cells. By combining these results with the quantification of sexual reproduction in cultures of decreasing cell size and other observed fysiological differences between large and small diatom cultures, like differences in their growth rate and cell cycle phases, this project must lead to a better understanding of the molecular mechanisms regulating this unique coupling of cell size and sexual reproduction in diatoms.

As microalgae are promising organisms for renewable energy and the commercial production of biological products like oils, pigments, proteins and hydrocarbons, a good understanding of their biology is essential. Economical analyses are for the moment investigating the future potential of products and technologies based on diatoms, in particular their usability against pollution and the use of diatoms for CO2-reduction purposes by an integrated economical lifecycle. So it is obvious that major breakthroughs in the commercialization of microalgae will result from the optimization of diatom strains. To this end, a good knowledge of the diatom life cycle will contribute to the commercial exploitation of diatoms.

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MONITORING THE IMPACT OF OFFSHORE WINDFARMS ON THE SEASCAPE: PREPARATORY YEAR

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There is a big concern on the impact on the seascape of the planned offshore wind farms in the Belgian part of the North Sea, This study describes the preparatory work done for the monitoring of the impact on the seascape.

The main goals of the sociological landscape study is to see what people's opinions are on the existing wind farm with six wind turbines and their opinion on the planned extension of the wind farm and the completion of other wind farms. For achieving these goals an inquiry will be held amongst people regularly staying at the coast. The landscape imagery focuses on simulations of the planned wind farms, they are used in the inquiries.

As a previous study is available on people's opinion on renewables and wind energy it will be possible to compare peoples opinion of today (when the wind farm exists at sea) with that of some years ago (when the wind farm wasn't built yet).

Also see abstracts of related projects further in this publication:

Brabant *et al.*; Coates *et al.*; Degraer *et al.*; Haelters J.; Kerckhof *et al.*; Reubens *et al.*; Vandendriessche *et al.*

GENETIC ADAPTATION IN COMMON SOLE (*SOLEA SOLEA* L.) UNDER NATURAL AND ARTIFICIAL SELECTION

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The management of commercial marine fish species requires a thorough understanding of natural and anthropogenic selective influences, which impact natural populations. During my PhD I study the level of adaptive genetic variation in natural sole populations, to assess the geographical distribution and the influence of overfishing on functional diversity. It might provide indications for genetic adaptations. As well historical time series (otoliths) as contemporary populations will be analysed using gene-linked markers (microsatellites and SNPs). My PhD consists of four main objectives: (1) the bioinformatic analysis of sole transcriptome sequences (based on Next-Generation Sequencing) to develop markers linked to candidate genes and potentially involved in life-history traits like growth, maturation and temperature adaptation; the high-throughput screening of (2) contemporary and (3) historical sole populations using both neutral and targeted SNPs to assess jointly the connectivity and potential local adaptation in sole; and (4) the experimental validation of genetic adaptations in a controlled breeding population of sole to assess genotype by environment interactions. Preliminary results indicate the existence of polymorphisms in candidate genes linked to growth and maturation, two economically important traits. On the one hand, this information is highly relevant for sole management by mapping genetic management units and by pinpointing potential irreversible anthropogenic effects on adaptive genetic variation. On the other hand, the exploitation of functional diversity is of importance for the efficient selective breeding of sole.

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STUDY OF METHYLMERCURY AND SELENIUM EFFECTS ON HARBOR SEAL (*PHOCA VITULINA*) T LYMPHOCYTES *IN VITRO*

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Mercury (Hg) is a widespread pollutant which organic form, methylmercury (MeHg), gains particular attention because of its numerous toxic properties, notably towards the immune system. The MeHg is formed by methylation of inorganic mercury through microbial activity, and undergoes the process of biomagnification leading to increasing concentrations at higher trophic levels (Palmisano *et al.,* 1995). It is mainly absorbed by the digestive tract of marine mammals and constitutes the predominant form of mercury present in their blood (Nielsen *et al.*, 2000). The blood cells, including the immune cells, are therefore exposed to the toxic properties of that chemical. Nevertheless, selenium (Se), which is an essential element absorbed concomitantly to MeHg, seems to modulate this toxicity. The goal of this study is to evaluate the immunotoxicity of MeHg on the harbor seal (*Phoca vitulina*) T lymphocytes, highly important in the adaptative immune response, and the modulating effect of Se on that toxicity. In parallel, the concentrations of MeHg, total mercury (THg) and Se are determined in free-ranging harbour seals blood in order to follow their contamination levels.

To reach that goal, Peripheral Blood Leukocytes (PBLs, comprising lymphocytes, monocytes and granulocytes) of 12 harbor seals (6 juveniles and 6 adults) were isolated from the whole blood and exposed *in vitro* to various MeHg concentrations (from 50µg/l to 500µg/l) and to 5µg/ml of mitogenic ConA, specifically stimulating harbour seal T lymphocytes. The exposure effects were estimated by functional tests including the evaluation of viability, proliferation, DNA and proteins synthesis, and by morphological analysis by Transmission Electron Microscopy.
The results concerning the effects of MeHg on T lymphocytes *in vitro* showed a decreasing number of viable cells with increasing concentrations of MeHg in a dose-response relationship, and numerous ultrastructural defects. The T lymphocytes exposed to MeHg notably displayed distortion of the plasmic membrane, nucleus fragmentations, swelling mitochondrias and cytoplasmic vacuolisations.

Blood from 22 harbor seals was sampled to measure MeHg, THg and Se concentrations. The mean THg concentration was 172 ± 143 µg/l of whole blood. The concentrations varied widely, from 43 to 611µg/l, reflecting high interindividual variations (Das *et al.*, 2008).
Those results highlight various immunotoxic effects of MeHg, both at the functional and ultrastructural levels. The next analysis will help to better understand the antagonistic role of Se on MeHg immunotoxicity.

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TOXICODYNAMICS OF POLLUTANTS IN POÏKILOTHERM SPECIES

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Marine turtles are critically endangered species facing several human activities such as poaching, fishing, shipping, coastal development and chemical pollution. Although scare in the scientific literature, effects of chemical pollution on these species raise many concerns. The oestrogen-like effects of some organochlorine pollutants (e.g. PCBs, DDT and metabolites) have been displayed in the American alligator *Alligator mississipiensis* (Guillette *et al.,* 2002) while *in vitro* effect of PCBs and mercury on immune system has been described in the loggerhead marine turtle *Caretta caretta* (Keller *et al.,* 2006; Day *et al.,* 2007). The lack of toxicity thresholds at which deleterious effects are observed shows the necessity to undertake this kind of investigations in these poïkilotherm amniotes, and especially in marine turtles. In this present study, we develop a strategy to apprehend levels, effects and transfer to offspring of several pollutantsa in marine turtles as well as their effects on the metabolism of some biomolecules (thyroid hormones and vitamins). From August to September 2008, a sampling campaign was carried out in Guadeloupe (French West Indies). During the laying, three eggs and subcutaneous tissue were collected from 15 gravid green marine turtles *Chelonia mydas* as well as the sand from the nest. Tissues were stored in a -80°C freezer until analysis. Trace elements were analyzed by ICPMS and T-mercury by DMA milestones while pesticides and vitamins were analyzed by HPLC. The first results show that the organic compounds (OCs) observed in marine turtle' tissues are in accordance with their anterior use in the French West Indies, and that those observed in subcutaneous tissue are present in eggs as well suggesting a maternal transfer of these compounds. PCBs and chlordecone are observed in all the analyzed tissues while DDTs and HCHs are more prevalent in eggs than in subcutaneous tissue (DDTs: respectively 80% and 23% ; HCHs: respectively 88% and 23%). In eggs, PCBs are the most observed compounds (mean percentage contribution to the sum of organochlorine pollutants: 71%) and the lower chlorinated congeners are the predominant ones representing about 72% of the total amount of PCBs. This observation is consistent with the biochemistry of these congeners and with other studies already performed in oviparous species (Cobb and Wood, 1997; Guirlet *et al.*, 2009). Pollutant levels measured in this study are generally lower than those observed in other poïkilotherm species (Cobb *et al.,* 2002; Alava *et al.,* 2006), but higher than those from other populations of *C. Mydas* (van de Merwe *et al.*, 2009). These patterns could mainly be explained by the trophic level of the species as well as the contamination level of their feeding areas. In parallel to the field study, an *in vitro* model of pollutant mobilization from fat tissue was designed using tissue collected from the red-eared slider turtle *Trachemys scripta elegans*. This *in vitro* exposure aims to determine the mobilization pattern of Aroclor 1254 and vitamin A from fat tissue as well as potential impact of PCBs on cell metabolism.

[a] *Organochlorine pollutants: PolyChlorinated Biphenyls, DichloroDiphenylTrichloroethane and metabolites, HexaChlorocycloHexanes, Aldrin and Dieldrin, chlordécone ; Trace elements: Cu, Zn, Se, Hg et methylmercure, Cd, Pb.*

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SHELTER FROM THE STORM? USE AND MISUSE OF BIOSHIELDS FOR MANAGING NATURAL DISASTERS ON THE COAST

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Vegetated coastal ecosystems provide goods and services to billions of people. In the aftermath of a series of recent natural disasters, including the Indian Ocean Tsunami, Hurricane Katrina and Cyclone Nargis, coastal vegetation has been widely promoted for the purpose of reducing the impact of large storm surges and tsunami. In this paper, we review the use of coastal vegetation as a 'bioshield' against these extreme events. We begin with an overview of the scientific literature, in particular focusing on studies published since the Indian Ocean Tsunami in 2004 and discuss the science of wave attenuation by vegetation. We then explore case studies and evaluate the detrimental impacts bioshield plantations may have upon native ecosystems, drawing a distinction between coastal restoration and the introduction of exotic species in inappropriate locations. The values of coastal ecological systems are realized over the long term and we must find better ways to communicate the value of conserving these ecosystems. For example, vegetation can, over the long-term, alter topography and bathymetry through processes of sediment accretion, reducing the vulnerability of the landscape to future inundation (Day *et al.* 2007). Finally, we place bioshield policies into a political context, and outline a new direction for coastal vegetation policy and research.

LONG-TERM INFLUENCE OF MARITIME ACCESS WORKS ON THE DISTRIBUTION OF COHESIVE SEDIMENTS: ANALYSIS OF HISTORICAL AND RECENT DATA

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Most of the coast of the southern North Sea has had a long history of human impact, due mainly to coastal defence and harbour infrastructure works. The latter are associated with the deepening of navigation channels and harbour entrances, and disposal of dredged material at designated sites. The construction of the port of Zeebrugge in the 20th century, including the dredging and deepening of navigation channels and the associated disposal of sediments, represents the most conspicuous anthropogenic impact in the Belgian nearshore area. The construction of the port was carried out between 1899 and 1903; in those times, the breakwater had a length of 1.7km and a maximum distance from the coast of 1.1km. A navigation channel towards the port was dredged in 1903 through a sandbank. Since then, many modifications have been carried out in order to deepen and widen the access channels and, finally, to extend the outer port between 1980 and 1985, with the construction of two 4km long breakwaters extending about 3km out to sea.

Long-term changes in the cohesive sediment distribution of the Belgian–Dutch nearshore zone are related to these human activities (Fettweis *et al.*, 2009). The results are based on the combined analyses of recent and historic (100 years ago, Gilson collection) sediment sample information and bathymetric maps. Data processing was based mainly on field descriptions of the samples (consolidation, thickness) and on bathymetric maps of 1866–1911. Results indicate that the distribution of fresh mud and suspended sediment has changed during the last 100 years, due mainly to maritime access works. Most of the present deposition of thick layers of fresh mud (>30 cm) has anthropogenic causes. The results further indicate that erosion of older Holocene mud has increased in recent times and, as a consequence, higher amounts of fine-grained sediments are being released into the southern North Sea today.

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THE TERRESTRIALISATION TRENDS OF STRESSED MANGROVE FORESTS USING SATELLITE IMAGES CLASSIFICATION: STUDY CASE FOR CUBATÃO, SÃO PAULO STATE - BRAZIL

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Most of the world's population inhabits the coastal region and human pressure is reducing mangrove areas around the globe. Mangroves are amongst the most threatened ecosystems, subjected to pollution, overexploitation and land conversion. The documentation and study of the response of mangroves to human pressure is still incomplete and sometimes controversial. Activities like urbanization can produce an irreversible ecologic degradation. This paper presents the importance to investigate the terrestrialisation trends of stressed mangrove forests using satellite images classification. Landsat images were used to classified mangrove in the area of Cubatão, São Paulo State – Brazil. For a satellite image of the year 2008 different segmentation processes and classifications (supervised and unsupervised) were done with SPRING GIS (Georeferenced Information Processing System - INPE, version 5.0.4). Supervised classification like Batthacharya occurred to be the best in this case. It is still difficult to do a supervised classification if the study area is not well known. In order to improve this classification; ground truthing was realized in the study area, totalizing 30 hours of navigation into and around the estuary. The 51 places where there were doubts for the classification of the 2008 image were visited. For the different places we took GPS coordinates and some pictures, including views of soil, canopy and general aspects of the forest. A visual description of the vegetation was done as well in order to characterize mangrove forests, Atlantic forests and *restinga* vegetation. These data were used to correct the classification. The stressed mangrove forests studied had trends to terrestrialisation, and patches of typical mangrove vegetation - *Rhizophora mangle* (L.), *Laguncularia racemosa* (L.) Gaert. and *Avicennia schaueriana* (Stapf and Leechman) - and associated species (*Acrostichum aureum* L., *Hibiscus pernambucensis* Arruda and others species) were registered. This study will point out the importance to investigate stressed mangrove forests and their trends to terrestrialisation using satellite images classifications. Ground truth methods cannot be neglected to understand the real environmental conditions. The produced maps are important tools for the conservation and management of natural resources of the coastal zone.

MATRIX-MEDIATED BIOMINERALIZATION OF THE CALCAREOUS MASSIVE BASAL SKELETON OF THE MEDITERRANEAN HYPERCALCIFIED SPONGE *PETROBIONA MASSILIANA*

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Hypercalcified sponges were the most important reef builders during Paleozoic and early Mesozoic eras. They were believed to be extinct until about thirty years ago, when scuba diving and submersible explorations allowed unexpected findings (Hooper and van Soest, 2002). Today, about twenty living species have been described, principally distributed in deep and cryptic habitats of tropical seas, at depths under the distribution limit of scleractinian corals which are the present reef-builders (Vacelet, 1985). Recently, these relict sponges have stimulated much interest due to their potential (1) to provide insights on the oldest mechanisms of biomineralization and their evolution in pluricellular organisms and (2) to provide information on past environmental climate changes recorded in the chemical composition of their basal massive skeleton. Nevertheless, as the composition of those skeletons is under biological control, the validation of these sponges as true environmental recorders is still requiring an accurate comprehension of their biomineralization processes and an evaluation of all related physiological effects, well known as "vital effects", which could modify these environmental records.

Petrobiona massiliana is a small hypercalcified sponge dwelling in dark submarine caves at shallow depths in the Mediterranean Sea. This species represents an abundant model of larger but less-accessible tropical hypercalcified sponges to study biomineralization mechanisms and vital effects. The present study is a first description of the biologically-controlled formation of the basal skeleton of *P. massiliana*. We highlight (1) some cellular mechanisms, (2) the mineralization sites and (3) the implication of an organic matrix in the biomineralization process. A spatial and temporal discontinuity of the biomineralization mechanisms, which is defined as a major vital-effect, is also demonstrated.

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CADMIUM EXPOSURE IN CHELONIANS: DESIGN OF AN EXPERIMENTAL STUDY USING THE RED EARED SLIDER TURTLES, *TRACHEMYS SCRIPTA ELEGANS*

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Environmental pollution is known to be a major threat for many species including reptile populations that have been declining in the past few decades. However there is a real need of understanding the processes and effects of pollutants, such as uptake rates, accumulation, depuration of toxic compounds and effects on reproductive parameters particularly in chelonians such as marine turtles. Among environmental contaminants, Cadmium (Cd) is one of the most widely distributed and dangerous pollutants for marine organisms. Cd is known to be teratogen, carcinogen and a possible mutagen even at low concentrations. Marine turtles are protected species and therefore ethical consideration precludes experimental exposure. The use of the red eared slider turtle, *Trachemys scripta elegans*, is an interesting alternative model that bypasses many difficulties related to the study of wild chelonians: this aquatic species considered as an ecological pest can be raised in controlled conditions for experimental approaches.

The objectives of this study were (1) to study Cadmium (Cd) kinetics in the blood of red eared slider females fed with Cd contaminated food at environmental concentrations and (2) to investigate the effects on maternal transfer of Cd on hatching success.

Twenty nine female's red eared slider turtles were randomly divided into four groups. Control females received uncontaminated food, while other groups received contaminated food (T1=0.100, T2=0.275 and T3=0.750 µg/g). Females were fed three times a week during 13 weeks and blood samples were collected every two weeks for Cd and other elements analysis by ICP-MS. To induce reproduction, males fed with non contaminated food were added into each group of females.

As expected, survival rate in females was 100% after 13 weeks of exposure. Out of the 29 females, 14 nested successfully, and 66 eggs were incubated. At the end of the incubation period, eggs were checked for sign of emergence and hatching success was recorded. Hatching success differed for each treatment with the highest rate for the control group and the lowest rate for the more contaminated groups (control=57.1%, T1=41.7%, T2=11.1% and T3=33.3%).

To the best of our knowledge, this study is the first to develop a method to assess the exposure to endogenous Cd in turtles, to investigate the kinetics of accumulation of Cd in females (uptake rates in blood) and to quantify the effects on hatching success as reproductive parameters. This kind of experimental data are greatly lacking in the literature and we hope that the results of this study in controlled laboratory conditions will help to better understand the processes and effects of environmental contamination in wild populations of species of chelonians.

MATERNAL TRANSFER OF MERCURY TO OFFSPRING IN PHOCIDS

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Marine mammals may display high mercury (Hg) levels in their tissues, which raises the question of the importance of toxic metal transfer from mother to offspring. Indeed, Hg could be transferred from mothers to fetuses via the placenta and to suckling pups via the milk, potentially affecting them during their most sensitive periods of development. Some lactating female phocids fast during the suckling period. This fasting period involves not only an important mobilization of energy reserves, but also mobilization of potentially associated contaminants. We studied and compared maternal transfer of Hg to offspring in two phocid species: the northern elephant seal (NES, *Mirounga angustirostris*) and the grey seal (GS, *Halichoerus grypus*). We collected samples of NES during the breeding season at Año Nuevo State Reserve, in California, and samples of GS during the breeding season on the Isle of May, in Scotland. Total mercury concentrations (THg) were measured in whole blood and maternal milk of mother-pup pairs (10 for NES and 21 for GS) in early and late lactation. Organic Hg was only measured in grey seal whole blood. Total and organic Hg levels were analysed by atomic absorption spectroscopy. Total Hg levels in NES were 4-5 times higher for blood and twice higher for milk than Hg levels in GS. Although levels were different, both species showed a similar distribution and dynamics of Hg in blood and milk throughout lactation. Results indicated that Hg passed from the maternal tissue into the milk. The mean levels of total Hg in milk ranged from 12 to 35ng.g^{-1} ww. From the first days after birth, pups already displayed relatively high blood Hg levels in comparison with their mother, suggesting that a high Hg transfer through placenta occurred. Blood Hg levels in mothers and pups varied significantly throughout lactation. While maternal levels increased, pup levels were reduced by half between the beginning and the end of lactation. Remobilization of proteins and lipids during fasting and milk production in mothers might lead to a release of Hg in blood and therefore increase the levels in late lactation. On the contrary, Hg would be progressively stored in pup organs during their development. Decreasing Hg levels in pups also suggest that the Hg intake via the milk might be lower than that via the placenta. Organic Hg levels in whole blood of GS pups and females represented 85-95% of total Hg. Any variation of organic Hg was not observed throughout lactation. This study highlights (i) the first determination of contamination levels by Hg in both phocid populations and (ii) a transplacental and transmammary transfer of Hg in both species. However, further toxicological studies are needed to help understanding the potential impact of this Hg transfer. Results also showed that (iii) physiological processes such as lactation and/or fasting can modify Hg levels in the blood of mothers and pups. Therefore, such processes and body condition should be considered carefully when interpreting Hg levels in the framework of biomonitoring.

OFFSHORE WINDFARMS AND MARINE MAMMALS: THE DEVELOPMENT OF A MONITORING PROGRAMME

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Assessing the effects of the construction and exploitation of offshore windfarms on marine mammals is not straightforward. It is not only difficult to study and describe physical changes in the marine environment, also assessing direct and indirect effects on marine mammals is a real challenge. For this assessment, a multidisciplinary monitoring programme was developed. Given that the harbour porpoise *Phocoena phocoena* is by far the most abundant marine mammal in Belgian waters, the programme focuses on this species.

The monitoring methods, some of which have only been developed recently, consist of:

1) Line transect surveys with a specially equipped aircraft. These provide us with estimates of the ad hoc density and abundance of marine mammals in and around the windfarm areas; density surface modelling can provide for distribution maps of porpoises.
2) The deployment porpoise detectors (PoDs). These static, passive acoustic devices can detect the presence of porpoises and dolphins in selected locations in and outside windfarms. They provide information complementary to the aerial surveys, given that estimates of relative abundance can be made over a longer period of time (months).
3) The collection of additional data. Other monitoring activities, such as bird surveys in and around wind farms, the investigation of marine mammal strandings data and the assessment of changes in the fish community in windfarm areas, yield additional information; also ad hoc observations made by persons working at the construction sites are useful and therefore collected.
4) The investigation of underwater noise. For marine mammals, and especially cetaceans, the primary means for communication, foraging and navigation, is noise. As such, they are sensitive to increased underwater noise levels due to human activities. Through measuring the levels and characteristics of underwater noise during the construction and exploitation phases of the windfarm projects, and the consultation of literature, possible short-term and long-term effects can be assessed.

Individually and in combination the results of the studies can provide qualitative and quantitative information of the effects on marine mammals, and especially on harbour porpoises. Consequently, they will provide a basis for the possible adjustment of activities in relation to the construction and exploitation of windfarms, and the establishment of relevant preventive actions and mitigation measures.

Also see abstracts of related projects further in this publication:

Brabant *et al.*; Coates *et al.*; Degraer *et al.*; Di Marcantonio M.; Kerckhof *et al.*; Reubens *et al.*; Vandendriessche *et al.*

DNA BARCODING REVEALS CRYPTIC DIVERSITY IN ANTARCTIC SPECIES OF *ORCHOMENE SENSU LATO* (CRUSTACEA: AMPHIPODA: LYSIANASSOIDEA)

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Recent molecular analyses revealed that several so-called 'circum-Antarctic' benthic crustacean species appeared to be a complex of cryptic species with restricted distributions. In this study we used DNA barcoding to detect possible cryptic diversity and to test the circumpolarity of species belonging to the amphipod genus *Orchomene sensu lato* (superfamily Lysianassoidea).

A fragment of the cytochrome *c* oxidase I gene performed as a powerful barcoding marker for these taxa, showing a clear barcoding gap between intra- and interspecific divergences. In addition, DNA barcoding served as a quick survey for species diversity in this group. While in some species a genetic homogeneity was found among specimens from remote sampling sites, we detected genetically divergent, cryptic taxa in other species. Based on these observations, our current view on the species richness and distribution of the Antarctic Lysianassoidea may have to be modified. As polar regions are more affected by climate change than others, biodiversity assessment studies are of particular importance since they may serve as a basis for monitoring and conservational efforts.

GLOBAL ECOLOGY OF MANGROVES: A SURVEY ANALYSIS OF DIVERSITY, FUNCTIONALITY, AND DEGRADATION OF MANGROVE ECOSYSTEMS

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Mangroves are coastal ecosystems that are among the most degraded ecosystems in the World. It is estimated that 20 to 35% of the worldwide mangroves have disappeared since 1980. Usefulness of mangroves, although mainly described in the specialized literature, is increasingly recognized. Mangroves avoid erosion of the coast, protect from flood, storm and waves, serve as nursery for the reproduction of certain fishes, and their plants have been used for a wide range of purposes since centuries. The main factors that trigger mangrove degradation are urban development, shrimp aquaculture and overexploitation of mangroves for their resources. However, researches are carried out at the country's level in order to find out if some socio-economic factors are or are not responsible for the mangrove degradation. For instance, increasing population literacy has been found to be negatively correlated with mangrove degradation.

Degradation naturally triggers loss of biodiversity. This is a major problem for mangroves which have a very low diversity (70 true mangrove species). Local factors determining mangrove diversity have been intensely studied. However, recent research established that large scale factors (continental precipitation, regional mangrove extent etc.) can eventually influence mangrove diversity at a narrower scale. Precipitations and mangrove area are key factors, closely related to diversity of mangroves from the Indo West Pacific biogeographic region. The greater the mangrove and the higher the precipitations, the more diverse mangrove forests become. However, other factors such as temperature and length of coastline also have their importance.

Mangrove plants are used for many purposes such as timber wood, fuel wood, sources of tannins and medicines, telegraph poles etc. However, some mangrove plants do provide these functions whereas other plants do not. Genera like *Avicennia, Bruguiera, Ceriops, Heritiera*, and *Rhizophora* are crucial mangrove plants for they not only provide excellent fuel wood and timber wood but are also among the best species that protect the shoreline against storm and waves and that serve as nursery for fishes. Some genera like *Pemphis* or Acanthus do not fulfil as many functions as efficiently. Being aware of the functions fulfilled by the different mangrove genera is an important step for rehabilitation and sustainable use of mangroves. Such studies are expected to increase the general knowledge about the uses of mangrove species, which is still fragmentary.

A SAMPLE OF BIAS, THE BIAS IN SAMPLING

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Forest inventories for either commercial or scientific purposes require accurate data on density and basal area. Mangrove forests grow worldwide on (sub) tropical seashores in saline environments. Within these forests, plotless sampling methods are typically used for density and basal area estimations. A methodological study was conducted to verify the accuracy of several plotless sampling methods, among which the Point Centered Quarter Method (PCQM). Two approaches were used: one fieldwork approach in which the spatial coordinates of all trees in 4 sites in a mangrove forest near Gazi Bay- Kenya were recorded. One modeling approach in which 6 vegetation dispersion patterns were generated based on the literature. Both approaches resulted in datasets on which the plotless sampling methods were applied in silico (MATLAB 7.7.0) and the estimations compared with the true densities.

The results show strong bias for each method, depending on the site and pattern. Overestimations and underestimations were found of more than 80%, which gives density estimations with 5 times fewer trees per area than the real value. In general the results correspond with previous findings from for example Engeman et al. (1994), Steinke and Hennenberg (2006) or White et al. (2008). Additionally in this study an emphasis is placed on PCQM, which is the most often used method within mangrove research, and the zonation pattern occurring in some mangrove forests. Overall, PCQM is in the group of worst performing methods. Zonation gives a larger underestimation in every method.

One argument given for using PCQM is the assumed comparison benefit, as other researchers also use this method. This study however shows that both underestimations and overestimations do occur when using PCQM, which gives a double bias when comparing two sites.

Care should be taken when using plotless sampling methods. Deviant estimations of resources can generate large errors when valuing ecosystem services. Especially with the potential of the Reducing Emissions and from Deforestation and forest Degradation (REDD) situations can come in which communities receive too little or societies pay too much for carbon sequestration.

This study argues for a change in the research methodologies. When plotless sampling methods are a necessity because the forest is difficultly accessible or very sparse, it is recommended to measure the distance to the second individual when using PCQM. Preferably however the Variable Area Transect (VAT) method should be used.

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A TRANSBOUNDARY INSIGHT INTO FLOOD RISKS OF THE NORTH SEA COASTAL ZONE

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In recent years, the prospect of climate change, in particular sea level rise and its effects on low-lying coastal areas have generated renewed attention. Although to some extent uncertain in terms of magnitude and frequency, there is the prospect of more intense storms and extreme events in the future. This rising hazard means increased coastal erosion and increased probability of flooding. As the risk of flooding is a product of both the probability of a flood event and its potential consequences, it is necessary to study both carefully in a proper flood risk assessment.

Within the EU Interreg Safecoast project, the international project team of Soresma-Oranjewoud conducted this transnational risk assessment for the North Sea Coastal region. Within the project the flood risk is determined both for the actual and for the 2050 situation, taking into account the effects of sea level rise and socio-economic development. It is the first time flood risks have been calculated and mapped on the global level of the entire North Sea Region.

Because of the large scale of the project area existing flood risk methodologies have been adapted and tailored to the use in a trans-national (European) context taking into account required uniformity of data sources in a flexible framework. The risk assessment focussed on using a uniform method to compare the flood risks along the North Sea Coast. Doing so, the target was not to perform a high-tech state of the art flood risk calculation, but to generate a global, comparable view on the flood risks on the whole North Sea level.

The project resulted in on one side a spatial view on actual flood risks in the studied North Sea areas and on the other hand a trend analyses of the change in flood risk (now-2050), the change in potential tangible damage within the flood prone areas and the change in vulnerability to flooding. As a proper visualisation of the global risk assessment, an atlas with maps of the flood risk, the potential flood damage and the vulnerability has been generated.

The outcomes of this study could be used to benchmark ideas and strategies in order to secure the region from flooding, now and in the future. Furthermore, this study may contribute to raised awareness on flood risk amongst flood prone societies in the North Sea basin and may serve as a reference framework for the implementation process of the EU Floods directive.

The results have been presented on the final congress “Risk meets Crisis” of the EU Interreg projects Chain of Safety and Safecoast (may 2008, Scheveningen).

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GENOME-WIDE ANALYSIS OF THE DIATOM CELL CYCLE UNVEILS A NOVEL CYCLIN GENE FAMILY INVOLVED IN ENVIRONMENTAL SIGNALLING

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Despite the enormous importance of diatoms in aquatic ecosystems and their broad industrial potential, little is known about diatom life cycle control. Diatoms typically inhabit rapidly changing and unstable environments, suggesting that cell cycle regulation in diatoms must have evolved to include efficient and adequate environmental signal integration networks. The recent genome sequencing of *Thalassiosira pseudonana* (Armbrust *et al.*, 2004) and *Phaeodactylum tricornutum* (Bowler *et al.*, 2008) provides the basis to explore the molecular conservation of cell cycle control in diatoms.

Here we present the profile-based annotation of cell cycle genes in *T. pseudonana* and *P. tricornutum,* including counterparts of conserved key regulators as well as new regulators. A *P. tricornutum* cell cycle synchronization method was established that enabled us to assign the transcription of the different annotated genes to specific cell cycle phase transitions. Remarkably, compared to other eukaryotes, the cyclin gene family was found to be extensively expanded and a novel cyclin class was discovered. Members of these diatom-specific cyclins (dsCYCs) are predominantly transcribed at the early phases of the cell cycle and respond to nutrient supply, suggesting a role in connecting growth to environmental stimuli.

The discovery of highly conserved and new cell cycle regulators suggests the evolution of unique control mechanisms for diatom cell division, likely contributing to their ability to adapt and survive in highly fluctuating abiotic conditions. The results presented here will provide the basis for studies aimed at understanding the evolution of the diatom life cycle and optimizing diatom growth.

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OPTIMISING THE MARITIME ACCESS TO THE PORT OF ZEEBRUGGE: EXAMPLE OF A LARGE MULTI-TOOL STUDY

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During the previous years a lot of efforts (among which a deepening campaign) were undertaken by the Flemish government to improve the accessibility of the port of Zeebrugge. This has resulted in the current situation in which the port is accessible for ships with a draught up to 16,0 m. However the inbound sailing window for these large container ships is restricted to a couple of hours a day. There are 2 reasons for this rather small sailing window.

The first reason is the flow in front of the harbour mouth of Zeebrugge. Due to the construction of the harbour approximately 3 km into the sea, the flow – which is mainly oriented along the Belgian coastline – is concentrated at this location. As a result of the flow concentration, the ships sailing in the navigation channel Pas van het Zand to the port of Zeebrugge experience a rather strong side current. Around high water – the period of maximum flood flow as well as the period during which the biggest ships could enter the port – the side current is so strong that these ships are not able to enter the port safely. Another reason for the rather small sailing window is the fluid mud layer in the harbour itself. Every tide a huge amount of water containing a concentration of mud enters the harbour. Due to the low flow velocities in the harbour, the biggest amount of the inflowing muddy sediments will settle here. This process has resulted in a fluid mud layer with a thickness of a couple of meters in the harbour itself. It is a daily challenge for the Flemish government, responsible for the dredging works, to carry out the maintenance dredging works in the harbour in an efficient way. As a consequence of this fluid mud layer it is not possible to guarantee the necessary draught at any time and at any location.

The Maritime Access division – division of the Flemish government responsible for the dredging works – asked the researchers of Flanders Hydraulics Research to set up a study on the optimization of the maritime access to the port of Zeebrugge. In order to investigate this difficult issue, a multi-tool approach was suggested including field measurements, a physical scale model, a numerical model as well as the ship manoeuvring simulator of Flanders Hydraulics Research. While the large scale model (approximately 75m x 30m) is being built at Flanders Hydraulics Research, the numerical model has been calibrated and validated. Combining the *in situ* measurements and the numerical model, the water and sediment exchange at the mouth of the harbour of Zeebrugge has been analysed. And last but not least the experience of the pilots will also be included in this study using the ship manoeuvring simulator. The research plan of the study – which will last for a couple of years – involves the combination of all different tools, in order to be able to increase the inbound sailing window of the harbour of Zeebrugge for the very large ships.

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EARLY COLONISATION OF A CONCRETE OFFSHORE WINDMILL FOUNDATION BY MARINE BIOFOULING ON THE THORNTON BANK (SOUTHERN NORTH SEA)

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With the construction of windmills in the Belgian part of the North Sea (BPNS), a new habitat of artificial hard substrate is being introduced in a region mostly characterized by sandy sediments. This will increase the habitat heterogeneity of the region and the effect of the introduction of these hard substrates – the so-called reef effect – is regarded as the most important change of the original marine environment caused by the construction of windmill farms (Petersen and Malm, 2006).
A monitoring programme was set up to sample the biofouling on the new hard substrates associated with the windmills. At the moment of sampling, only the sub- and intertidal parts of the turbine foundations, made of concrete, were available for colonisation by subtidal and intertidal organisms as the scour protection was not yet fully deployed yet. A total of six semi-quantitative samples for epibiota were collected in the autumn of 2008. The subtidal samples were taken by scuba divers at four different depths all along the foundation and a vertical video transect was made. Samples were taken by scraping the fouling organisms from a sampling surface area of 6.3dm². The scraped material was collected in plastic bags that were sealed and transported to the laboratory for processing. After preservation of the sample, the organisms were indentified and an estimate of their density was made.

One of the most direct and obvious impacts of the construction of six windmills at the C-Power site, was the fast and intense colonisation process by hard substrate epifauna. After 3.5 months already, a high species richness was found, with a dense Bryozoan (*Electra pilosa*) cover, with associated species, such as small crustaceans, polychaetes and *Aequipecten opercularis*.

A species list was compiled listing 49 species: 1 Protoctista, 4 algae and 44 invertebrates. The vegetation was restricted to the intertidal zone and rather sparsely developed. Only four species of mainly filamentous algae were present: *Blidingia minima, Ulva intestinalis, U. compressa* and *Bangia fuscopurpurea*. A total of 44 invertebrate species was identified in the samples. However, only a few species were really abundant. The most numerous (> 1000 ind/m²) or abundant species were the giant midge *Telmatogeton japonicus*, the amphipod *Jassa herdmani*, the barnacle *Balanus perforatus* and the bryozoan *Electra pilosa*. All other species were far less abundant with the exception of *Phtysica marina*, the only caprellid present (100-1000 ind/m²). Taking into account the short period of time available for colonization of the foundation, the number of 49 spp. is considered high in the Belgian part of the North Sea (BPNS) and included several uncommon species for the Belgian fauna. Four non-indigenous species were found: the slipper limpet *Crepidula fornicata*, the New Zealand barnacle *Elminius modestus*, the giant barnacle *Megabalanus coccopoma* and *T. japonicus*. All four species, already known from the area, are opportunists and early colonisers after disturbance, taking advantage of man-made structures and disturbed conditions to settle.

A clear depth zonation of three zones could be observed: (1) an intertidal and splash zone, characterized by the dominance of the chironomid *Telmatogeton japonicus* and the presence of four filamentous algae, (2) a shallow subtidal to low intertidal zone, dominated by barnacles and tube building amphipods *Jassa* spp., and (3) a subtidal zone, with a dense *E. pilosa* turf.

Also see abstracts of related projects further in this publication:
Brabant *et al.*; Coates *et al.*; Degraer *et al.*; Di Marcantonio M.; Haelters J.; Reubens *et al.*; Vandendriessche *et al.*

VARIATIONS OF SOUND PRODUCTION IN YELLOWTAIL DAMSELFISH *DASCYLLUS FLAVICAUDUS*

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Damselfishes (Pomacentridae) are prolific callers which emit sounds in different behaviors. In the yellowtail damselfish *Dascyllus flavicaudus*, six behaviors are known to be related to six types of sounds. Generally speaking, these sounds are mainly involved in courtship (signal jump and visiting-mating) and agonistic behaviors (hetero- and conspecific fighting, and hetero- and conspecific chasing). However, temporal variability of sound production has never been explored in this species. In this context, the present study aimed to identify the periods of acoustic activity in this species.

Recordings of sound production by *Dascyllus flavicaudus* were made from January to March 2009 in the Moorea lagoon (French Polynesia). Hydrophone was associated to an IT program allowing the searchers to plane the recording time slot and is used to study periodicity of sound production.

Dascyllus flavicaudus produces sounds mostly during the day and shows the highest rate of production at dusk, suggesting the reproduction is more developed at this period of the day. Moreover, sound production activity increases during the periods between last quarter and new moon, and around first moon quarter. Full moon phases show the lowest rates of sound production. These peaks of activity during the month seem in relation with adequate period of egg release and reef settlement of the larvae, both behaviors being safer during dark nights.

LOADING CONDITIONS AND STRUCTURAL RESPONSE DUE TO VIOLENT WAVE IMPACTS ON COASTAL STRUCTURES WITH CANTILEVER SURFACES

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Vertical breakwaters and seawalls are frequently used to protect land from sea actions like high water levels and waves. They have to be designed to resist quasi-static loads as well as short but intensive violent wave impacts. Because of stricter regulations and change in environmental conditions, vertical walls would be dimensioned higher and higher for tolerable wave overtopping. Therefore, most of the coastal engineers/designers provide the vertical walls more and more with a return crown wall or even a completely horizontal cantilever slab to reduce the wave overtopping. However, wave impacts on horizontal decks (or return crown walls) provoke an important uplifting force. These are impact (or shock) loads which are high in magnitude and short in duration and can't be substituted by a static equivalent. A detailed description of the space and time distribution of the wave impacts is necessary.

In the past decades, the qualitative and quantitative determination of wave loads on vertical structures has already been examined (e.g. Oumeraci *et al.*, 2001). In the framework of several international efforts focused on wave loading (e.g. EC MCS and PROVERBS; UK BWIMCOST), model and prototype tests have been intensively conducted to determine the history and spatial distribution of wave impact. Uplift loads below horizontal decks are examined (e.g. McConnell *et al.*, 2003) and recently prediction methods for wave loading have been developed in several research projects (e.g. Coumo *et al.*, 2007).

Contrary to the previous simple vertical wall or horizontal decks, structures consisting of both vertical parapets and horizontal cantilever slabs have scarcely been considered. A consensus on the necessary approach for the research of this type of structures lacks completely (Okamura, 1993). Even the structure prevents the most of the overtopping due to the special geometry-involving closed angles, which do not allow incident waves to dissipate- the loading condition is more severe from the preceding situations. For example, Clopotis waves on a single vertical wall creating quasi static loads result in dynamic impact loads on the horizontal part of the combined structures. The Pier of Blankenberge which is located along the Belgian coast is an illustrative example of a vertical wall with an overhanging horizontal cantilever slab. Throughout the high tide and storm condition the structure is exposed to the violent wave impacts. Waves are running up against vertical wall and slamming on the horizontal part. The structure was damaged due to violent wave impacts during heavy storms in the winter of 2002-2003 and 2007-2008. In Verhaeghe *et al.* (2006) a description of the field monitoring equipment installed on the pier for measuring wave loading has been provided.

The main objective of the present study in this sense is to bring a new design tool to estimate violent water wave impacts on a vertical wall with an overhanging horizontal cantilever slab, based on the correlation between the kinematics of breaking waves and the height, distribution, duration and characteristics of the violent wave impacts. In this work, small scale model tests were done to fulfil the above goals.

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NEW SPECIES AND NEW GENERA OF POLYCYSTIDIDAE (PLATYHELMINTHES, RHABDOCOELA, KALYPTORHYNCHIA) FROM THE MEDITERRANEAN

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Eleven new species of Polycystididae from the Mediterranean are described and discussed. Three of them cannot be placed in an existing genus and therefore two new genera are erected, namely *Brachyrhynchoides* n. gen. for *Brachyrhynchoides triplostylis* n. sp. and *B. pilifer* n. sp., and *Jarreella* n. gen. for *Jarreella aprostatica* n. sp. The remaining seven taxa could be placed in allready known genera: *Austrorhynchus morrissoni* n. sp., *Gallorhynchus bidaformis* n. sp. and *G. elegans* n. sp., *Paulodora corsa* n. sp., *P. curini* n. sp., *P. martensi* n. sp., *P. picta* n. sp. and *Psammopolycystis unguis* n. sp. All of these new species can be distinguished from their congeners by the morphology of the copulatory stylet. Apart from these eleven new species, additional notes on five already known species are given, namely: *Albertorhynchus amai* Schockaert 1976, *Austrorhynchus bruneti* Karling 1977, *A. karlingi* Brunet 1965, *Djeziraia euxinica* (Mack-Fira 1971) Schockaert 1982, *Papia bifida* Karling 1956, *Polycystis naegelii* Kölliker 1845, *Progyrator mamertinus* (Graff 1874) Reisinger 1926, *Psammopolycystis bondensis* Karling 1956 and *P. forcipiens* Brunet 1979.

SAILING THROUGH A SHALLOW SEA

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In contrast with the wide horizon seen while standing on the Belgian coastline, the North Sea is not as deep or wide as may be expected from the point of view of large seagoing vessels. These vessels sail through manmade fairways such as Het Scheur and Pas van het Zand with an under keel clearance (distance between ship's keel and seabed in terms of percentage of the ship's draft) of 15% or less, and only a few ship's beams separated from the borders of the dredged section.

Compared to the increase of the main dimensions of seagoing ship types like container carriers, LNG-carriers and RoRo vessels during the last decades, the dimensions of the access channels called by these vessels did not increase at the same rate. As a result, the behaviour of ships arriving at or departing from harbours will increasingly be influenced by the fairway's restrictions.

Because of the vicinity of banks, as horizontal restrictions of the fairway, an asymmetric flow around the vessel is induced. This asymmetry causes pressure differences between port and starboard sides. As a result, a lateral force will act on the ship, mostly directed towards the closest bank, as well as a yawing moment pushing her bow away from the channel boundary. The proximity of banks increases the blockage (ratio between the midship section and cross section of the fairway) as well as the vessel's resistance and sinkage. A reliable estimation of all these phenomena, known as bank effects, is important for determining the limiting conditions in which a ship can safely navigate a waterway. A comprehensive research project is being carried out at Flanders Hydraulics Research (Flemish Government, Antwerp, Belgium) in cooperation with Ghent University. This project consists of over 10000 captive model tests carried out in the fully automated towing tank for manoeuvres in shallow water (Lataire *et al.*, 2009).

Based upon these test data a mathematical prediction model is created and implemented in the ship manoeuvring simulators of Flanders Hydraulics Research. These virtual ship's bridges are extensively used for training purposes of the Flemish pilots and for research to support the Flemish admittance policy.

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DEVELOPMENT AND VALIDATION OF THE BIMODAL FLOCCULATION MODEL: TWO-CLASS POPULATION BALANCE EQUATION

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The bimodal flocculation describes the physicochemical process in which particles or flocs aggregate and fragment with developing two separate peaks in their size distribution. This is caused by the different bonding strength of two constituent flocs, (1) dense micro-flocs and (2) floppy macro-flocs. The bimodal flocculation has been repeatedly reported by many marine and estuarine scientists and thus it seems to be very common in marine and estuarine environments. However, the empirical correlation between sediment settling velocity and solid concentration (ws versus Cs) has been simply used as a flocculation model, without considering the bimodal flocculation behaviour (van Leussen, 1994). Furthermore, Population Balance Equations (PBEs), which are recently being adopted as a mechanistic flocculation model for marine or estuarine cohesive sediment transport, still have limitation in simulating the bimodal flocculation, due to the excessive simplification of the Single-Class PBEs (SCPBEs) (Winterwerp, 2002; Son and Hsu, 2008) and the large computational load of the Multi-Class PBEs (MCPBEs) (Xu *et al.*, 2008). Therefore, to simulate the bimodal flocculation as well as to enhance the computational efficiency, the Two-Class PBE (TCPBE) consisting of (1) the size-fixed primary micro-flocs and (2) the size-varying secondary macro-flocs was developed and tested in this research. The capability of the TCPBE for simulating the bimodal flocculation was validated with the curve fitting analysis to the experimental data obtained from one dimensional settling column tests (van Leussen, 1994). In contrast to the SCPBEs, the TCPBE was able not only to simulate the interaction between two particle classes but also to estimate the collector efficiency of marine or estuarine cohesive sediments for fresh primary particles. In addition, the TCPBE required hundreds times less computational time than the elaborate MCPBEs, to generate the simulated results fitted well to the experimental data. Thus, the TCPBE proved the computational efficiency for simulating the bimodal flocculation of marine or estuarine cohesive sediments. In short, the TCPBE takes both the outstanding advantages, the computational efficiency and the model accuracy, from the SCPBEs and the MCPBEs, respectively, and so it will be an attractive mechanistic flocculation model for future application to large-scale cohesive sediment transport modelling.

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SPATIAL HETEROGENEITY IN THE MANGROVE VEGETATION STRUCTURE IN THE ZHANJIANG MANGROVE NATIONAL NATURE RESERVE (CHINA): AN APPROACH USING REMOTE SENSING (GEOEYE-1 IMAGERY) AND GIS-ANALYSES

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The Zhanjiang Mangrove National Nature Reserve (ZMNNR), established in 1990, is situated in the Guangdong province and has the largest mangrove area with the highest number of species in mainland China. It was included into the Ramsar list in 2002. Gaoqiao (21°33'520", 109°45'167") is the largest of those sites and has not been largely modified by man since its protection status was established.

The study is based on cartography (remote sensing and GIS) and field work. We used the PCQM and Plot-based method to describe the vegetation. We collected data on tree height, diameter, species name, number of stems and canopy surface. The mangrove species concerned are: *Aegiceras corniculatum*, *Avicennia marina*, *Bruguiera gymnorrhiza*, *Excoecaria agallocha*, *Kandelia candel*, *Rhizophora stylosa*, *Sonneratia apetala*.

The study emphasizes on the abiotic and biotic factors that are influencing the vegetation structure using a cartographic approach. The spatial heterogeneity will first be studied through classified maps of the vegetation. These maps will be developed with help of image-analysing software based on GeoEye-1 imagery and geographical information systems (GIS).
Data were collected on abiotic factors (pH, salinity, soil texture, depth of the anoxic layer surface, inundation class and tidal levels) and biotic factors (counts of propagules and leaves on the ground, crab burrows, and snails) to match the vegetation data through extrapolation of point data to the scale of maps.

This study is ongoing, but we aim at confirming or invalidating the hypotheses on the environmental factors underlying the mangrove vegetation structure, and we aim at establishing at which scale and through which extrapolation methods these factors can best be investigated. This will also involve landscape metrics.

OPERATIONAL OCEANOGRAPHIC PRODUCTS FOR THE BELGIAN SCIENTIFIC COMMUNITY

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MUMM's team for OPerational TOols and Services (OPTOS) develops and manages a series of mathematical models for providing assistance to human activities at sea. Twice a day, these models issue five days ahead forecasts of sea surface elevation, three dimensional currents, waves, temperature and salinity. Such information is useful for, e.g. navigation in coastal waters, diving activities and flooding risk assessment. In case of pollution, combating teams also receive information on drift, spreading and fate of the pollutant.

Besides these traditional applications, OPTOS is enlarging its products catalog in order to improve its support to environmental researchers concerned by the Southern Bight of the North Sea. Following the recent recommendations of the ICES Working Group for Operational Oceanographic products for Fisheries and Environment (WGOOFE), OPTOS is developing an operational identification procedure for water masses, fronts and river plumes. That new product uses passive tracers to characterize the signature of the different water masses in terms of the Atlantic salty waters and fourteen different riverine freshwaters (Thames, Rhine, Meuse, Scheldt, Seine, Wash, Humber, Tees, Tyne, Forth, Ems, Weser, Elbe and IJssel). Useful for assessing the Belgian compliance with regard to the EU Water Framework Directive, this new operational product can also guide the interpretation of *in situ* samples or demonstrate trans-boundary pollution.

NUMERICAL SIMULATION OF HIGHLY NONLINEAR WATER WAVES BY LVOF

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Introduction
LVOF is a highly efficient Navier-Stokes solver, constructed by a novel VOF fully implicit cell-staggered finite volume cut-cells approach that incorporates surface tension plus a dynamic subgrid-scale model. LVOF has been extensively illustrated with well-described examples, which are of particular value in distinctly different applications, especially in the area of nonlinear shallow water-wave propagation problems and slamming.
By developing LVOF, we now achieve:

- overtopping of breaking waves over a sloping and fixed vertical structure in the presence of a current or not,
- water slamming, landslide-generated water waves and oscillations of a moving body in waves,
- a two-phase model, characterized by a body to be treated as a fluid.

LVOF has been validated according to the numerical aspects as follows: (i) the convergence behavior; (ii) the grid refinement effects; (iii) and comparison with measurements available. LVOF can be found in our paper, published in the leading International Journal (Li *et al.*, 2004; 2007) for a general description of the method. In this progress report, the results are represented in terms of the instantaneous velocity fields and the time history of the surface elevation η (m) at the selected wave gauge (WG).

Wave-current coupling
Fig. 1 gives the comprehensive comparison for waves on three types of the current states. This provides the physical insight for wave-current interaction. A major feature is essentially that waves on an adverse current are shorter than waves on a positive one, as the current compresses the wavelength somehow.

Wave overtopping
As observed, the flow becomes fully turbulent (see Fig. 2), often subjected to the steepness of the free surface most likely associated with a cycle of splashing and the vortex formation created by the velocity. The wave height shows strong non-linear and waves continuously break, while the energy of waves is dissipated by turbulence and convected by vortices.

3D computation
Fig. 3 illustrates that the results in 3D remain very similar to those in 2D within the nonbreaking region (WG: x=2.02 m) but far from satisfactory at the position adjacent to the wave-breaking region (WG: x=3.81 m to 5.2 m), indicating that waves in breaking are a rapidly dissipative process in the localized region. Hence, the use of a 3D solver coupled with SGS models helps to capture the wave-induced small-scale turbulent flows, in case the configuration in 2D becomes unstable due to waves breaking.

Two-phase model
Owing to the interaction with eddies in the air, it is found that the discrepancy concerning the flow near the interface is significant, as compared with that in the one-phase model. It seems that the results look better (see Fig. 4), when the effects of the air are considered. Consequently, most of the typical features (e.g. vortices and a leading positive wave) in the landslide-induced motions are captured by LVOF, especially the two-phase model could give more promising results for the test cases under consideration.

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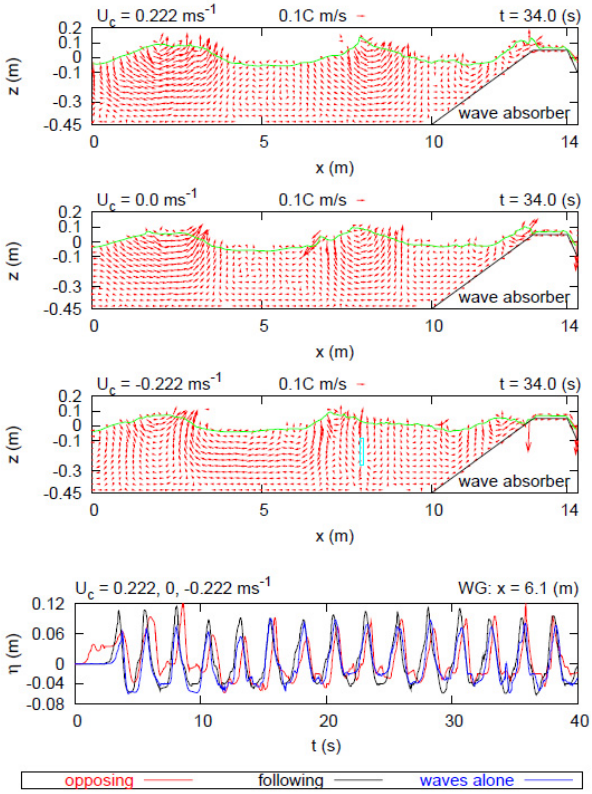

Fig. 1. Following regular waves (U_c>0), regular waves (U_c=0) and opposing regular waves (U_c<0) at the current, defined by U_c.

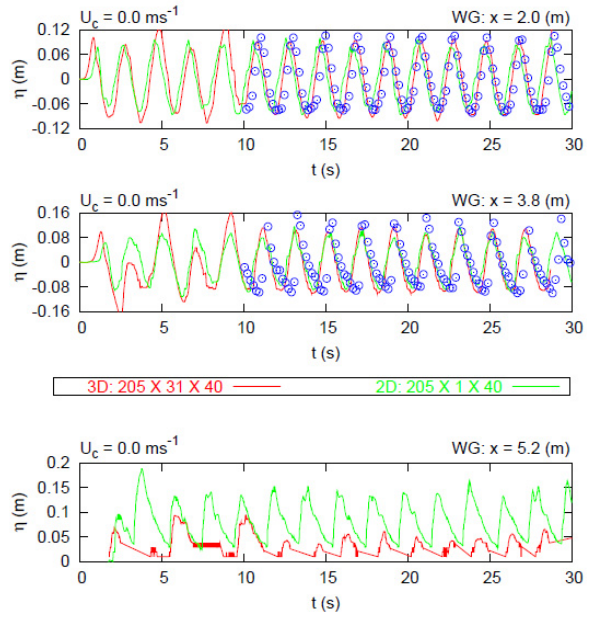

Fig. 3. Comparison of 3D with 2D for regular waves alone over a sea dike.

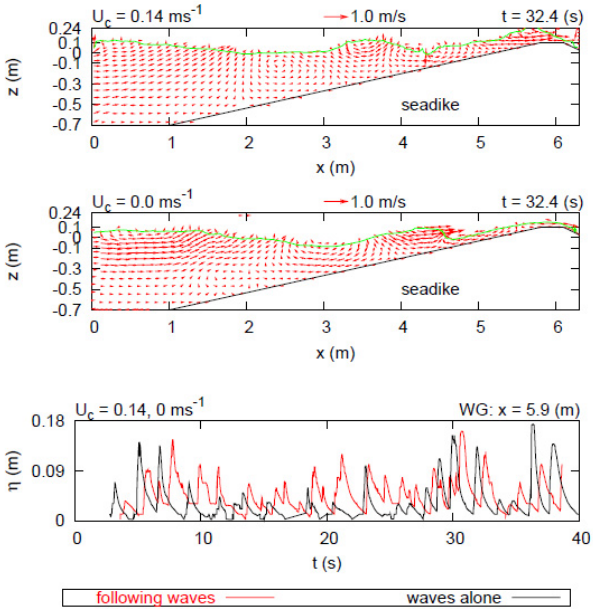

Fig. 2. Overtopping of irregular waves over a seadike.

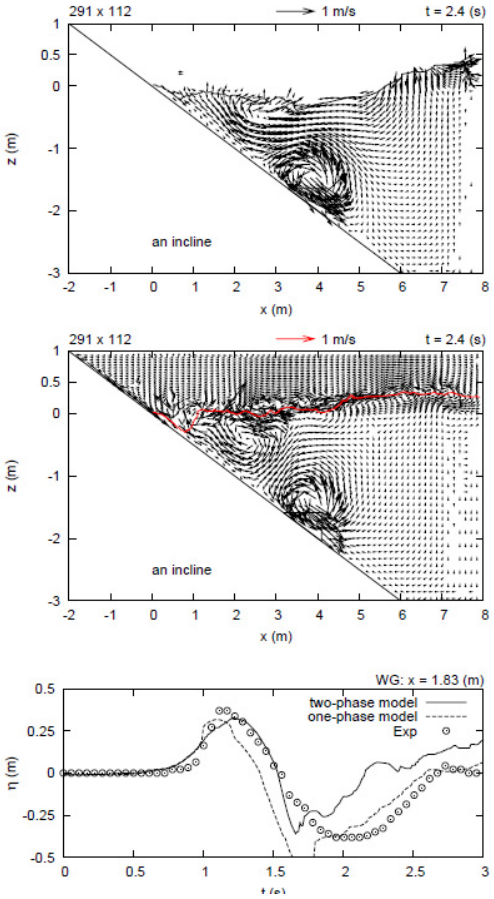

Fig. 4. Comparison of the one- and two-phase models over grid (291 x 112) for impulsive waves caused by the landslide.

PRODUCTIVITY OF A TIDAL POWER PLANT IN THE SPUIKOM OF OOSTENDE

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Nowadays, energy resources such as oil, gas and coal have to be limited not only because of the imminent shortage, but also because of the CO_2-emission and damage to the environment by energy production

During the last decades, renewable energy resource technologies have been developed tremendously with regard to efficiency and reliability. These technologies are fully ready to come onto the market. Water power is, next to wind power, one of the most important renewable energy resources.

In 1894, a co-operation between the city of Oostende and the Belgian State started the construction of the 'Spuikom' with a surface of 85ha. In 1926, the Spuikom was definitely out of service because of the damage it caused to the harbour entrance channel and rising dredging activities.

The objective of this study is the investigation of the potential productivity of a tidal power plant in the 'Spuikom' of Oostende. Objective parameters such as total power supply, stability of the power supply, period of effectiveness of the power plant,... are taken into account.

Through literature review, the current position of tidal power plants within the renewable energy market is determined. An overview of the different types of water power plants is given, in particular the tidal power plants. The most effective turbine is the VLH-turbine (Very Low Head) turbine because of the rather limited tidal variations along the Belgian coast (4.60m at spring tide, 2.97m at neap tide, 3.88m on average).

In a second part, calculations and simulations have been made. The most optimal configuration for a tidal power plant has been searched for by varying the various parameters such as the number of turbines, the diameter of the turbines,... The environmental-technical boundary conditions have been omitted. The productivity of the tidal power plant has also been optimised.

The most optimal configuration for the tidal power plant produces an average power of 1338kW. This is 58% more than the same configuration without the optimisation operations and the period of effectiveness of the tidal power plant is reduced from approximately 12.5h to 8.5h per tide cycle.

Finally, a reflection with regard to reality has been made to estimate damage to the environment: influences to fauna and flora such as damage to fish stock, oyster farming, algae, uncertainties about sedimentation,...

A comparison of the power production of a tidal power plant at the 'Spuikom' and an offshore wind mill of the Thorntonbank shows that the power supply per year of the tidal power plant in the 'Spuikom' is only 1.15% of the production of the 60 planned wind mills of the Thorntonbank, which is very limited.

It is concluded that a tidal power plant at the location of the 'Spuikom' is not a defensible option as a site for renewable energy production, not only because of environmental arguments, but also because of cost-effectiveness considerations.

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SAND, SEA, SUN AND BEACH LITTER? - THAT IS RUBBISH!

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The Coordination Centre on Integrated Coastal Zone Management is working together with several coastal municipalities in Belgium and the Netherlands to improve the accessibility, safety and ecological value of the beaches.

The ecological value at the beaches is at risk, caused by an extensive use of mechanical beach cleaners. Mechanical beach cleaners not only remove most of the man-produced waste, but unfortunately also take away organic material. Manuals for more sustainable beach management are necessary, because coastal communities spend yearly over EUR 10,000 per km sand to keep the beaches clean.

The amount of litter on the beach is enormous. During an annual spring clean activity, 253 volunteers collected 956.6kg litter over 4.9km beach. In the first 14 days of July over 34 000kg litter was collected on the 12km long beach strip of one coastal town. To manage the amount of litter, over 200 trash cans with a size of 300l are installed on the beach during the summer months. During the summer months the coastal communities collect 54% more litter in the towns than during the winter months.

Still a lot of effort needs to be done in rising awareness and preventing litter on the beaches to different sectors as tourism and fishery. Big communication campaigns as 'in the vuilbak' try to convince people to bin their rubbish. In 2009 several types of litter have been brought to the attention of the broader public such as the effect of balloons which led together with other types of plastic to the dead of many sea birds. 41% of the amount of litter on the beach originates from the fishing industry. The project 'fishing for litter' works together with the fishing industry to keep the oceans and seas clean.

An assessment on the accessibility of the beaches showed that it's necessary to aim for a complete accessibility. The whole chain should be adjusted, from arriving in a coastal town with or without public transport, up to access to the beaches. Also the information on locations of infrastructures for people with special needs, should be communicated properly by different manners to reach the target groups optimally. As local government it is necessary to work together with all the existing organisations and facilitate the debate between the involved parties. An elaborate report combines practical guidelines and useful examples to adapt the beaches to a more disabled friendly environment.

In July 2009 the rescue services had to rescue 45 people from drowning. As such, the rescue posts play an important role to secure safety on the beach and in the water. In order to identify the rescue posts and workers more easily, improvement on the recognisability is necessary. A study conducted on the beaches in West-Flanders and Zeeland, showed that the standardisation of rescue services will make the communication to beach visitors more easily and uniform. Extra efforts should be made with regard to equipment, communication tools and training opportunities.

Hopefully we can come to a more sustainable management of the beach in the future with attention to safety, accessibility and ecological values.

IMPACT OF ANTHROPOGENIC INPUTS ON THE NITROGEN CYCLE IN A PERI-URBAN MANGROVE SYSTEM (DAR ES SALAAM, TANZANIA)

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As main intertidal ecosystems lining tropical coastlines mangroves are increasingly affected by anthropogenic inputs. Being inherently oligotrophic they are usually considered as nutrient sinks and may help in mitigating coastal pollution. However, their filtering capacity and the mechanisms involved have rarely been assessed in natural systems. We investigated the nitrogen cycling in an estuarine mangrove system submitted to anthropogenic nutrient inputs (Dar es Salaam, Tanzania). Rates of main N-transformation processes in the sediment and the water column were assessed via 15N-tracer experiments. Results indicate high inputs of nitrate with the freshwater inflow, whereas ammonium and dissolved organic nitrogen appear enriched toward the marine end-member. Nitrate is efficiently removed along the mangrove creeks, partly as a result of denitrification in the sediment which was observed to be high compared to pristine mangrove systems. Production measurements indicated that benthic diatoms were more efficient to take up ammonium as compared to nitrifying bacteria. Nitrification rates were thus relatively low and limited the overall nitrogen removal potential of the system.

SOCIO-ECOLOGICAL VALUATION OF COASTAL ECOSYSTEMS IN KENYA: A GIS-BASED ANALYSIS LINKING GOODS AND SERVICES FROM TERRESTRIAL FORESTS, MANGROVE FORESTS, SEAGRASS BEDS AND CORAL REEFS

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Coastal ecosystems often offer an abundant source of goods and services for local populations. However, it is difficult to find a balanced use of it without a deep analysis. Management policies lack of information to determine a proper use of these zones, the latter of which often suffer from human activity. In this context, the goal of the present study is to develop an evaluation method of the value of goods and services in the case study of Kenyan coasts through a cartographic analysis. Transects through several ecosystems (terrestrial forest, mangrove forest, seagrass beds and coral reefs) will be characterized through field observations and socio-ecological studies. They will permit to compare these environments and to answer to some questions: Which environment has the largest value, from the ecological or economic point of view? Do the different goods and services from the different ecosystems complement themselves? What are the most important goods and services in coastal areas? Moreover, this study will enable us to know what the utilization level of certain goods and services is.

The evaluation model that will be developed from this analysis, taking into account actual and potential use of goods and services, will support decisions on coastal management, both in natural and in artificial ecosystems (Bockstael, 1995).

We know that several goods are used in the studied ecosystems, such as wood for construction or combustion (Walters 2005), raw materials (Moberg and Folke, 1999), alimentation (Rönnbäck, 1999; MacArthur and Boland, 2006) or medicinal products (Bandaranayake 1998). Moreover, socio-ecological services imply coastal protection (Teas, 1977), regulation of biogeochemical cycles, preservation of biodiversity (Moberg and Folke, 1999) but also cultural and recreational activities. This study will focus on which goods and services, between all of these mentioned in literature, are used by local population in the concerned area. Goods will be translated into monetary value, and socio-ecological questionnaires will be distributed among the population to estimate indicators (like biodiversity) of the ecosystems services.

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RESTORATION OF A FRESHWATER TIDAL MARSH ON A LOWERED RURAL SITE: A NEW METHOD APPLIED IN THE SCHELDE ESTUARY

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When considering estuarine restoration, managed realignment is not always an option, due to site characteristics or safety considerations. We present a restoration technique that combines safety with ecology on a site with an elevation far below mean high water.

Lippenbroek is a flood control area with a controlled reduced tide (CRT), a technique similar to Regulated Tidal Exchange (RTE), but with major ecological advantages. A well designed sluice system allows semi-diurnal water exchange between the study area and the estuary. This setup offers opportunities to restore estuarine functioning in embanked areas.

Although the tidal amplitude was strongly reduced, the newly created marsh faces inundation characteristics similar to macrotidal estuaries, with a wide range of indundation frequencies. Most RTE on the contrary, reduce these essential inundation gradients. The CRT system shows however a prolonged hydroperiod with stagnant phase. Nevertheless, we observed relationships similar to natural marshes between indundation frequency and sedimentation rate, vegetation or benthos. Sedimentation (and ecological development) on the long term is hard to predict because tidal volume entering the CRT is independent of site elevation. It is only depending on sluices parameters, that can be fully controlled. In this way, tidal regime, sediment dynamics and ecological evolution can be manipulated.

Mass balance studies illustrate the potential functions of a CRT within the estuarine nutrient cycling. When implemented on a larger scale it will improve overall estuarine functioning.

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ESTIMATION OF ROTIFER FILTRATION RATE ON DIFFERENT PHYTOPLANKTON SPECIES AS THE BASIS FOR A FOOD WEB MODEL

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Understanding the fate of primary productivity in the Ecuadorian Pacific Ocean and coastal aquaculture ponds is crucial in determining the food chain regulation of these ecosystems. Early studies of coastal waters showed that they support an abundant zooplankton that is usually dominated by rotifers. Rotifers are thus an important link in the food chain between phytoplankton and higher trophic levels. Rotifer grazing on various phytoplankton species was estimated in the laboratory at different temperatures (24, 28 and 32°C). Rotifers filtering rates (FR) and ingestion rates (IR) varied for each phytoplankton species and temperature level. These data will be used in a preliminary model for the prediction of trophic interactions at the coastal level and in coastal ponds where shrimp culture is practised.

THE MANGROVE REFERENCE DATABASE AND HERBARIUM

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The main objective of the online Mangrove Reference Database and Herbarium is to give a current and historic overview of the global, regional and local distribution of true mangrove species. This database has been initiated in 2001 by the Vlaams Instituut voor de Zee (VLIZ) and the Flanders Marine Data and Information Center (VMDC) in collaboration with the Université Libre de Bruxelles (ULB) and the Vrije Universiteit Brussel (VUB). All the data are based on records containing species location information (literature, maps, herbaria, expert access, etc...) and all mangroves species (approximately 75) display distribution information from many study sites around the world. All the mangrove zones around the world are recorded in this database and a particular species list is available for those sites that have been studied or sampled. This can be viewed and zoomed on easily using a GIS-interface. In addition, the database provides information and pictures of plant physiognomy and ecological adaptations to the intertidal mangrove habitat. Attention is also paid to the nomenclature, systematic (incl. the most recent phylogeny of APGII) as well as vernacular (information can be visualized on synonyms, vernacular names and direct child taxa). Finally, all the information in the database is completed by a Mangrove Reference Herbarium in collaboration with the National Botanical Garden of Belgium and the Belgian Biodiversity Platform, while collaboration with other international herbaria is furthered. Herbarium boards can be consulted using webtools to zoom in on diagnostic characteristics.

In summary, the Mangrove Reference Database and Herbarium (abbreviated to 'Mangroves ' in Aphia) has different purposes:

- to provide a **relational database** for all true mangrove plant species using an expandable taxonomic tree;
- to display a **fact sheet** for each mangrove plant species including basic information with photographs, a scanned herbarium specimen and distribution data;
- to provide a **searchable online distribution map** for each species based on point-locations submitted by researchers world-wide (through papers, herbaria or through online access). The aim is to display historic as well as current distribution maps by filtering the data in the database with the respect to the time the fieldwork/collection was done;
- to preserve a **herbarium reference specimen** for each true mangrove species;
- and, on a longer term, to provide an **automated determination key** to identify mangroves world-wide.

This online Mangrove Reference database is an additional step in the knowledge of mangrove species distribution through several examples in many study sites. It is a dynamic database that gives a widespread view of literature, herbaria and other references on mangrove distribution and invites researchers to collaborate on understanding the functioning of this threatened ecosystem.

The database is continually updated and can be accessed through:
http://www.vliz.be/vmdcdata/mangroves/

THE QUATERNARY GEOLOGICAL EVOLUTION OF THE BELGIAN CONTINENTAL SHELF, SOUTHERN NORTH SEA

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With respect to the Quaternary deposits, the Belgian Continental Shelf (BCS) was one of the last unmapped and unknown areas of Belgium. Because of the absence of a distinct shelf break and the virtually complete lack of subsidence, the BCS had very little accumulation space to accommodate and preserve Quaternary sediments. The Quaternary on the BCS is very patchy and discontinuous, and has a maximum thickness of only 45m. From this fragmented record it was very difficult to produce a coherent reconstruction of the Quaternary evolution, in times when only analogue data were available. At present, > 5000km of analogue high-resolution seismic profiles have been scanned, converted into digital 'SEG-Y' format, and integrated with over 500 core descriptions, enabling us to develop the first genetic model for the Quaternary evolution of the BCS.

The seismic data show seven seismic-stratigraphic units, in agreement with previous studies on one of the sandbanks of the BCS. Three basal units (U1, U2, U3) infill a large valley, incised during the Saalian ice age in the Top-Paleogene (former Top-Tertiary) surface, i.e. the Ostend Valley. The three units, separated by tidal-ravinement surfaces, represent successive phases of a transgressive estuarine infilling during the Eemian sea-level rise. During the subsequent Weichselian lowstand, a minor sinuous river incised in the Eemian transgressive surface, where previously the Ostend Valley was present. Directly on top of this surface no Weichselian cover sands have been encountered, but early Holocene tidal-flat deposits, i.e. seismic unit U4. The tidal-flat environment developed behind a coastal barrier which migrated landward with the Holocene rising sea-level. In the sand layer left by the barrier migrating over former tidal-flat deposits, coastal storm-generated banks formed (U5). These coastal banks were partly eroded when the barrier stabilised and started prograding seaward again, in reaction to the slowing down in the Holocene relative sea-level rise. The tidal-flat area behind the barrier, silted up and an extensive surface peat developed. With a new tidal pulse, the barrier migrated landward again, but stabilised before it reached the present-day coastline. Until in the 15th century, storm surges induced the drowning of the island Wulpen, which caused irreversible hydrographical changes in the mouth of the Western Scheldt. Due to these changes and the consequently stronger tidal currents, the original shoreface ravinement surface was deepened. This did not happen though until the middle of the 16th century. After that, the eroded, high-organic muddy sediments (of former back-barrier deposits) could settle, alternated with sandy storm layers. This represents seismic unit U6. Since around 7000 cal BP, tidal sandbanks and intervening swales (U7) developed on top, and from, the former deposits, and form now the main features of the present-day bathymetry.

As the BCS appears more often in the news nowadays, on issues such as the construction of offshore windmill parks or requests for extending sand and gravel extractions permits, reliable knowledge of the nature and composition of the shallow subsurface of the BCS, which is closely related to its geological evolution, is truly indispensable.

MULTIDISCIPLINARY STUDY OF THE TROPHIC DIVERSITY AND FUNCTIONAL ROLE OF AMPHIPOD CRUSTACEANS ASSOCIATED TO *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 are critical features of the Mediterranean coastal zones, and are of great ecological and economic importance.

Posidonia oceanica meadows shelter high biomasses and biodiversities of amphipod crustaceans. In other temperate meadows, such as Atlantic *Zostera marina* meadows, the amphipods play an important part in the functioning of the ecosystem, notably in organic matter transfers from producers to higher level consumers. However, the situation in *Posidonia oceanica* meadows remains unclear, due to the lack of precise studies, and little is known about the trophic ecology of amphipods. In this context, our research is structured in three main tasks. We chose the Calvi Bay (NW Corsica, France) as a study site, and sampling is undertaken from the STARESO research station (University of Liège, Belgium).

First, we study the exact composition of the amphipod community, as well as its temporal variation at diel and seasonal scale. This task is based on *in situ* collection of samples using three methods: the hand-towed net, litter collection and light traps. Completion of this task will allow us to have accurate and reliable data, taken on our study site, concerning the abundance specific diversity of amphipods associated with *P. oceanica* meadows.

The second task is a reconstruction of the diet of the studied animals. Indeed, amphipods from *P. oceanica* meadows are usually regarded as vegetal epiphytes grazers, or generalist detritivores, but few studies focus on the interspecific trophy diversity, or on the importance of alternative food sources. Our approach relies on *in situ* sampling of amphipods and potential food items. The techniques used combine traditional methods (gut content observation) and use of trophic markers, such as measurements of C and N stable isotope rations and fatty acid composition analysis.

Finally, we use *in vitro* and *in situ* microcosms experiments to evaluate the impact of amphipod feeding activity on the ecosystem functioning, and more precisely on the dynamics of the epiphyte cover. By quantifying this interaction, our purpose is to put back the results obtained in the first two parts into a wider context, the functioning of the *Posidonia oceanica* meadow as an ecosystem.

Thus, by combining *in situ* sampling and *in vitro* experimentation, and by combining traditional and innovating techniques, we hope, at the end of this research, to enhance the knowledge of the trophic diversity and the functional role of amphipod crustaceans associated with Mediterranean *Posidonia* meadows.

PASSIVE SAMPLING: THE FUTURE OF MARINE MONITORING?

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Development and use of accurate, reliable and sensitive methods for measuring concentrations of organic marine contaminants remains a major challenge in controlling pollution in the sea. Recent EU-legislation, such as the Water Framework Directive and the upcoming Marine Strategy Directive, makes this challenge even more pressing. Persistent organic pollutants (POP's) which are identified as a threat to the marine environment are often insoluble in water and the actual dissolved concentrations are generally very low. A sampler made of silicone rubber sheets overcomes this problem. These thin sheets, measuring approximately 100cm^2, are exposed to water for a given period and absorb dissolved hydrophobic contaminants, thus concentrating per day the chemicals present in 40L of seawater. This approach reduces analytical problems and the problems of short-term field variability in concentrations. It is also known that POP's have the ability to accumulate in the lipids of fish and shellfish (i.e. they bioaccumulate). A passive sampler can mimic this bioaccumulation. It is suggested that passive samplers can therefore be used to predict concentrations of these contaminants in both water and biota. For these reasons passive sampling could give an answer to today's challenges of marine monitoring.

USE OF PASSIVE SAMPLING IN INTEGRATED ENVIRONMENTAL MONITORING

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In conventional laboratory ecotoxicity studies, test organisms are exposed to various (high) concentrations of a single test compound. This is in sharp contrast with the situation in the field where organisms are exposed to low concentrations of multiple contaminants. Other than exposing organisms directly to grab samples, there are no feasible approaches to expose test organisms to realistic environmental mixtures of pollutants. Grab samples however, only offer a snapshot of the field situation, and differences in physico-chemical parameters (e.g. pH or salinity) often make it difficult to compare test results from different sampling sites. A potential solution to these limitations are passive samplers. These devices are able to absorb contaminants by diffusion and when subsequently transferred to uncontaminated water, these contaminants are released into the test medium. When using passive samplers previously deployed in the environment, organisms are exposed (in standard test medium) to the contaminant mixtures absorbed in the field.

In the present study, various ecotoxicity tests were executed using passive samplers previously deployed in various marine harbour sites. The samplers were subsequently used as a dosing device in 72h growth inhibition tests with *Phaeodactylum tricornutum* and 24h larval development tests with *Crassostrea gigas*. These tests show good reproducibility and high relevancy.

Concentrations of contaminants were measured in the passive samplers and converted to water concentrations. These corresponded well with the observed toxicity of the mixtures.

ENDIS-RISKS: ENDOCRINE DISRUPTION IN THE SCHELDT ESTUARY - RESULTS OF A 4-YEAR SURVEY

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ENDIS-RISKS is a multidisciplinary research project conducted by five institutes. This project aimed to assess the distribution, exposure and effects of endocrine disruptors in the Scheldt estuary, with specific attention to invertebrates. The Scheldt Estuary is known to be one of the most polluted estuaries in the world.

Water, sediment, suspended solids and biota were sampled 3 times a year for a period of 4 years (2002-2006). The presence of known and suspected endocrine disrupting chemicals in the Scheldt Estuary was demonstrated. These included: estrogens, pesticides, organotins, polyaromatic components, polyaromatic hydrocarbons and phenols. Detailed knowledge of the pollutants physico-chemical partitioning (between the different compartments: sediment, water, suspended solids), their concentration in biota (mussels, shrimps and mysids) and their geographic distribution were assessed and short and long-term effects of these substances were investigated. The resident mysid shrimp population, which is potentially exposed to these substances, was studied. The most important results and findings are presented and discussed.

FROM FISH TO QUOTA

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Several commercially important fish stocks in the European waters have seriously declined or triggered even the edge of stock collapse due to overfishing over the past few decades. Therefore, quota regulations have been developed and applied, together with other measures, as a tool for sustainable fisheries management in Europe.

But what exactly are these quota, how are they calculated, and do they provide a good management basis? Fishermen and policy makers, as well as scientists, have a lot of questions about these topics. What is the role of a national fishery institute, the national government, the International Council for the Exploration of the Sea (ICES), the Regional Advisory Committee's (RAC's), the Scientific, Technical and Economic Committee for Fisheries (STECF), and the European Community (EC), in the quota-calculations? What are Total Allowable Catches (TAC's) and what is their relation to quota? What type of data do we need for the calculations? Where do fishery dependant and fishery independent surveys come in? What will be the impact of the multi-species approach and of the ecosystem base management approach on TAC's? How sensitive are the calculations to yearly changes in the data? How can the sector help the process in collecting more and better data? This poster will briefly touch on all these items, and critically discuss the value of quota as a management tool.

RESULTS FOR THE ON GOING SOCIOECONOMIC MONITORING PROGRAM IN DIANI-CHALE AND MSAMBWENI AREAS, KENYA

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Socioeconomic monitoring data in the Western Indian Ocean region has been commonly used for management due to the design of the local projects which includes participation from the local sites. SocMon WIO is an ongoing monitoring program that includes a network of 14 sites in 7 countries implemented by local MPAs, local area management authorities, fisheries departments and community groups. A simple access database which can be used by sites to manage their own data, do simple analysis with the data and therefore give reports in time, was created. There has however been lack of capacity in data entry, management and analysis at some of the sites which has often resulted in delayed submission of monitoring results and subsequent use of these results in management. This problem has been taken care of through training of representatives from sites in a data analysis workshop and follow-up trainings for the data managers in each of the sites. The SocMon WIO database has undergone a series of versions to try and make it easy to use by site teams as well as tailoring it to accommodate all the variables as explained in the SocMon guidelines for coastal managers of the Western Indian Ocean. The database is divided into two sections; the data entry section into which key informant, focus group and survey entries are made, and the data analysis section which gives reports for all entries made. However, the database is open for changes according to site needs. In this report, we present results for some of the data collected between 2007 and 2009 that has been stored in the SocMon WIO database for Diani-Chale and Msambweni sites and which has provided extremely important information for decision makers and stakeholders in the management of the sites.

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TELEMETRY TAGGING AND COLLABORATIVE SEA TURTLE CONSERVATION IN KIUNGA MARINE NATIONAL RESERVE, KENYA

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Turtle nesting reports from Kiunga Marine National Reserve (KMNR) (10 49.730'S, 410 26.685'E) account for approximately 50% of all the nesting reports recorded along the Kenyan coast. Turtle nests reported are predominantly for green turtle (*Chelonia mydas*) though olive ridley (*Lepidochelys olivacea*) and hawksbill (*Eretmochelys imbricata*) occasionally nest in KMNR.

Artisanal fishing is the main economic activity in KMNR. Turtling and turtle species are of cultural significance to the Bajuni community. Marine turtles are caught incidentally in gillnets or intentionally with a traditional form of gillnet locally referred to as *Lasha* set in known turtle foraging grounds. The sea turtles products such as the carapace, oil and meat have a lot of cultural significance to the Bajuni community.

Marine turtle conservation in KMNR is joint initiative between the local community and WWF/KWS. It endavours to protect nesting sea turtles on the beach and all turtle nests are protected in situ only when the survival and eventual success of the nest is direly threatened by either predation or inundation by sea water is the nest translocated. The local fishermen alongside their fishing duties act as nest reporters and the local youth form the turtle youth volunteer program. The participation of the local community is augmented through an incentive programme.

A preview of the results from data collected from 2001 to 2008 reveals the following:
- nesting turtles and reported nests show exponential increase from 2006;
- turtle tagging and return tags show marked increase across years;
- two beaches with high nesting incidence reveal an inverse nesting relationship;
- fisherfolk account for over 50% of turtle nest reports;
- telemetry tagged nesting turtles forage in KMNR general area during the nesting season;
- telemetry tagging data indicate a wide geographical range and habitat harnessed by sea turtles.

STUDY ON FEEDING MECHANISMS IN DAMSELFISHES (POMACENTRIDAE)

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The damselfishes (family Pomacentridae) are a species-rich, widely distributed family of reef fishes that inhabit tropical and temperate near-shore waters around the world, with their greatest diversity residing on coral reefs. This family includes 29 genera and over 350 species. According to recent molecular phylogenetic studies, pomacentrids have been divided into five subfamilies: Stegastinae, Lepidozyginae, Chrominae, Abudefdufinae and Pomacentrinae. Additionally, a few ecological studies focus on the various trophic niches present in this family. Generally speaking, three main feeding guilds are considered: herbivorous, planktivorous and omnivorous.

To date, their spectacular adaptive radiation remains still unexplained. An unusual ligament might partly be responsible for this success. This ligament, considered as a synapomorphy of the Pomacentridae, joins the hyoid bar to the internal part of the mandible.

Recently, it has been shown that the hyomandibular ligament is involved in the sound production mechanism in clownfishes. This structure can be compared to a drawbridge. Acting as a cord, it forces the mandible to turn around its articulation during the lowering of the hyoid bar; leading to fast mouth closing and sound production by jaw teeth snapping.

However, it is improbable the role of the ligament is only limited to sound production mechanism. It represents a novel skeletal adaptation for a new behavioral function. Besides, this functional movement could be an exaptation of the feeding mechanism. In this context, the hyomandibular ligament represents a key innovation because it allows a mouth closing while the hyoid bar is completely lowered, and without the intervention of the adductor mandibulae muscles which are usually responsible for this movement.

This study aims to determine the functional implication of the hyomandibular ligament in the feeding mechanisms of different damselfish species, displaying different diets and belonging to different taxa. This approach should help to understand how the role of the hyomandibular ligament evolved throughout the radiation of the Pomacentridae.

CAN TESTATE AMOEBAE OF A TIDAL FRESH WATER MARSH (NOTELAAR, BELGIUM) BE USED TO PREDICT WATER LEVEL CHANGES OF THE SCHELDT ESTUARY (BELGIUM)?

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We investigated present testate amoebae communities on an inland tidal fresh water marsh (Notelaar) of the Scheldt Estuary with the aim of making a transfer function for reconstructing former water levels. These will be related to a series of land loss and – reclamation events that took place at the mouth of the Scheldt during the period of 1550-1800 and will serve as model to estimate the effect of nowadays wetland restorations on the water level of the Scheldt.

We analysed testate amoebae communities along an altitudinal gradient of 1.23m (5.34m TAW-6.57m TAW), covering the different types of marsh vegetation (vegetation cover of *Salix* sp., *Phragmites* sp., or other vascular plants). The analysed samples exposed a very rich testate amoebae fauna of more than 80 species, mostly consisting of fresh water species and ubiquists (most common: *Trinema lineare, Trinema enchelys* and *Tracheuglypha dentata*) and also containing one marine interstitial species *Cyphoderia littoralis*, probably transported upstream by the river. A highly positive relationship is found between five testate amoebae species and height: *Trinema complanatum, Arcella arenaria, Difflugia globulus, Difflugia globulosa* and *Cyclopyxis kahli*.

STRUCTURAL AND FUNCTIONAL DIVERSITY OF MEIOFAUNA IN RELATION TO POREWATER GEOCHEMISTRY AT THE DARWIN MUD VOLCANO (GULF OF CADIZ)

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As all cold seeps, mud volcanoes (MV) are characterized by strong gradients and a high variability in biogeochemical conditions in the sediment on a relatively small scale. The Darwin mud volcano in the Gulf of Cadiz (1100m) was sampled for meiofauna and pore water geochemistry (nutrients, sulphide and methane amongst others) along a gradient from a vent site on the rim of the crater towards the slope. The combined analysis of meiofaunal community structure and geochemistry on the same cores allows unraveling fine scale variation in the micro- and macrohabitats and its associated fauna. More specifically, we were able to get a better understanding of changes in meiofaunal community structure (1) from the MV centre towards the edge in relation to increasing cover of hemipelagic sediment on top of mud breccia and (2) from the sediment surface to the deeper sediment layers in relation to vertical geochemical sediment profiles. Besides community analysis, we investigated whether the meiofauna relies upon thiotrophically, methanotrophically or photosynthetically derived food sources by applying carbon and nitrogen stable isotope analyses.

Overall, meiofaunal densities and biomass were higher in sediments surrounding the vent site, compared to the reference stations. Highest meiofaunal densities and nematode biomass were observed at a station sampled at 2m distance from the vent site. Lower densities at the vent site itself are probably due to the high sulphide levels measured here (15mM in the upper cm of the sediment; >20mM in the deeper sediment layers). This finding also explains the lack of meiofauna in the deeper sediment horizons. Moving closer to the vent site, nematodes tend to be longer. A greater body length may favor increased mobility and represent an adaptation to low oxygen concentrations. Nematode genus diversity was positively related to the distance from the vent site; vent site sediments were dominated by both *Sabatieria* (60%) and *Desmodora* (20%). Dominance at seep systems by a few stress-resistant (eg tolerance to high sulphide concentrations) taxa has been reported before (e.g. Van Gaever *et al*., 2006). The (large) species *S. vasicola* was restricted to the vent site and dominated the community. Both the increasing hemipelagic sediment cover and the stable isotope profiles suggest an increasing dependence upon photosynthetically fixed carbon sources with increasing distance from the vent site. The meiofaunal communities living closer to the vent appear to be feeding upon S-oxidizing bacteria as TEM did not reveal the presence of symbiotic bacteria.

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KITE AERIAL PHOTOGRAPHY FOR MONITORING REMOTE NATURE RESERVES: A TEST CASE IN A GREEN TURTLE BREEDING AREA ON MASIRAH ISLAND (OMAN)

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Aerial photography is an excellent monitoring tool in the management of nature reserves: detailed maps of large areas can be acquired in a short time. However, aerial photography from an aircraft is very expensive and sophisticated. It is therefore not eligible for relatively small areas and authorities in developing countries. In comparison, kite aerial photography (KAP) is extremely cheap and simple and may represent a good alternative in some cases. Additionally, weather conditions are less stringent: a kite never exceeds cloud height and stability often increases with wind force. The lower acquisition altitude also yields more detail on the imagery. In order to map a large area, a kite can be trailed in different ways while taking pictures automatically or remotely controlled: on foot, by bike, (4WD) car or even by boat. The resulting images can be stitched together in post-processing and analyzed in much the same ways as airborne and spaceborne imagery. Here, I present a test case in a sensitive coastal area in Oman on the verge of development, illustrating the potential of KAP for frequent monitoring of various coastal features related to the conservation of green turtle (*Chelonia mydas*) populations.

EVOLUTION AND SPECIES BOUNDARIES OF THE *PORTIERIA*-COMPLEX (RHODOPHYTA, GIGARTINALES)

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Portieria hornemannii is a common and widespread Indo-Pacific red seaweed. Our studies suggest, however, that *P. hornemannii* does not represent a single species. Extremely high levels of diversity, based on mitochondrial (*cox*1, *cox*2-3 spacer) and chloroplast (*rbc*L, *rbc*L-S spacer) markers, are encountered among isolates spanning the entire geographical range of the 'species'. Model based species delineation based on lineage through time plots reveal at least 27 species. These results are corroborated by assessments of DNA barcoding gaps. In the Philippines, these individual lineages possess a near exclusive distribution pattern in the Central Visayas region, with most species restricted to one or a few localities. These observations are in stark contrast with the diversity pattern observed in the northern Batan Island, Batanes where a high sympatric diversity is encountered. Given the high diversity encountered at small geographical scales, we used low-copy nuclear genes (EF2 and Actin) to assess for reproductive isolation among the various lineages encountered in the Philippines. Gene trees of nuclear markers are in full concordance with the phylogenies based on organelle genes, suggesting complete reproductive isolation under natural conditions. Current efforts are dedicated at understanding the causes of this unexpected diversification, which apparently has not been accompanied by significant morphological differentiation. Ecological modes of speciation driven by herbivore interactions are investigated. The algae in question are grazed upon by *Aplysia* sea hares and are known to produce a wide variety of halogenated monoterpenes which probably act as antigrazing defence mechanisms.

THE MONITORING AND ASSESSMENT OF MACROBENTHOS AT THE BELGIAN COAST FOR THE WATER FRAMEWORK DIRECTIVE

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The Water Framework Directive (2000/60/EG) aims to achieve a good ecological and chemical quality status for all water types by 2015. This 'healthy' status corresponds with a more or less undisturbed habitat and will be based on the evaluation and integration of different quality elements. Each of these quality criteria has to support a classification (bad, poor, moderate, good and high) aiming at measuring the 'health' of the system compared to reference (high level) conditions.

In this study, the quality element macro-invertebrates in the Belgian coastal zone (<1 nautical mile) was investigated by means of the BEQI (Benthic Ecosystem Quality Index) evaluation tool. This tool is based on deviations from a defined reference state at three levels: the ecosystem, habitat and community level.

The first level gives a reflection on the ecosystem functioning in the water body by evaluating the relation between macrobenthic biomass and system primary production. The second level is the habitat level which attempts to evaluate changes in habitats due to anthropogenic pressures. The third level evaluates the changes in the benthos for a certain habitat compared to the reference situation of the habitat, based on four parameters: density, biomass, species richness and species composition. For each parameter at the three levels, reference values were determined for each ecological status class boundary of the WFD. The habitat approach presumes a habitat typology within each water body. For the Belgian coast, three habitat types can be considered: (1) *Abra alba* habitat (muddy fine sand), (2) *Nephtys cirrosa* habitat (well sorted medium sand), (3) *Macoma balthica* habitat (mud). The reference boundary values for the 3 main habitat types are based on all available macrobenthos data (ILVO-Fisheries and Ghent University) for the Belgian coastal zone (within 6 Nmiles) for the period 1994-2004.

With a random stratified sampling strategy, 9 groups (each 0.6m²) of 15 Van Veen samples (2007) and 11 groups (2008) along the Belgian coastline were taken.

Based on the combined EQR-score over the three levels the quality element benthos for the Belgian coast can be considered as 'good' with some habitats in certain zones in a moderate status.

ANALYSING SPATIAL AND TEMPORAL TRENDS IN EUKARYOTIC MICROBIAL COMMUNITIES IN METAL CONTAMINATED NORTH SEA SEDIMENTS

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Coastal areas are often contaminated with heavy metals, such as Cd, Cu, Pb, Zn, Hg and Ni, and these metals usually accumulate in the sediment. Virtually nothing however is known about the impact of this contamination on the composition and structure of eukaryotic microbes in these sediments. In the framework of the Belgian MICROMET project (Microbial Diversity and Metal Fluxes in Contaminated North Sea Sediments), the diversity and structure of protist communities were studied in 2 muddy, heavily contaminated subtidal stations (130 and 700) of the Belgian Continental Plate. Sediments were sampled on a monthly basis between January and July 2008 to take different organic matter sedimentation patterns into account; various sediment horizons (0-10cm) were considered. Microbial diversity was determined using molecular methods (DGGE, DNA clone libraries based on the SSU rRNA gene). A surprisingly high diversity of eukaryotic microbial communities was found in the subtidal contaminated marine sediments, of which most species are still unknown. Furthermore, changes in geochemistry – including the metals – as a result of phytoplankton bloom deposition, was an important factor, being responsible for pronounced variation in the community composition in relation to depth and season.

CAN WE USE EXERGY INDEX AND THE MICROBENTHIC LOOP AS INDICATORS OF PERTURBATIONS IN *POSIDONIA OCEANICA* (L.) DELILE MEADOWS?

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Nowadays, many anthropogenic perturbations threaten the Mediterranean Sea. *Posidonia oceanica* , its endemic phanerogam, is often used as a pollution descriptor (Montefalcone, 2009). Unfortunately, it does not react very fast because of its low turnover rate (i.e. $1.5y^{-1}$).

To solve that problem, this project proposes to use the microbenthic loop (meiofauna, bacteria, microphytobenthos and organic matter) of this important coastal ecosystem to detect anthropogenic pollutions earlier, because its components may react more rapidly than the posidonia plant. All components of the loop are investigated and characterized, in order to determine their reactions to perturbations and use them in the calculation of the exergy index (Jørgensen and Mejer, 1979). This index comes from the thermodynamic theory of ecosystems and expresses the distance of an ecosystem, at a given state, from its equilibrium. The higher this index, the closer from its optimum state (climax) the ecosystem is. To calculate it, the biomass of each part of the studied ecosystem, weighted by a factor called β, is needed. This factor is estimated on a genetic basis and given in Jørgensen *et al.* (2005). The final aim of this project is to show if the exergy index can be used in the Mediterranean Sea as a tool in monitoring strategies, specifically in the sedimentary compartment of *P. oceanica* meadows.

To realise these goals, a reference meadow was chosen near the research station STARESO (STAtion de REcherches Sous-marines et Océanographiques) in Calvi Bay (Corsica, France). This meadow is studied since the 80's and its good state of health is proven (Gobert *et al.*, in press). Seasonal, spatial (small scale) and bathymetric variations in the microbenthic loop are studied there since 2007, by sediment cores (diameter=4.7cm, length=10cm). Those results are compared for 2008 with the patterns observed in a supposed perturbed site, situated close to a fish farm, in Calvi Bay too. In situ experiments were also led in summer 2009. During three months, a shading experiment and an enrichment of the sediment with sediment coming from under the aquaculture (once a week) were performed. Those experiments aimed to understand reactions of the microbenthic loop to those kinds of perturbations, that are often occurring close to a fish farm.

Up to now, that study has led to a better understanding of seasonal and bathymetric patterns in the microbenthic loop of *P. oceanica*. The most important result obtained is the existence of an important spatial heterogeneity at small scale in that ecosystem. This phenomenon must absolutely be taken into account in every study based on the sediment in *P. oceanica* meadows.

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CHALLENGES FOR ABANDONED SHRIMP PONDS IN CHILAW (SRI LANKA)

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Since the 1970s, there has been an exponential increase in the number of shrimp farms in tropical coastal areas. Shrimp pond construction took place on a wide scale at the expense of mangroves. Through the outbreak of diseases and a fluctuating export trade, many farms were abandoned only 5 to 10 years after construction. In this study we focus on the challenges for the abandoned shrimp farms in Chilaw Lagoon (Sri Lanka).

A land-use change analysis - based on remote sensing and fieldwork - in Chilaw Lagoon showed that the mangrove area declined with 57% due to the construction of shrimp ponds. In August 2006, 75% of the shrimp farms were abandoned. There is reportedly less fish in the lagoon. Together with better management practices in the shrimp farms, re-conversion of the abandoned ponds to mangroves will encounter the mangrove loss, increase the sustainability of shrimp farming and to restore part of the lagoon fish stock because of the ecosystem functions that mangroves fulfill.

Because the abandoned shrimp ponds are excluded from the brackish lagoon, terrestrial vegetation is encroaching. On the field, we saw that mangrove vegetation is not spontaneously recovering. The first management practice to make mangrove restoration possible is to breach the dykes to reintegrate ponds in the hydrology of the brackish lagoon system. As a result of our study, we could define the most suitable ponds for mangrove restoration.

‘DE ZEE VAN TOEN’ (YESTERDAY’S SEA), ORAL HISTORY AND LOCAL ECOLOGICAL KNOWLEDGE OF BELGIAN FISHERMEN IN THE CONTEXT OF THE ENVIRONMENTAL HISTORY OF THE SOUTHERN NORTH SEA (1930-1980)

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‘De Zee van Toen’ (‘Yesterday’s Sea) is a project aiming at recovering valuable ecological information from the memories of retired fishermen. It focuses on the southern North Sea (the nearby fishing grounds) and a period in the middle of the 20th century (1930-1980). Going back in time much further is nearly impossible and the recent quarter of a century was deliberately left out, hoping that fishermen no longer active in the field would speak freely. Also the former year marks the end of sailing, the latter year the end of absolute freedom at sea, EU fisheries policy only gaining impetus in the eighties of last century. The basic idea is that fishermen are expert witnesses of the changes that may have happened at sea in the course of half a century. The methodology largely followed the rules of good conduct in projects of oral history. The prepared questionnaire left room for the unexpected facts or twists of the story. Conversation used local tongue (West-Flemish, a dialect of Dutch). Interviews were recorded digitally.

The project illustrates the most important changes in fisheries practice in that period: evolution of the fleet (number and power of the vessels), fishing technique (driftnets, otter trawl and boom of beam trawl), technical aids of navigation and communication, shifts in fishing grounds... To retrieve interesting data a basic approach by biological species was followed, as would be the focus of a professional fisherman. A practical division in categories of marine biodiversity was made, co-inciding with the amount of expertise expected: main commercial fish, crustacean and mollusc species, less common commercial fish species, non-commercial fish species, marine mammals, seabirds, annoying biodiversity (e.g. jellyfish, brittlestars)...

The results, in combinating with historic landings and oceanography, proved highly interesting.
Severe winters (1956, 1963) played an important role in implementing beam trawling in shrimp and demersal fisheries respectively. Passive fishing techniques disappeared completely, as did the associated herring and sprat fisheries. Abundance of prey triggered a predator fishery (sprat-cod). From an oceanographic (abiotic) point of view the period can be devided in three: a warming period in the 1930s, a warm period till about 1960, a cooling down and cool period till the end of the 1970s. Salinity shows gradual and spasmodic changes, co-inciding with inflowing Atlantic water, including a Great Salinity Anomaly in 1976-1978, causing/strengthening the crash of herring stocks. NAO shows an important link with dominating plankton communities, affecting the ecology of the North Sea. The North Sea is periodically ‘oceanised’, with associated slope communities (cephalopods, marine mammals).

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MACROBENTHIC BIODIVERSITY AND SEDIMENT CONTAMINATION IN THE BELGIAN COASTAL ZONE

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High levels of pollutants such as organotin compounds, polyaromatic hydrocarbons, perfluorinated organochemicals and polybrominated diphenylethers are measured in the sediments of the Flemish coastal harbours and to a lesser extent in the sediments of the Belgian coastal zone (Janssen *et al.*, 2009). These findings require the assessment of the potential impact of these chemicals on macrobenthic infauna of the harbours and the coastal zone. Therefore macrobenthos and sediment were sampled simultaneously during integrated sampling campaigns in the spring and the winter of 2007. Sixteen stations were sampled according to a gradient from the inner harbours of Zeebrugge, Oostende and Nieuwpoort towards the coastal zone (stations at approximately 1 and 8 mile from the coast). In order to measure changes in the macrobenthic community caused by pollution, biodiversity analyses of the macroinfauna were undertaken as well as chemical and granulometry analyses of the sediment.

The results show a gradient of decreasing pollution levels from the interior of the harbours towards the coastal zone. Macrobenthic species mirror this pollution gradient as macrobenthic biodiversity is increasing from the inner harbours towards the coastal zone. Besides sediment contamination, dredging activities and sediment characteristics might be influencing factors.

This study gives an indication of a relationship between the macroinfauna in the sediment and the effect of contaminants on the medium. It underlines the necessity of a proper assessment of sediment contamination and its biological and ecological significance.

The research is part of the INRAM project, financed by the Belgian Science Policy. www.vliz.be/projects/inram.

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DERIVING WATER QUALITY PARAMETERS AND BOTTOM REFLECTANCE FROM SHALLOW CASE-II WATERS BY REMOTE SENSING

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The value of remote sensing for water management is generally recognized as it can be applied to monitor large water bodies at high temporal resolution (Chen *et al.*, 2004). Airborne and satellite images are often used to derive water quality parameters such as the concentration of algae, Total Suspended Matter (TSM) and Coloured Dissolved Organic Material (CDOM). Our research focuses on the Spuikom (Oostende, Belgium) which serves a major recreational function and is recognized as 'shellfish water' because of the commercial culture of oysters. From remote sensing perspective, the Spuikom is an interesting site since the reflectance properties and locations of macrophytes and other bottom substrates can easily be measured when the water is let out. From 2007 until 2009, 8 intensive field campaigns were organised in the framework of the BELCOLOUR-project. Apparent optical properties of the water were measured each time at different points on the Spuikom, using an ASD Fieldspec Pro spectroradiometer and a B3 backscatter meter. These measurements are accompanied by water samples analyses in the lab in order to derive inherent optical properties (absorbtion and backscattering) and Chlorophyll-a, TSM and CDOM concentrations. Bathymetrics and relative bottom substrate hardness was measured using a Lowrance Fish-finding Sonar & Mapping GPS. On three dates a field campaign was set up to measure in-situ bottom reflectances in an empty Spuikom. Based on the study of Heytens *et al.* (2007), typical spectra and a comparison of measured bottom reflectance spectra, distinctive bottom reflectance spectra could be derived for the major bottom substrates (e.g. sand, *Ulva* spp, *Sargassum* spp,..). Four of the campaigns were accompanied by remote sensing imagery acquisition (CHRIS/Proba,CASI, AHS and APEX sensor). All available data are currently used to retrieve a 2D image of the water quality and bottom reflectance.

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LOCALISATION OF GFP-LABELLED *LISTONELLA* (*VIBRIO*) *ANGUILLARUM* IN THE GI-TRACT OF GERM-FREE SEA BASS (*DICENTRARCHUS LABRAX* L.) LARVAE

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The portal of entry of *Listonella anguillarum*, the causing agent of vibriosis in fish is not clarified yet. In order to localize the bacteria inside the host, we used the recently established germ-free model system of *Dicentrarchus labrax* sea bass larvae (Dierckens *et al*., 2009; Rekecki *et al*., 2009). This model system can be used to detect pathogens in the gastrointestinal (GI) tract in such a germ-free host. This is achieved by labelling the bacteria with Green Fluorescent Protein (GFP) and visualizing them with confocal microscopy.

According to our results, GFP-labelled bacteria can be tracked in both the mid- and hindgut of sea bass larvae 24 and 48 hours after oral infection. Future tests on GFP-labelled *Listonella anguillarum* in germ-free fish larvae can significantly contribute to our knowledge on host-microbe interactions. Furthermore, by the use of Image J software, it may be possible to determine the intensity of the fluorescing bacteria, thereby allowing a semi-quantitative measurement of the presence of bacteria in the GI tract. Consequently, this method can become a powerful tool to study pathogenic adherence and colonisation in the larval gut. Furthermore, as the exact location of bacterial colonisation can be determined, complementary studies by Transmission Electron Microscopy can investigate translocation of bacteria on cellular level.

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THE IMPORTANCE OF ARTIFICIAL HARD SUBSTRATES ON THE NORTH SEA BOTTOM FOR THE ECOLOGY OF THE ICHTHYOFAUNA

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In the year 2008 the kick off for the construction of the first windmill farm at the Belgian part of the North Sea (BPNS) was given. The foundations of these windmills act as secondary artificial reefs, attracting different kinds of fish species (Fabi *et al.* 2002; Arena *et al.*, 2007; Santos and Monteneiro, 2007). Initially, high densities of fishes present at artificial reefs where related to an increased productivity. Bohnsack (1989) stated that artificial reefs may attract fishes due to behavioral preferences but do not necessarily increase productivity. In this way an artificial reef may act as an ecological trap.

As many fish species have a complicated life cycle and are highly migratory it is hard to quantify 'possible' net production. For this reason it is important to interpret the dimensions and distribution areas of the populations of fishes involved and to stipulate factors influencing structure (densities) and functionality (production *versus* dispersion).

This PhD study aims to determine attraction and/or net production of the ichthyofauna present at the artificial hard substrates of the wind turbines placed at the Thornton ridge. Nearby artificial hard substrates (ship wrecks) and sand banks without windmills will act as reference sites.

The main goals are:
- to follow-up evolution of fish communities, densities and biomass;
- to determine which mechanisms/processes can result in an increased fish production;
- to determine (daily) migration patterns of some fish species.

Different techniques will be integrated to understand, quantify and visualize the functional relations between the ichthyofauna and the artificial reef.
Quantification is done using visual (camera observations, visual census) and invasive techniques (gill nets, line fishing).
Cod (*Gadus morhua*) and pouting (*Trisopterus luscus*) are selected for detailed investigation on habitat- and food preferences, condition index and migration patterns using different techniques (e.g. stomach content analysis, fatty acid analysis, telemetry).

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Also see abstracts of related projects further in this publication:

Brabant *et al.*; Coates *et al.*; Degraer *et al.*; Di Marcantonio M.; Haelters J.; Kerckhof *et al.*; Vandendriessche *et al.*

DECISION SUPPORTING TOOLS FOR DETERMINING TIDAL WINDOWS FOR DEEP-DRAFTED VESSELS

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A computer program called ProToel has been developed with the purpose of supporting the decision making of pilots and the in advance planning of daily traffic schemes for deep-drafted shipping traffic in harbours, based on up-to-date environmental data, such as tide, currents and waves.

The access to harbours is, especially for deep-drafted vessels, often restricted to so-called tidal windows: the time span in which the tidal elevation is high enough for vessels to pass. The length of these windows depends on the draft of the ship, the planned route, the water depth, tide, and the ship speed along the route. For a more accurate representation of the time span in which a ship may arrive at or depart from a harbour, additional factors can be taken into account, such as the ship's penetration into the soft mud layer on the seabed and the speed of cross-currents at the harbour mouth. Furthermore, a transition to a probabilistic tidal window can be made by taking account of waves and the resulting probability of bottom touch, instead of a more traditional, deterministic way of defining tidal windows, based only on a required minimum gross under keel clearance during the transit.

A computer program has been developed that calculates probabilistic tidal windows for the harbour of Zeebrugge, based on either astronomic tide, current tables and standard wave spectra, or short term predictions of tide, currents and waves that are made available through the HYDRA-server. For the calculation of the probability of bottom touch, the motion characteristics of deep-drafted ships that are of interest for the traffic to Zeebrugge were obtained through model tests and additional numerical calculations using the 2D strip theory program Octopus Office (formerly Seaway) and the 3D BEM program Aqua+.

The user can define a route, a ship, her loading condition and the date and time of departure to calculate whether the ship can arrive (or depart) at that time with an acceptable probability of bottom touch. To calculate tidal windows, such a calculation is performed consecutively for a number of departure times, with a constant time step between each other. The output is given in a table view, where each column represents one time of departure. Through the colouring of the table, it can be easily seen where tidal windows begin and end.
If data are available, the program can easily be extended to other regions. In the past this was done for the harbours of Flushing and Antwerp, where only the astronomical tide was taken into account for a long-term accessibility assessment.

To extend the probabilistic approach to the River Scheldt however, further work on the program is necessary, because the vertical motion of a ship sailing on a river mainly depends on other parameters than waves, such as wind, drift, other shipping traffic, etc.

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ASSIMILATION OF PARTICULATE AND DISSOLVED ORGANIC MATTER BY THE DEEP SEA VENT MYTILID *BATHYMODIOLUS AZORICUS*

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The nutrition of mussels from the Azores Triple Junction deep sea hydrothermal vents at the Mid-Atlantic Ridge (MAR) seems to be supported by sulphide- and methane-oxidising bacterial endosymbionts. We demonstrated that *Bathymodiolus azoricus* has the ability to supplement symbiotically acquired carbon and nitrogen by feeding on particulate and dissolved organic material (POM and DOM, respectively). Using stable isotope tracer experiments in the LabHorta aquarium facility at atmospheric pressure with ^{13}C- and ^{15}N-labelled marine cyanobacteria or a labelled amino-acid mixture, we demonstrated for the first time the assimilation of POM and DOM in all tissues of *B. azoricus*. The rates of carbon assimilation were quantified under POM and DOM concentrations similar to those measured near the natural mussel beds. Scanning electron microscopy enabled us to identify diatoms, foraminifera and silicoflagellates in the stomachs of *B. azoricus* from Lucky Strike (1700m depth) and Menez Gwen (840m depth), indicating that even at this depth, the mussels can still be linked to primary production at the ocean surface. However, particles collected by a sediment trap at Lucky Strike and Menez Gwen showed low $\delta^{13}C$ signatures of ~ −25 and −29‰, and $\delta^{15}N$ values around −2.7‰ at both sites. This could indicate that POM at MAR vent sites consists of a mixture of chemosynthetically-derived organic matter (sulphide- and methane-oxidising bacteria) and phytodetritus. Particulate nutrition is thus not limited to sea-surface derived material. Overall, our results underline the importance of dissolved and particulate heterotrophic nutrition of both chemo-autotrophic and photosynthetic origin in *B. azoricus*.

SUCCESSIVE CAMBIA IN THREE DIMENSIONS: THE MANGROVE *AVICENNIA* INSIDE

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Successive cambia are a rarity in nature. Only a few number of plants, although out of different phylogenetic clades, have secondary growth by more than one vascular cambium. The mangrove genus *Avicennia* is one of the three genera for which successive cambia are described since years. However, a three-dimensional description of the internal structure is still lacking, as is insight in the development and ecological implications of successive cambia. In *Avicennia* the successive cambia seem to be of a complex nature as all *Avicennia* species studied have a complex network of non-circular wood patches from which the characteristics change with ecological conditions. The spatial organisation as well as the growth type of *Avicennia* wood could provide advantages in the ecological stressful conditions the mangrove genus is growing in. This study elucidates the phenomenon of successive cambia by a three-dimensional description and an ecological interpretation of the hydraulic architecture of *Avicennia*, creating herewith more insight in the strategies trees have developed to be able to survive in harsh environments such as coastal habitats.

A JACKET AS AN ALTERNATIVE FOUNDATION STRUCTURE FOR OFFSHORE WINDMILLS

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In order to construct wind farms at larger water depths, existing foundation types have to be extended and new types must be developed.

In this study, an overview of the different possibilities to found wind turbines is given. The specific advantages and disadvantages of the methods are discussed. A relatively recently developed foundation type has been studied in detail: the jacket.

A pile foundation is used to found the jacket. Because of this, a full study of the axial and lateral bearing capacity of a pile foundation has been made.

In the second part of the study, three jacket structures have been designed, each for a different water depth: 16m, 22m and 45m.

Designs have been made using the software programmes “PowerFrame” by BuildSoft and “MPile” by Delft GeoSystems.

The results show that for the water depth of 16m, the complete foundation (pile foundation + jacket) weighs about 778 tonnes. At a 22m water depth the weight of the structure amounts about 865 tonnes and for 45m water depth the weight increases to about 1200 tonnes.

From the designs, it can be decided that the jacket structure is certainly a good alternative for the foundation of wind turbines at larger water depths. Being an open structure, the jacket weighs about 30% less then a similar monopile (for large water depths). Depending on the water depth, this means a saving of some hundreds of tonnes of steel. Despite the material savings though, the jacket is not cheaper. This is because of the complexity of the structure, which means that the time to design, fabricate and assembly will be longer.

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MANGROVE SPECIES' ASSOCIATION AND DISTRIBUTION PATTERNS IN TUMPAT, KELANTAN DELTA, EAST COAST OF PENINSULAR MALAYSIA

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We studied mangrove vegetation at Tumpat to estimate different tree structural parameters (e.g., stem density and basal area) at selected sites (PCQ-Method). There were 5 dominant taxa in the vegetation, i.e., *Sonneratia caseolaris*, *Nypa fruticans*, *Avicennia alba*, *Rhizophora mucronata*, and *Bruguiera gymnorrhiza* in order of importance. Total tree density varied between 79 and 132 stems $0.1ha^{-1}$, and basal area from 0.14 to $4.9m^2$ $0.1ha^{-1}$. Based on species composition and stem density, the mangrove sites could be separated into two groups (Bray-Curtis similarity: 60%). While Group-1 (sites G9, J5, K4, N6 and O4), dominated by *S. caseolaris* and *N. fruticans*, was distributed throughout the forest, Group-2 (sites C6 and G6), represented largely by *A. alba*, is present close to the bay-mangrove boundary. Elevation measurements indicate that Group-1 species occupied low-lying to elevated grounds (0.87-2.23m above the mean sea level) with a (mean) salinity between 0.38 and 14.6psu, whereas Group-2 occurred preferentially at low to medium elevations (0.86-1.29m) and high salinity (14.6psu). Discrete mangrove associations (=groupings) were discerned, wherein the distribution of species is governed by factors such as proximity of land or sea, freshwater input and elevation.

ON THE IMPORTANCE OF ADAPTIVE GENETIC VARIATION IN THE ENDANGERED EUROPEAN EEL

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The spatial and temporal scales of phenotypic and genotypic variation in marine systems provide an explicit framework for conservation of resource species. Studies of the geography of phenotypic variation have been used to identify population structure although phenotypes often vary spatially in association with environmental gradients such as temperature, salinity, predators and competitors. Molecular genetic surveys using neutral DNA markers have been the principal tool to study the spatial variation of genetic variability. However, the small levels of observed geographical differentiation in marine fishes pose challenges to define clear management units. Furthermore, the subtle neutral genetic differences among marine populations reveal little about the adaptive side of the evolutionary coin. Insights into local adaptation, adaptive response to global change and evolutionary consequences of selective harvesting can now be generated through population genomics studies, allowing the separation of the effects resulting from neutral (demographic) processes from those due to natural selection. Such knowledge is important not only for improving our basic understanding of natural as well as human-induced evolutionary processes, but also for predicting future trajectories of biodiversity and for setting conservation priorities. The European eel (*Anguilla anguilla*) is a broadly distributed fish with a fascinating but complex life cycle. Due to a 90% decline in recruitment since the 1980s, it has now been added to the CITES list of endangered species. Hence, improving our knowledge on the geographic and temporal scales of adaptive genetic variation in eel is crucial for the conservation of the entire species. The aim of this study is to investigate the combined phenotypic and genomic adaptive response of the eel under natural and anthropogenic influences. These processes are studied on a broad spatial (Europe) and historical (100 years old archived otolith collection) scale, using a combination of ecological data and various molecular techniques. Our results will provide important information to define biological relevant management units and to assess the long-term anthropogenic impact on ecological relevant traits.

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APPROACHES FOR ASSESSING POTENTIAL IMPACT OF THYROID HORMONE DISRUPTING CHEMICALS IN SEABASS (*DICENTRARCHUS LABRAX*)

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Studies in the laboratory have shown that a number of synthetic and natural chemicals can interfere with the endocrine system in fish. Among them, organic compounds such as pesticides and polychlorobiphenyls (PCBs) are well described endocrine disrupters (Schnitzler *et al*., 2008ab). Of particular interest are effects on thyroid function, but data on effects of PCB exposure on these hormones and related metabolism has been lacking. We propose here a thorough approach to assess effects of these compounds on the thyroid function of European sea bass (*Dicentrarchus labrax*).

To assess the ability of occurring pollutants in European coastal areas to disrupt the thyroid system in these fish, a field study in the major European estuaries, namely, the Scheldt, the Seine, the Loire, the Charente and the Garonne has been conducted. Each region has its own contamination levels and profiles reflecting the contribution of pollutants from rivers. Meanwhile, an experimental exposure of sea bass to commercial PCB mixtures has been designed to understand underlying toxicity mechanisms and effects on the thyroid system.

Several thyroid endpoints were simultaneously examined. Diameter of follicles and the epithelial cell heights give an indication on the production and secretion activity of the thyroid gland. The activity of enzymes involved in the metabolism (deiodination, glucuronidation and sulfatation) of thyroid hormones was analyzed. Finally thyroxine (T4) and triiodothyronine (T3) concentrations were analyzed in muscle by radioimmunoassay. The combined use of all those endpoints gives us an overview of the complex thyroid hormone system.

PCB concentration in wild fish varied from 10 to 100 ng g^{-1} wet weight (ww) depending on length and location. The contamination levels were as follows: the highest concentrations were measured in individuals collected from the coastal region near the Scheldt > Seine > Loire > Charente and the lowest levels were observed in sea bass from coastal regions near the Garonne. The measured levels were generally higher than those reported in literature in sea bass from other regions in the Mediterranean Sea. Contamination patterns were different depending on the sampling area and thus the river input of pollutants.

Experimental exposure revealed that environmental relevant doses of PCB (0 to 1$\mu g.g^{-1}$ ww Σ 7 ICES PCBs in food) altered hepatic T4 outer ring deiodinase and T4 sulfatation whereas T4 glucuronidation was not affected. Owing to the extensive autoregulatory feedback at both central and peripheral levels, the thyroid hormone concentrations were preserved despite the PCB induced changes in thyroid hormone dynamics. Fish exposure to higher PCB concentrations (10$\mu g.g^{-1}$ ww Σ 7 ICES PCBs in food) severely altered T3 and T4 levels in muscles, which are apparently caused by other mechanisms than metabolic pathways. Additional endpoints are therefore necessary to interpret changes in thyroid hormones levels in fish exposed to environmental contaminants as toxicity mechanism might differ based on exposure levels.

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THE EFFECT OF FLOATING NET CAGE AQUACULTURE ON THE COMMUNITY STRUCTURE OF PHYTOPLANKTON IN DJUANDA RESERVOIR, WEST JAVA – INDONESIA

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A research about the effect of floating net cage aquaculture on the community structure of phytoplankton in Djuanda reservoir was carried out during February 2007 to April 2007. The aims of this research were to investigate the community structure of phytoplankton in Floating Net Cage Aquaculture Zone with different crowd level in Djuanda Reservoir.

The method used in this research was survey methode. Water sampling had been done weekly at four chosen stations; Station I (the firth of Cilalawi River), Station II (Ubrug), Station III (Tanggul Usman) and Station IV (Intake Zone) which represent the area with varying density of floating cage nets. The data of phytoplankton were analyzed by using phytoplankton abundance, Simpson's dominance index, Simpson's diversity index and Sorenson similarity coefficient. The Pearson's Correlation and F-test was applied to identify interrelation between the crowd level of floating cage net and abundance of phytoplankton and Simpson's diversity index.

The results showed that there was a relationship between the floating net cage aquaculture density and the phytoplankton community structure. The diversity index on Station I, which represents the area without floating net cage, showed highest value in range 0.503-0.771. Meanwhile the diversity index on Station III, which represents the area with high density, showed lower value in range 0.059-0.647. This condition was supported by the high abundance and the dominance index of phytoplankton on Station III, especially for genera Microcystis.

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BIOLOGICAL MODULE OF BILATERAL FLANDERS-UKRAINE PROJECT OCEAN-UKRAINE. OVERVIEW, ACHIEVEMENTS, PERSPECTIVES

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The Ocean-Ukraine project (1March 2007 – 30 November 2009) involved VLIZ and two major Ukrainian marine institutions: IBSS (marine biology) and MHI (oceanography and operational services). The general objectives of the project were to strengthen capacity in both institutions and to integrate them in European networks through a bilateral partnership with Flanders. Within the biological module of the project, two main topics of work were planned: (1) general activities of the National Oceanographic Data Centre (NODC) and strengthening of existing infrastructure, including creation of a national distributed data center; and (2) biological data management, including data archaeology and rescue.

Within the first topic the big step ahead was realized by the IBSS capacity building. A set of the installed enterprise level equipment and laid fiber channel line gave a possibility, not only to entirely fulfill the planned tasks of the Ocean-Ukraine project, but also to provide the IT support to the work within all international and national projects that are now being executed by the IBSS. Merging best European practice and modern technologies available through VLIZ, IBSS on the basis of created infrastructure is implementing international standards in the field of marine data and information management. As the result of the activities within the Ocean-Ukraine project in 2008, Ukraine decided to shift to the distributed model of the NODC. From now on there is in Ukraine, in addition to the NODC based at the MHI, one more NODC based at the Laboratory of the Marine Information Systems (LaMIS) of IBSS. NODC on a basis of the IBSS is dealing with the marine biological data.

Within the second topic the very important tasks addressed by the project were archaeology and rescue of unique biodiversity data collected by Ukrainian scientists during many years that exists now in non-digital form as tables, field notebooks, logbooks, etc. and that are now at a growing danger to be lost forever. As a backbone for the digitized data the cruise inventory for the scientific research cruises of IBSS ships and cruises of other ships where IBSS staff worked was created. For the moment the inventory includes 150 cruises and 12205 stations for the all world oceans and is being actively populated with the new information. Thousands of biodiversity records were digitized or extracted from the old or inappropriate formats (Excel, Paradox etc.) and put in the properly managed MS SQL database where all standard data management procedures are ensured. Archived biogeographical records were contributed to Ocean Biogeographic Information System (OBIS), through the European node of OBIS (EurOBIS), which is hosted at VLIZ.

The project improved the national and regional resources aiming to provide data, related data products, and results of analyses to meet societal needs. This was achieved through elaboration of management strategies, institutional capacity building and development of pilot activities in specific fields. Transfer of knowledge and capacity building within Ocean-Ukraine created a sound basis for achieving the European standards in the Black Sea region.

LEARNING FROM MICROWORLDS: EVIDENCE FROM A FISHERIES SIMULATION GAME

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Microworlds, as a specific form of simulation models, are in many fields often referred to as: (i) insight generators (Morecroft, 1984), (ii) tools for inquiry into dynamic decision making processes (Brehmer, 2005; Gonzalez *et al.*, 2005), (iii) tools to visualize and rehearse decisions and strategies (Morecroft, 1999; Morecroft, 1984), (iv) tools to debate and discuss strategies (Morecroft, 1999; Morecroft, 1984), (v) laboratories for ex ante evaluation of decision making (De Geus, 1997; Keys *et al.*, 1996), (vi) learning laboratories (Kim, 1993; Romme and Dillen, 1997), (vii) learning environments (Wolfe, 1976), (viii) learning spaces (Senge, 1996), and (ix) educational tools (Sindre *et al.*, 2009). In other words, various scientists believe, explicitly or implicitly, that some form of 'learning' occurs when using microworlds. Nevertheless, this belief still generates widespread disagreement within several scientific communities (Bakken *et al.*, 1993; Langley, 1993; Langley and Morecroft, 1996). The main reason for this disagreement is the remaining absence of a well structured body of evaluation research which structurally tackles this research question of whether any valuable 'learning' takes place from the use of microworlds (Akili, 2007; Bakken *et al.*, 1994; Cavaleri and Sterman, 1995; Gresse von Wangenheim *et al.*, 2009; Huz *et al.*, 1997; Raia, 1966; Sweeney and Sterman, 2000; Wolfe, 1976). Since this absence of a structured body of evaluation research is unwarranted, this study intends to contribute to this body through addressing this research question.

For this, the Belgian fisheries is chosen as a case study and three stakeholder groups (i.e. policymakers, scientists and ship owners and skippers) were invited to participate in a 'before-after with control group'-experiment developed at assessing learning effects (i.e. changes in their knowledge, attitude and behaviour) from the used microworld related to the effect policy instruments have on the fisheries system. The results of this experiment indicate that using the microworld did not result in changes in participant's subjective knowledge, attitude and behavioural intention towards commonly used policy instruments in Belgian fisheries management. This outcome is somewhat contradictory to the fact that all stakeholders groups reported that they had learned from the microworld about the effect policy instruments have on the fisheries system and that they had confidence in the microworld and perceived its behaviour as valid. At first glance this seems contradictory, however, three alternative explanations are: or (i) methodological issues made it impossible to detect changes in participant's subjective knowledge, attitude and behavioural intention, or (ii) the way in which the microworld was administered did not result in changes in participant's subjective knowledge, attitude and behavioural intention, or (iii) participants have not 'learned' anything new from the microworld and therefore no changes in participant's subjective knowledge, attitude and behavioural intention occurred. Finally, emphasis should be made that the presented research at its current stage is a first step in contributing to evaluating learning from microworlds. So far, this study cannot conclude that decision makers learn for microworlds. Hence, there are still plenty of opportunities for future research.

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LARGE SCALE EXPERIMENTAL INVESTIGATION ON WAVES-*POSIDONIA OCEANICA* INTERACTION

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Posidonia oceanica, is a species of seagrass endemic to the Mediterranean Sea included in the Barcelona convention list of protected species. This marine plant forms large underwater meadows that are considered to be of high importance to the environmental conservation of the region which occupies, supporting a highly biodiverse habitat and protecting from coastal erosion. *P. oceanica* seagrass meadows are distributed in shallow areas from the surface to a depth of 30.0-40.0m in clear conditions, while it colonises sandy substrata, rocky shores and old matte reefs.

The effects of marine/estuarine submerged vegetation on unidirectional flows has been studied at a variety of scales in the field (Prager and Halley,1999; Neumeier and Ciavola, 2004) 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) and numerically (Li and Yan, 2007; Suzuki and Dijkstra, 2007; Souliotis and Prinos, 2008) examined. Very few small scale experiments have been performed dealing with waves and *Posidonia oceanica*.
The research was carried out in the CIEM wave flume (Canal d'Investigació i Experimentació Marítima) at UPC Barcelona (Universitat Politècnica de Catalunya), which is one of the big research installations (100.0m length, 3.0m width and 5.0m depth). 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 squared meter) on the above characteristics are investigated. The experiments target as well, the measurement of mean velocities above and within the simulated *P. oceanica* and the estimation of wave induced flow within the *canopy*, which influence processes such as nutrient uptake, waste removal and larval dispersion.

A meadow with a total length of 10.70m was constructed by polypropylene artificial plants, selected for the most similar physical properties to real *Posidonia oceanica* leaves (Folkard, 2005), according to a dimensional analysis performed for determining the characteristic parameters for prototype and laboratory conditions. Each plant was modeled by four stripes: two stripes 55.0cm long and two stripes 35.0cm long. Two different plant 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.

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 patch for various wave conditions using regular and irregular waves and three different submergence ratios hs/D (0.500, 0.423 and 0.323) as discussed in Stratigaki *et al.* (2009ab). Results are also analysed with regard to the wave induced flow within the field and the effects of submergence ratio and seagrass density on mean flow characteristics are investigated based on measurements of mean velocities taken at three locations within the seagrass field (front, middle and end of *P. oceanica* field).

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NUMERICAL MODELLING OF NEAR-FIELD AND FAR-FIELD WAKE EFFECTS OF A FARM OF WAVE ENERGY CONVERTERS

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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).

Traditionally, research is carried out on WECs based on the oscillation principle (type (i)) in an array. The use of Boundary Element Methods based on potential flow is an example, e.g. WAMIT applications for a single WEC only. The study of the far-field effects requires a large computational domain which makes WAMIT less convenient. Therefore, numerical wave propagation models have been recently used, where the WEC is simplified as a porous structure which extracts a certain amount of wave power. The latter models have only been applied to devices of type (ii), i.e. WECs based on the overtopping principle, using absorption only and no radiation. Examples found in Millar *et al.* (2006) and Venugopal and Smith (2007) give a very restricted and rough approximation of the actual farm behavior due to severe limitations, as discussed by Beels *et al.* (2009a).

The present study refers to the development of the numerical modeling of the above mentioned wake effects of a WEC-farm, by using irregular short-crested waves and the effect of wind regeneration. A mild-slope wave propagation model, MILDwave, based on the equations of Radder and Dingemans (1985) and developed by Troch (1998) has been recently used in the simulation of single WECs and basic WEC-farm layouts. The evolved technique has been applied on the Wave Dragon (type (ii)) (Beels *et al.*, 2009b) and on a basic implementation of a combined radiating and absorbing WEC (type (i)) (Beels *et al.*, 2009c).

The numerical optimization of MILDwave will reduce the computational time and allow the introduction of larger WEC-parks in larger domains, as well as the implementation of new physical processes, a.o. wave directionality and wind regeneration. The implementation of radiating devices of type (i) with the use and development of WAMIT, and further study of the configuration of the WECs in a farm are also objectives of the present study.

Finally, applications in close-to-market-devices (Pelamis, Wave Star) will lead to an analysis of the results of the studied Wave Energy Converters in terms of cost and [(produced power).km^{-2}].

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DISSOLVED INORGANIC CARBON DYNAMICS IN THE GULF OF BISCAY

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Over the last 420000 years (Siegenthaler *et al.*, 2005) the maximum atmospheric CO_2 variations were ~100 ppm. A remarkable stability in atmospheric CO_2 variations of <20 ppm was observed during at least the last 11000 years before the Industrial Era (Sabine *et al.*, 2004). In this longer-term context, the CO_2 increase of ~100ppm during the past 200 years is a dramatic alteration of the global carbon cycle (Sabine *et al.*, 2004). Ocean uptake of CO_2 will help moderate future climate change, but the expected decrease in pH of 0.14-0.35 in the 21st century (IPCC, 2007) is 3 times higher than what was experienced during glacial-interglacial periods (Falkowski *et al.*, 2000). This has important repercussions on the chemistry and equilibrium of the oceanic carbonate system, where the observed atmospheric variations, increase the acidity (ocean acidification) and decrease the solubility of the ocean, making the surface ocean dissolved inorganic carbon (DIC) more sensitive to added CO_2 (Smith *et al.*, 1999).

The decreasing $[CO_3^{2-}]$ as a result of ocean acidification makes it more difficult for marine organisms to produce $CaCO_3$ structures, such as for example coccolithophorids (Riebesell *et al.*, 2000). But the precipitation of $CaCO_3$ is one of the main minerals transporting C to the deep ocean and hence buffering CO_2 uptake at the ocean surface. Balch *et al.* (2007) recently estimated the global pelagic calcification to be 1.6±0.3PgCyr^{-1}, based on remote sensing data of coccolithophorid blooms. This would imply that coccolithophores would be the single most pelagic calcifier in the ocean, since other estimates of global pelagic calcification rate range between 0.7PgCyr^{-1} (Milliman *et al.*, 1999) and 1.4PgCyr^{-1}, which is the highest estimate (Lee, 2001).

In the Northeast European continental margin, blooms of the coccolithophore *Emiliania huxleyi* have been frequently reported (Harlay *et al.* 2009a). Here, we present a data-set of carbonate chemistry in surface waters obtained during three cruises in the Northern Bay of Biscay (in 2006, 2007 and 2008). We evaluate the relative effect of calcification and organic carbon production on seawater carbonate chemistry, and related air-sea CO_2 fluxes. During the cruises, the northern Bay of Biscay acted as a sink of atmospheric CO_2 (on average ~ -9.7mmolCm^{-2}d^{-1} for the 3 cruises). The overall effect of net community calcification in decreasing the CO_2 sink during the cruises was low (on average ~12% of total air-sea CO_2 flux). If this is a general feature in naturally occurring phytoplankton blooms in the northern North Atlantic Ocean (where coccolithophore blooms are the most intense and recurrent), and in the global ocean, then the potential feedback on increasing atmospheric CO_2 of the projected decrease of pelagic calcification due to thermodynamic CO_2 "production" from calcification is probably minor compared to feed-backs related to changes of net community production.

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HOLOCENE RELATIVE SEA LEVEL CHANGES IN THE LÜTZOW HOLM BAY REGION (EAST ANTARCTICA)

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The Antarctic ice sheets (AIS) are probably the biggest wild card in our knowledge regarding past ice sheet volume and their contribution to post glacial sea level rise. Published estimates of the Antarctic contribution to eustatic sea level rise since the Last Glacial Maximum vary by an order of magnitude and the existing ice sheet models are poorly constrained in some regions. All the models underestimate past ice sheet thickness in the Antarctic Peninsula region and the Lützow Holm Bay region (Enderby Land, East Antarctica). In addition, little is known about the response of the AIS to Holocene climate variability and its potential contribution to future global sea level changes. To date, there is thus an urgent need for geological constraints on past ice sheet thickness and dynamics. This information can be obtained from Relative Sea Level (RSL) records, which represent the relation between global (eustatic) sea level change and the regional isostatic variability as a result of changes in ice sheet thickness. Here we developed a RSL curve by dating the transitions from marine to lacustrine sediments in isolation basins and by measuring the lakes' sill height in relation to the present sea level. To this end, we analyzed the diatom communities in sediment cores from 6 lakes in West Ongul Island and Skarvsness (Lützow Holm Bay, East Antarctica) in order to identify marine to lacustrine transitions. Our RSL revealed a significantly different uplift rate in the Skarvsness region compared with West Ongul Island, although the distance between both regions is only c. 60km. Our results imply that (i) the ice sheet volume in Skarvsness was higher than previously believed and/or (ii) that the region deglaciated during the Holocene. Hence, the East Antarctic Ice Sheet, which is the largest remaining ice sheet on Earth, responded to Holocene climate change, making it a likely contributor to future sea level changes.

MATING AND FEEDING BEHAVIOUR OF THE EURYHALINE COSMOPOLITAN FLATWORM *GYRATRIX HERMAPHRODITUS*

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The rhabdocoel flatworm *Gyratrix hermaphroditus* is a distinct member of the Rhabdocoela (flatworms with a proboscis). It is very easy to recognise and has been recorded from all over the world, both in fresh water and marine habitats. However, almost nothing is known about its general biology. In this contribution we describe in detail its mating and feeding behaviour.

Mating starts with a 'sniffing' behaviour, during which the worms use their proboscis to probe the rear end of the partner. Both worms alternate positions several times before proceeding to the mating proper. During the copulation, both worms take a strange triangular shape and align their posterior parts. Suddenly after a few seconds, both partners simultaneously insert their male copulatory stilet into the vaginal opening of the partner, and further into the bursa copulatrix.

Although in rhabdocoels the stilets are typically thought to have their function exclusively in mating, *G. hermaphroditus* also uses its stilet to sting its prey. After that, the pharynx is placed on the stab wound produced by the stilet and used to suck the contents of the prey into the body.

COHESIVE SEDIMENT TRANSPORT RESEARCH: THE SCIENCE OF MUD

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Mud in the natural environment is a mixture of clays, silt, sand, water and organic matter. It can be found in large quantities in estuaries and along neighbouring coasts, as is the case for Belgium. The usually high content of fine-grained particles (clays and some silts) explain the cohesive nature of mud, which is the net result of electrostatic forces from the clay particles and the sticky organic substances produced by bacteria and other micro-benthos. Therefore, cohesive particles consist of flocs of aggregates of the primary particles, which structure and density are determined not only by the internal properties, but also by those of the ambient water and the external mechanic forces (especially turbulent shear and particle interactions). When cohesive particles settle, they form a layer of slowly consolidating fluid mud. The siltation of navigation channels, docks and aquaculture farms is a well known problem. Managing authorities rely on model predictions in order to estimate the related economic cost and environmental impact of cohesive sediment transport and the effects of human interference by dredging and the construction of structures. However, the accuracy of these models is very low. The Hydraulics Laboratory of the KU Leuven investigates possibilities to improve the modelling capacities of presently used engineering software for sediment transport. The present focus of the research is on fluid-particle interactions, high-concentration effects, mud-wave interaction, flocculation and bottom erosion resistance. The model improvements are strongly physically-based and supported by experimental data.

SPECIES DELINEATION IN DICTYOTA, A COMBINED MOLECULAR AND MORPHOMETRIC APPROACH

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Delineating species based on morphology remains problematic in numerous marine macroalgae due to a low degree of external dissimilarity among the species and at least in some groups a high morphological plasticity. The brown algal genus *Dictyota* represents a prime example to address species delineation in marine macroalgae, since exclusive diagnostic characters do not exist for the majority of the species. Diagnostic descriptions, therefore, consist of a circumscription of the gross morphology followed by a series of continuous numerical characters relating anatomical features (sizes and dimensions of cells) and reproductive characters (spores size). Our study aims to evaluate the suitability of multivariate methods based on morphometric data for species delimitation and to detect which morphological variables contribute most to the discrimination of species in this genus. Results based on a combination of morphometrics and molecular analyses have allowed us to recognise cryptic species from the Canary Islands. The morphometric analysis of a large amount of variables demonstrates that *Dictyota* species have a high degree of intraspecific morphological variation. Analyses of similarity (ANOSIM) confirm the existence of significantly different groups of individuals, observed in the n-MDS ordination. SIMPER analysis reveals that specimens differ most in anatomical characters. Morphometric data fit in properly with molecular results. Morphometrics turns out to be a decisive tool to help bringing an objective approach together with molecular evidences to solve taxonomic problems on genera with such morphological variation.

MODELLING AND OBSERVATION OF AN UPWELLING FILAMENT OFF CAPE GHIR (NW AFRICA) DURING THE CAIBEX CAMPAIGN

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Upwelling filaments are characteristic features of eastern boundary current upwelling systems (EBUS), such as the California Current System, the Canary Current system, or the Humboldt Current system. They can be defined as elongated structure (a few hundred km) that propagates from the coastal zone to the open ocean, with typical time scales of a few days. The biological importance of these filaments consists of an exportation of nutrient-rich upwelled water towards the ocean interior, which can drive a high primary production, as evidenced by chlorophyll pigment satellite images.

The object of this presentation is twofold:
We will present the results of a high-resolution numerical model centred on the Cape Ghir (Marroco), known to be frequently affected by upwelling filaments. Using a numerical model allows us to assess the role of certain mechanisms (wind, bathymetry, bottom friction, etc) in the generation and propagation of filaments.
We will use in situ measurements and satellite images obtained during the CAIBEX campaign to compare and assess the results of the numerical model.

A particular attention will be paid to the interactions between numerical modelling and hydrographic campaign, as we believe they constitute essential pieces in order to achieve our goal of understanding the generation mechanisms of filaments.

MACROECOLOGY MEETS MACROEVOLUTION: EVOLUTIONARY NICHE DYNAMICS IN THE SEAWEED *HALIMEDA*

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Because of their broad distribution in geographic and ecological dimensions, seaweeds (macroalgae) offer great potential as models for marine biogeographic inquiry and exploration of the interface between macroecology and macroevolution. This study aims to characterize evolutionary niche dynamics in the common seaweed genus Halimeda, use the observed insights to gain understanding of the biogeographic history of the genus, and predict habitats that can be targeted for discovery of species of special biogeographic interest.

The evolutionary history of the genus is characterized using molecular phylogenetics and relaxed molecular clock analysis. Niche modeling is carried out based on macroecological data derived from global satellite imagery with Maximum Entropy techniques. Evolutionary niche dynamics are inferred through application of ancestral character state estimation.

A nearly comprehensive molecular phylogeny of the genus was inferred from a six-locus dataset. Macroecological niche models showed that species' distribution ranges are considerably smaller than their potential ranges. We show strong phylogenetic signal in various macroecological niche features.

The evolution of Halimeda is characterized by conservatism for tropical, nutrient-depleted habitats, yet one section of the genus managed to invade colder habitats multiple times independently. Niche models indicate that the restricted geographic ranges of Halimeda species are not due to habitat unsuitability, strengthening the case for dispersal limitation. Niche models identified hotspots of habitat suitability of Caribbean species in the East Pacific Ocean. We propose that these hotspots be targeted for discovery of new species separated from their Caribbean siblings since the Miocene rise of the Central American Isthmus.

COMPOSITIONAL CHANGES IN PHYTOPLANKTON SUMMER BLOOMS IN THE FRESHWATER TIDAL REACHES OF THE SCHELDT ESTUARY (BELGIUM)

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The highly nutrified Scheldt Estuary is a typical macrotidal estuary, characterized by high turbidity and an extensive freshwater tidal area. As typical for many western European estuaries, the Scheldt Estuary is heavily polluted due to waste water discharges. Thanks to an increase of waste water treatment, water quality improved significantly during the last years (Maris *et al.*, unpublished).

Centric diatoms are a typical component of the phytoplankton community and these organisms develop blooms every summer. During winter, allochthonous green algae, originated from the tributaries, become more important. We investigated long-term changes in summer phytoplankton biomass and species composition in ten sampling stations in the freshwater tidal part of the estuary, and linked these to changes in abiotic factors. A long lasting structural change in the diatom community is observed as since the end of the summer 2003 the large centric diatom *Actinocyclus normanii* replaced *Cyclotella scaldensis* as dominant species in summer. The abrupt change in phytoplankton community covaries with a gradual increase in oxygen concentration and a decrease in ammonium concentration, caused by an increasing waste water treatment.

INNOVATIVE CREST DESIGNS TO REDUCE WAVE OVERTOPPING: PARAPET AND STILLING WAVE BASIN

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According to the Belgian Coastal Safety Plan, the coastline has to be protected against storms with a return period of 1000 year. A beach nourishment or heightening of the dikes are not always possible due to its price, the lack of space, the view on the open sea,...

Therefore innovative crest designs, with a significant reduction of wave overtopping but without heightening the crest level, are studied at Ghent University. Two of those designs are presented in this abstract: the Parapet and the Stilling Wave Basin (SWB). Model tests have been carried out and prototypes can be built along the dikes of some coastal cities such as Oostende, Nieuwpoort,...

A first design to reduce the overtopping is the construction of a parapet or wave return wall on the slope of the dike. A main characteristic is the crest level which remains the same compared to the initial dike. The parapet ensures the incoming waves are being returned to the sea. Test results show a great reduction in overtopping.

The second innovative crest design is a Stilling Wave Basin (SWB), composed of a seaward wall, a basin and a landward wall. The crest level of the SWB-dike remains the same, but the overtopping discharge decreases considerably based on the energy dissipation in the basin. Overtopping events at the landward wall are reduced to a minimum. In good weather conditions, the basin can be used as an extended promenade in front of the original promenade near the apartments. The seaward wall can be integrated in the architectural desires with a height perfect to lean or sit on and overview the sea.

According to the van der Meer overtopping formula ($q^* = A \cdot \exp\left(-B \cdot R_C^*\right)$, with q^* the dimensionless overtopping discharge and R_C^* the dimensionless freeboard, TAW 2002), the efficiency of both SWB and parapet can be presented by adding a correction factor γ_{SWB} resp. $\gamma_{parapet}$ in the denominator of the dimensionless freeboard R_C^*. This creates a virtually higher freeboard without actually touching the dimensions of the freeboard. For an SWB, the reduction factor can become 0.44 (breaking waves) or 0.48 (non-breaking waves). For a parapet, gamma-values of 0.5 are found.

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ZOOPLANKTON IN THE SOUTHERN NORTH SEA AND THE LINK WITH (SEMI-)PELAGIC FISH AND FISHERIES

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Many European commercial fish stocks are overfished and, at the same time, fisheries are under substantial financial pressure in several countries. Beam trawl fisheries are suffering from high exploitation costs and a negative impact on the marine ecosystem. In order to work out a sustainable strategy for the Flemish fisheries sector, it is necessary to diversify the used fishing methods. This includes developing niche fisheries and a sustainable use of other natural marine resources.

As opposed to its benthic ecosystems, the North Sea pelagic ecosystems are less intensively studied. In pelagic food webs, the zooplankton plays a crucial role as main food source for higher trophic levels. This zooplankton consists of small animals living in the water column, who mainly feed upon other planktonic fauna and flora and on detritus.

Preliminary results of the WP2 Plankton samples taken in the Belgian part of the North Sea in 2009 show crustaceans to be the dominant fauna. Calanoid copepods are omnipresent and the species *Temora longicornis*, *Acartia clausi, Centropages typicus* and *C. hamatus* constitute the greater part of the copepod community. Further offshore, typical oceanic species such as *Calanus helgolandicus* occur. Additionally, high numbers of juvenile stages of benthic organisms dwell in the water column. Juvenile polychaete worms and barnacle larvae are found abundantly, implying a benthic-pelagic coupling. Bigger mesozooplankton species that actively hunt the other plankton are arrow worms (e.g. *Sagitta elegans*), fish larvae and mysids.

A better knowledge of the spatial and temporal distribution of this zooplankton, in relation to the present pelagic fish species, is needed to estimate the importance of the pelagic ecosystem.
Looking at the distribution of pelagic fish on one hand, and at their feeding ecology which plankton do they eat, where and when? on the other hand, makes it possible to assess the importance of zooplankton as a food source for fish.

The first findings show herring and sprat to be common during the winter half year. These fish are mostly age 0 and age 1 classes staying close to the shore. Adult herring can be found in autumn during the migration towards the English Channel spawning grounds. Summer brings along two other key species, namely mackerel and horse mackerel. Horse mackerel reproduces in the southern North Sea and juveniles are occasionally very abundant in the offshore pelagic fish community.
Furthermore there is, partially because of actual Climate Change, an increase in jellyfish and other low-trophic planktivorous pelagic species in many marine regions. In 2009 the first gelatinous zooplankton was observed in March and April (sea gooseberries and moon jellies) on the BPNS. An increase in sea temperature during summer and autumn facilitates an increase in gelatinous plankton such as blue jellyfish, compass jellyfish, marigold and the ctenophores beroe and *Mnemiopsis leidyi*.

HOW TO MEASURE THE IMPACT DEGREE OF DIFFERENT ANTHROPOGENIC PRESSURES?

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Many human actors are invading and impacting the Belgian Continental Shelf (BCS) or parts of it. The main impact types are physical disturbance (fisheries, sand extraction, dredging), pollution (chemicals, nutrients) and construction works (wind mills, harbours, coastal defence). Some of these impacts are situated in demarcated areas (e.g. sand extraction), while others are spread over the entire BCS (e.g. fisheries).

Recently, the concepts of natural resources management and marine spatial planning have been incorporated in many directives (Water Framework Directive, Marine Strategy Directive, Habitat and Bird Directive). For the implementation of these directives, policy makers and managers need tools for evaluating impacts in the marine system, and for the assessment of recovery after enforcement of measures. Biotic indices, which were designed to objectively evaluate changes in the ecosystem due to impacts or measures, are examples of such tools. The Benthic Ecosystem Quality Index (BEQI), for example, objectively scales the observed difference between impact and control data in five classes (bad → high) (www.beqi.eu). Using the BEQI tool, managers can get scaled information about the degree of impact.

A lot of monitoring data have been and are being collected concerning different impacts on the BCS (e.g. sand extraction, dumping of dredged material, construction of wind mills and pollution), which enables a comparison of impact scales. For the use of a biotic index to scale the impact degree of different pressures, however, a few important conditions have to be met. Firstly, it is very important to have adequate control areas, free of any impact. Therefore, there is an urgent need for established marine protected areas (MPA's), with limitations on human activities. Secondly, the sampling strategy has to be spatially and temporally adapted for optimal impact detection. Thirdly, impact evaluation based on biological data has to be accompanied by pressure data. These are for example available concerning sand extraction and dredging, but not for fisheries. Fourthly, biotic indices are tools that summarize patterns, but they do not provide full explanations of observed patterns. Therefore, caution is needed during interpretation of results. Nevertheless, biotic indices are evidence based tools, which can be used for managing the marine system and eventually for determining nature compensation measures.

MONITORING OF THE MACROBENTHOS ON THE BELGIAN CONTINENTAL SHELF IN THE FRAMEWORK OF THE OSPAR EUTROPHICATION ASSESSMENT (EUTROF PROJECT)

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The OSPAR convention for the protection of the marine environment states that the eutrophication status of marine waters should be evaluated regularly. The status of eutrophication also has to be documented in the European Marine Strategy Framework Directive (2008/56/EC) (EMS) by the description of loss in biodiversity, ecosystem degradation, harmful algae blooms and oxygen depletion in bottom waters. Both the OSPAR convention and the EMS aim to minimize human induced eutrophication by forcing the member states to take adequate measures. For the evaluation of the eutrophication problems regarding the OSPAR and EMS objectives, a monitoring programme for measuring nutrients, phytoplankton variables and benthos was introduced covering the entire Belgian Continental Shelf (BCS). Within the previous eutrophication assessment (2002, 2006), the parameter changes/death in benthos/fish was not taken into account. The EUTROF project tackles the question regarding possible eutrophication impacts on soft-bottom benthos. To that purpose the benthos and related environmental parameters (chlorophyll a concentrations in water and sediment, depth of the redox potential discontinuity layer, and sedimentological parameters) were sampled or measured seasonally or monthly at 10 stations on the BCS in 2009. Those 10 stations cover the different benthic habitats and the natural spatial gradient on the BCS. Next to gathering new information, the project also incorporated existing knowledge (pigment data in water column and sediment and sediment oxygen profiles) regarding the benthic-pelagic processes in soft-bottom sediments, by using them as a proxy to explain the observed patterns in the monitoring data of 2009. The project results show that, at a local scale, there were effects of temporal oxygen stress on the soft-bottom benthos, but not to such an extent that it resulted in extinction of the benthos at certain places. Potential effects of oxygen stress on the benthos are mainly situated in the muddy sediments in the coastal zone. In sandy sediments, especially at the offshore sandbanks, the hydrodynamic conditions prevent the occurrence of eutrophication problems at the level of the soft-bottom benthos. Additionally, most benthic animals at the BCS show a high resilience and recovery potential following local disturbance. The project results indicate at which areas on the BCS eutrophication problems regarding benthos can occur, and they constitute a basis for the evaluation of eutrophication in the framework of the EMS.

CHANGES IN THE MARINE ENVIRONMENT: THE BELGIAN PART OF THE NORTH SEA REVISITED

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Sustainable development requires the quantification of human impacts, against the seafloor's ecological value. Recent impact studies have shown localised effects only, though indications of a longer-term and broader-scale degradation of the seafloor exist. This is due possibly to cumulative anthropogenically-induced effects, but the natural evolution and the response of the seafloor due to sea-level rise are poorly known. Such evolution needs to be disentangled against the impact of dredging, aggregate extraction, fisheries and beach replenishment.

Naturally-, as well as anthropogenically-induced sediment dynamics are studied in detail along the Belgian part of the North Sea (Van Lancker *et al.*, 2009). State-of-the-art observations/sampling, advanced modelling, as well as analyses of long-term datasets on sediment nature and dynamics, geomorphology and macrobenthos are carried out. Additionally, integrated sand/mud models and dynamically coupled current/wave models are being developed, with boundary conditions generated from models focusing on the Scheldt Estuary and on the coast. A historic reference framework has been set up, based on a sediment and macrobenthos dataset of 100 yrs ago (Gilson dataset, van Loen and Houziaux, 2002). In representative areas, erosion/sedimentation patterns and rates are quantified and balanced against the occurrence and intensity of human activities.

Results are integrated in the view of developing criteria, monitoring strategies and recommendations for a more sustainable exploitation/management of the EEZ. Particularly, the allocation of efficient dumping grounds, large-scale aggregate extraction and sustainable coastal protection schemes are being considered, also in the perspective of future sea-level rise scenarios.

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CHARACTERISATION OF THE CRAB *NEOSARMATIUM MEINERTI* DE MAN (DECAPODA: SESARMINAE) PREDATION ON *AVICENNIA MARINA* PROPAGULES

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Mangrove forests are essential for coastal and reef protection. It is an ecosystem providing protection from sedimentation and a range of goods and utilities for local population (Walters *et al.*, 2008). *Avicennia marina* is a pioneering mangrove species. This tree plays an important role in the colonization and the recolonization of mangroves (Osborn and Beriak., 1997) as it is one of the first species to settle in unforested and deforested areas (loc. cit.). *Neosarmatium meinerti* is a herbivorous crab, feeding essentially of leaves fallen on the ground and propagules (Dahdouh-Guebas *et al.*, 1997). The propagule predation has a direct impact on mangrove regeneration (Bosire *et al.*, 2005) and therefore on their dynamics. In this perspective we intend to characterize this predation and assess its impact on mangrove forest dynamics and especially on *Avicennia marina*. We focus on the time and amount of propagules predated upon and on interactions amongst the predators during feeding.

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‘SHIFTING BASELINES’. THE ARCHAEOLOGY OF THE NORTH SEA FISH

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Look at the sea. The water is troubled by concerns about the protection of biodiversity, the sustainable exploitation of natural resources, the probability of human impact on long-term shifts in the ecosystem. Sometimes, the impression arises that these discussions are floating with the tides, lacking a solid bottom to stand on. Clearly, we need a reliable baseline to compare the present situation against. How did the North Sea look like in times of little or no human interference? And how did its flora and fauna evolve, be it naturally or as an adaptation to human exploitation, pollution, and other things evil?

The problem with baselines is that they are hidden towards the base, and thus hard to reach. Going back in time, oral history addresses people’s memories but these are of course limited to one or three human generations. Scientific reports, worthy of that name, generally do not go back beyond the 19th century and document a period already characterised by intensive fisheries. Historical sources provide a deeper time perspective but tend to be selective in their information and generally do not pre-date the second millennium AD.

And then there is archaeological material. Fish bones excavated at coastal and inland sites often offer less biased information about the exploitation of the sea in historical times, and represent the sole documentation of this process during the prehistoric period. The collections provide insight in the composition of catches, length distributions of the species consumed, the location of fishing grounds, the seasonality of fishing, fishing technologies applied.

Moreover, it should be realised that the archaeological fish assemblages represent real biological samples taken hundreds or thousands of years ago. From the skeletal material, analyses can be extracted documenting former pollution levels, or eutrophication in general (using stable isotopes), the genetic identity or relationships of fish populations (using ancient DNA), evolutionary trends within species (studying growth patterns, age structures, etc.).

From the results of the archaeological fish investigations, one general conclusion comes forward: all things that have ever happened to the North Sea, troubling our present interaction with this environment, started much earlier than traditionally assumed. To understand the marine environment, the baseline has indeed to be shifted backwards as far as possible. Archaeology offers this opportunity, and, reassuringly, is as far as one can go.

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THE INFLUENCE OF *PHAEOCYSTIS* BLOOMS ON OFFSHORE MUSSELS

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Every year the phytoplankton species *Phaeocystis globosa* blooms in the Southern North Sea. During these blooms the species forms large gelatinous colonies (500-1000µm) instead of the small cells seen during the year. A bloom offers a huge amount of food to the mussels, but the size of the colonies may prevent the uptake of the available food leading to a decrease in energy reserves. In the framework of the AMORE III project seawater and mussel samples were taken in the offshore D1-area for the measurement of *Phaeocystis* colony presence and of the mussel's physiological state respectively. Seawater analysis confirms the well known cycle of spring and fall blooms: a huge *Phaeocystis* bloom in spring and a second, smaller bloom in September.

The influence of *Phaeocystis* blooms on the mussel's energy metabolism cannot be investigated without taking the mussel's reproductive cycle into account. The production of gametes requires a huge amount of energy as the gametes are protein and fat rich. The effect of the reproductive cycle is mainly seen in spring when the release of the gametes causes a fast reduction in protein and lipid levels.

In situ observations showed seasonal variation in energy levels that could be possibly attributed to the detrimental negative effect of *Phaeocystis* colonies, mussel spawning or their combination. Short term bioassays show a positive relationship between mussel clearance rates and *Phaeocystis* colony size (up to 300µm). Further field observations and long term experiments will allow making a conclusion on the effect of *Phaeocystis* on offshore mussel farming.

INTER-ANNUAL VARIATION IN THE STRUCTURE OF BACTERIAL COMMUNITIES ASSOCIATED WITH COCCOLITHOPHORID BLOOMS IN THE NORTHERN BAY OF BISCAY

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We studied the structure of bacterial communities in phytoplankton blooms, dominated by the coccolithophore *Emiliania huxleyi* during three consecutive years (2006-08) in the northern Bay of Biscay, a hydrologically dynamic area where coccolithophorid blooms develop each spring. Bacterioplankton community composition was assessed by means of denaturing gradient gel electrophoresis (DGGE) in combination with 16S rRNA gene clone libraries. We used ordination analysis to relate bacterioplankton community dynamics to phytoplankton pigment data and environmental parameters (nutrient levels, concentration of transparent exopolymeric particles (TEP), and water column stratification). We found a clear difference in composition between the free-living and the particle-associated bacterial assemblage, of which we identified the characteristic members. While on the one hand we found recurring dominant bacterial phylotypes throughout the years, associated with particular environmental and phytoplanktonic settings, there were also clear differences in community structure with depth between years. Using variation partitioning approaches, we will assess to what degree the relationships between microbial communities and their environment are predictable, which may help us to anticipate how microbial communities and their activities will shift in a changing world (Fuhrman 2009).

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A PRELIMINARY PHYLOGENY OF THE DALYTYPHLOPLANIDA (RHABDOCOELA, PLATYHELMINTHES): SINGLE ESCAPE FROM THE MARINE ENVIRONMENT

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Rhabdocoela is one of the most species-rich taxa of free-living flatworms, consisting of two monophyletic groups: the Kalyptorhynchia and the Dalytyphloplanida. The Dalytyphloplanida are cosmopolitan and inhabit marine, brackish water, freshwater and even limnoterrestrial habitats. Within this group, recent molecular data suggest a monophyletic clade, consisting of all freshwater and limnoterrestrial taxa, supporting a single escape from the marine environment. These results contradict older hypotheses based on morphology. However, the monophyly of this freshwater clade was very poorly supported, and the analyses are based on datamatrices including very few freshwater dalytyphloplanids, using one molecular marker (18S rDNA) only.

In this contribution, we present the results of a phylogenetic analysis based on new molecular data from 18S rDNA and 28S rDNA sequences from much more dalytyphloplanid species, freshwater as well as marine. The resulting cladograms support the existence of a freshwater clade. As the analysis includes new representatives of freshwater taxa from different continents, this group was probably already well-established before the break up of Pangea, although long-distance dispersal cannot entirely be discarded.

FREEDOM OF NAVIGATION IN THE EXCLUSIVE ECONOMIC ZONE: THE EU APPROACH

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Freedom of Navigation (FN) on the seas and oceans in general, and in the Exclusive Economic Zone (EEZ) in particular, is a concept that has long been established and developed in public international law, dating back to 1609 – the year Hugo Grotius gave birth to his important work entitled Mare Liberum (Freedom of the Seas), confirming it as an inalienable right of all states, regardless of whether they are big or small. In the light of the United Nation Convention on the Law of the Sea adopted in 1982 (UNCLOS), an EEZ is seen as a separate functional zone of a sui generis character, situated between the territorial sea and the high seas. Under the EEZ regime, coastal States and other States have both rights and duties towards one another. In other words, while coastal States exercise their sovereign rights and jurisdiction entitled to them under UNCLOS, they must have due regard to the rights and duties of other States in the zone, and vice versa.

FN in EEZ is a right enjoyed by all other states, and considered as a continuation of FN enjoyed on the high seas. In practice, FN in EEZ, however, is becoming more and more conditional or limited since coastal States tend to capitalize on or even abuse their rights and duties concerning marine pollution, particularly ship-source pollution, which, to a certain extent, results in restriction of FN in EEZ. The EU is an example to explore in this regard. On a proposal of the European Commission, the Council of the European Union adopted the Framework Decision 2005/667/JHA to strengthen the criminal-law framework for the enforcement of the law against ship-source pollution on 12 July 2005. The European Parliament and the Council passed the Directive 2005/35/EC on ship-source pollution and on the introduction of penalties for infringements on 7 September 2005 respectively. Under the Directive, infringements committed with intent, recklessly or by serious negligence are regarded as criminal offences. The Directive is controversial in terms of international law and in terms of EU law, and has led to a debatable judgment of 3 June 2008 by the European Court of Justice. In international law, the EU instruments have clearly gone too far when they provide criminal penalties imposed on the vessels that have committed infringements beyond the outer limit of the territorial seas of the member states, and have applied a new criterion, namely serious negligence, in this respect. In EU law, the above-mentioned institutions seem to have exercised the competence (imposition of criminal penalties), which rests with the member states. This is now in the process of being corrected. Aside from possible consequences facing vessels flying the member states' flags as far as FN in EEZ is concerned, the legal impact of the instruments may be felt by the rest of the world as the uses of seas and oceans in general, and navigation of ships in particular, are of an international nature.

WHAT IS THE STRUCTURING ROLE OF BIOTIC INTERACTIONS IN EXPLAINING DISTRIBUTION AND ZONATION PATTERNS ON WEST EUROPEAN SANDY BEACHES?

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Biological communities on sandy beaches are generally considered physically controlled. Physical processes such as the movement of waves and tides, habitat characteristics and the swash climate are considered to be the strongest ecological factors structuring the communities on sandy beaches. Until recently, biotic interactions are regarded to be of minimal importance. Some recent studies however, suggest that biotic interactions might play a role in structuring communities on sandy beaches, especially on a small scale and on dissipative beaches.

The main objective of this research was to examine the role of abiotic and biotic factors in clarifying the distribution and zonation patterns of sandy beach macrobenthos in Western Europe. The seven most important macrobenthos species were selected based on their prominent abundance on the West European sandy beaches. These selected species were *Bathyporeia pilosa* and *B. sarsi*, *Eurydice pulchra* and *E. affinis*, *Scolelepis squamata*, *Nephtys cirrosa* and *Eteone longa*. Recently, modelling techniques have been used for analyzing ecological questions. In this study a regression model was developed for each of the selected species, including possible abiotic and biotic factors influencing their distribution. The most appropriate models with significant abiotic and biotic factors were then selected by the AIC method (Akaike's Information Criterion; Akaike, 1974). The variance explained by the total model was divided in a part explained by the abiotic factors and a part explained by the biotic factors. Results suggest that the two abiotic variables, generally considered as most important structuring factors on sandy beaches (mean sediment and emersion time), do not exclusively explain the variance in species distribution. Biotic interactions are suggested to explain up to one third of the variance in species distribution explained by the model. Both predator-prey interactions and competition were indicated. The modelling approach does however not give sound proof for the presence of interactions. Only experiments can elucidate true interactions but this study gives strong hypotheses for biotic interactions on sandy beaches.

CONNECTIVITY OF TURBOT AND BRILL POPULATIONS IN EUROPEAN WATERS AS A BASIS FOR SUSTAINABLE MANAGEMENT

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Many commercial marine fisheries have strongly declined or even collapsed due to the synergy between a changing climate and pernicious anthropological influences, such as habitat degradation and overfishing. Indeed, marine fishes are strongly influenced by environmental oscillations, leading to an unpredictable reproductive success, high mortality and unclear population delineation. A good knowledge of the dispersal capacity and realised genetic connectivity of marine organisms is therefore important for the management of exploited fish populations.

Turbot (*Psetta maxima*) and brill (*Scophthalmus rhombus*) are two important commercial flatfish species in Europe. They are mainly caught as by-catch in beam trawl fisheries targeting sole, plaice and dab. However, the current quota for turbot and brill are based on trends in historical landings rather than resulting from analytical assessments requiring detailed biological information (age-, length- and weight-distributions of successive cohorts). In addition, molecular information would allow to define biologically relevant management units and obtain insights on population connectivity.

The aim of this study is to investigate the spatio-temporal connectivity of brill and turbot populations using various classes of genetic markers on a large (European) and small (North Sea and adjacent seas) geographical scale. The main objectives are:

1) The characterization of the spatial connectivity and temporal stability of turbot and brill populations in the North Sea and adjacent seas, based on neutral and adaptive (linked to life-history traits) genetic markers. We will examine the extent of genetic discreteness of European populations, to define which population model can best be used for fisheries management of both species.
2) The comparative analysis and environmental correlation of connectivity patterns in both turbot and brill, providing novel insights into the evolutionary processes influencing population (adaptive) differentiation in flatfish.
3) Results leading to sustainable flatfish stock management in the future. (EU-project NESPMAN; ILVO).

INTERACTIONS BETWEEN ABOVE- AND BELOWGROUND INVERTEBRATE FAUNA ASSOCIATED WITH *AMMOPHILA ARENARIA* IN DYNAMIC COASTAL DUNES

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Over the past decades it has become increasingly clear that plants can act as mediators of interactions between the above- and belowground fauna (van der Putten *et al.*, 2001; Wardle *et al.*, 2004). These interactions can occur between taxonomically different groups and across trophic levels. They can be negative or positive in either direction and may arise through varying mechanisms (Bezemer and van Dam, 2005). *Ammophila arenaria* has been subject of extensive study in the context of plant-soil feedbacks. This plant only thrives in dynamic sand dunes with sufficient sand-drift. As soon as conditions start to stabilise, *A. arenaria* starts to die back. This phenomenon has been proven to be caused by a negative effect of soil borne organisms, among which nematodes play an important role (van der Stoel *et al.*, 2002, Brinkman *et al.*, 2005). Our research extends current knowledge of plant-soil interactions in this study system to the aboveground invertebrate fauna. We combine large scale field surveys with field experiments and laboratory microcosms. We demonstrated that plant genotypic variation differentially affects the colonisation by above- and belowground invertebrates in the field. We further discovered negative interactions between root feeding nematodes and shoot feeding aphids in the lab (i.e. competition) whereas in the field these interactions get overruled under the influence of environmental variables (Vandegehuchte *et al.*, 2009). In a cross-inoculation experiment we demonstrated that the relative importance of biotic and abiotic soil components to plant performance differs from that to aphid population dynamics. Currently we also study how colonisation of the plant by aboveground invertebrates is affected by root infection with mycorrhizae and root-feeding nematodes in combination with drought stress.

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ASSESSMENT OF DISCARDING RATES FOR COMMERCIAL SPECIES OF FISH IN THE BELGIAN BEAM TRAWL FISHERY, WITHIN THE FRAMEWORK OF THE EUROPEAN COMMON FISHERIES POLICY

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A beam trawl vessel drags two nets with close contact over the sea bottom. The target species in this Belgian mixed fishery are sole (*Solea solea*) and plaice (*Pleuronectes platessa*), but lots of other species are also caught while trawling. Once the catch is on deck, the crew sorts out the commercial interesting species (the landings) and the rest of the catch is mainly thrown back into the sea (the discards). There are several reasons for discarding: filled quota, fish below the minimum landing size, fish with a low market value or bad quality, non commercial species or debris, etc. Enormous quantities of fish species are discarded every year and the main part of those fish die during the catch and sorting process and are as such lost as potential for stock rebuilding. Currently, most of the fish stock assessments are only based on the landing numbers per age category, while the discarded fraction of the catch is not taken into account in the stock calculations. It is assumed that this causes considerable underestimations of the stocks. Within the ICES (International Council for the Exploration of the Sea) stock assessment workshops, there is an enormous need for evaluation of the existing discard data and an incorporation of those data into the stock assessments. This thesis focuses on the assessment of the discard rates of commercial fish species in the Belgian beam trawl fisheries and consists of three work packages.

In a first work package, the discards of the commercial fish species in the Belgian beam trawl fishery will be estimated and evaluated. Under the DCR (Data Collection Regulation) Belgium is since 2004, obliged to collect discard (and landing) information. Several questions will be answered in this chapter. What is the 'best' method to raise the Belgian data to fleet level? What is the species composition of the discards? How do the length and age frequency distributions of the most important species look like?

The second work package focuses on the refinement of stock assessments by means of the incorporation of discard data. Most stock assessments are based on times series of only landing data at age. The current stock assessment models fail when it comes to incorporating discard data. New and better models will have to be developed to cope with this problem. In this work package, the above will be applied to one or more stock(s) of interest for the Belgian beam trawl fishery.

In the third work package, the potential use of self sampled discard data in the Belgian beam trawl fishery will be tested. Currently, the Belgian discard data are collected by seagoing observers during commercial surveys. They can collect those data only during a few trips a year onboard of a few vessels. This causes a rather low spatial and temporal coverage. Fishermen on the other hand, can provide haul based discard data throughout the year, which can be a solution for the problem mentioned above. Fishermen of several vessels will be asked to fill out logbooks and bring discard samples ashore. The analysis of the samples will be carried out in the laboratory. This alternative method of discard sampling will be compared to the method used by the seagoing observers.

NATURAL *VS.* ANTHROPOGENICALLY INDUCED VARIABILITY WITHIN COMMUNITIES OF DEMERSAL FISH AND EPIBENTHOS IN THE BELGIAN PART OF THE NORTH SEA: IMPLICATIONS FOR IMPACT MONITORING

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Anthropogenic activities, such as sand extraction, fisheries, shipping, the construction of pipelines or windmill farms, dredging and dumping of dredged materials, have been shown to result in varying effects on the marine ecosystem. Numerous monitoring programs have been set up to evaluate the extent and nature of these effects. However, the effects of anthropogenic activities on the benthic life are often difficult to detect against a background of large and small scale natural variability in the environment, especially in the highly dynamic sandbank-dominated habitats in the Belgian part of the North Sea (BPNS). Therefore, a monitoring strategy based on medium term data acquisition at fixed stations is used to evaluate the spatial and temporal variability within the demersal fish and epibenthos communities in the BPNS.

In total, 80 locations were sampled with an 8m shrimp trawl during 1 to 9 (spring and autumn) campaigns between 2004 and 2008. The results indicate that the coastal - offshore gradient is the dominant structuring factor on a regional scale (BPNS), which is reflected by a transition from a coastal system characterised by sole, plaice, ophiuroids and bivalves to an offshore system characterised by dab, lesser weever, dragonet, shrimp, crabs, hermit crabs and squids. On a local scale (sandbank systems), the seasonal and interannual effects primarily determine the community structure, although topography (gully - sandbank position) also plays a role.

Due to the considerable natural variability in the sandbank-dominated habitats of the BPNS, the effects of anthropogenic activities are hard to detect. The lack of a sound description of the system prior to any activity (T0), the lack of pristine reference zones, and changes in the finality of the monitoring programs over decades present additional challenges.

In the light of commercially exploited species (e.g. sole, plaice, dab, shrimp) and the preservation of biodiversity in the zones subjected to anthropogenic activities, it is imperative to keep both ecosystem components in the monitoring programs. Future monitoring, however, would benefit from the allocation of reference zones, free from any human activity (including fisheries), for each impacted sandbank system (top and adjoining gullies) in the framework of integrated spatial management of the BPNS. Furthermore, the extent of the observed interannual variation confirms the importance to maintain or establish time series for the existing impact stations and their references. Finally, an adaptation of the sampling technique (more but shorter beam trawl tracks) would increase the spatial resolution and hence decrease the detection level of local impact effects, leading to a higher accuracy of the impact assessment.

MONITORING THE EFFECTS OF THE THORNTONBANK AND BLIGH BANK WINDMILL PARKS ON THE EPIFAUNA AND DEMERSAL FISH FAUNA OF SOFT-BOTTOM SEDIMENTS

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The study of the effects of windmill parks on epifauna and demersal fish is based on a sampling design covering the existing concession zones (Bligh Bank, Thorntonbank) and corresponding references zones (Goote Bank, Bligh Bank, Hinderbanken, Thorntonbank). The baseline study (Year-0, prior to construction) of the Thorntonbank was completed in 2005. The presented study evaluates the situation in 2008, when six wind turbines were already present on the Thorntonbank (Year-1). Additionally, the Year-0 situation of the Bligh Bank was described.

For demersal fish, variations in biotic characteristics (density, diversity, biomass, length-frequency) were linked to seasonal, interannual and spatial variation (sandbank tops versus gullies). Densities were higher (>200%) in autumn than in spring and were substantially lower in 2008 compared to 2005 (reduction of 65%). In the Thorntonbank monitoring area, differences between tops and gullies were outspoken in spring, with higher densities (on average 22%) in the gullies. Perciforms and flatfish were important groups throughout the years, supplemented by locally and seasonally high densities of clupeids (spring 2005) and gadoids (autumn 2008). In the Bligh Bank monitoring area, differences between tops and gullies were most distinct in autumn with higher densities on the tops. The species composition was again mainly determined by perciforms and flatfish, with locally high densities of gadoids. The species number was higher on the Bligh Bank than on the Hinderbanken.

For epibenthos, all analyses concerning community composition, density, biomass, diversity and length showed differences between sandbank tops and gullies, with generally higher (up to 6 times) values in the gullies. This indicated that gullies are more diverse and richer than the sandbanks themselves. Furthermore, gullies displayed more variation in species composition than sandbank tops. Nevertheless, seasonal, interannual and spatial variations were mainly due to changes in densities of a few common species such as brown shrimp, two species of brittle stars, hermit crab, flying crab, lesser bobtail and squid.

For both ecosystem components, no changes were detected in the patterns in and around the concession zones and, as such, they remain largely comparable with the reference areas. The selected reference areas are considered to be suitable; only limited differences were found concerning biotic variables between the concession zones and their respective reference zones.
For future baseline monitoring, adaptations to the sampling design will be implemented, since cables and other structures on the seafloor prevent the completion of the beam trawl tracks in the vicinity of the turbines. These adaptations will include a shortening of the tracks and an increase in track numbers. Additionally, multidisciplinary targeted monitoring activities concerning the demography and trophic interactions of the local faunal communities will yield a better understanding of the observations done during baseline monitoring.

Also see abstracts of related projects further in this publication:

Brabant *et al.*; Coates *et al.*; Degraer *et al.*; Di Marcantonio M.; Haelters J.; Kerckhof *et al.*; Reubens *et al.*

DEVELOPMENT AND EVALUATION OF LONG-TERM ADAPTATION STRATEGIES FOR THE BELGIAN SEA FISHERIES SECTOR

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Sea fisheries are an important activity for the coastal community of Flanders from a socio-cultural-economic point of view. The Belgian fishing fleet operates in a complex, changing and uncertain environment. The strong specialization of the Belgian fleet with regard to fishing method (mostly beam trawlers) and target species (mainly flatfish) makes the Belgian fisheries sector rather vulnerable to the continuously changing circumstances. Rising fuel prices, declining fish stocks, fluctuating fish prices, a global financial crisis and various European and national regulations threaten the livability of the sector. Recently the sector has been faced with yet another factor which contributes to the growing uncertainty: climate change. Climate change will most probably impose additional pressure on the sea fishery, but may also offer opportunities.
This PhD aims at the development and evaluation of long-term adaptation strategies as a support to the fisheries sector and policy makers. The PhD hopes to contribute to the development of the Belgian fisheries into an innovative, flexible and sustainable activity, able to cope with changing circumstances, including climate changes.

i. Describe Belgian sea fisheries sector/fleet/drivers.
ii. Scope the impact of climate change on the Belgian sea fisheries sector/fleet.
iii. Develop long-term scenarios for selected drivers and effects of climate change.
iv. Develop adaptation strategies for the Belgian sea fisheries sector.
v. Develop model for the evaluation of the adaptation strategies (decision support system).
vi. Organise stakeholder input/consultation and formulate recommendations.

Based on a literature study and specialist experience a sector analysis describing and quantifying the sector/fleet/drivers was carried out.

A comprehensive literature study focussing on the impact of climate change on fish stocks (potentially) important for Belgian fisheries and the operational functioning of the fleet is ongoing. Different effect categories (ecological, economic and social) were selected and used to categorise the identified impacts. Appropriate indicators will be selected.

A number of divergent (clustered) scenarios for the selected drivers and effects of climate change focussing on a range of time frames (2040, 2100) will be selected and will form the basis for the development of several adaptation strategies.

An evaluation model/framework using multi-criteria analysis (MCA) will be developed. This integrated assessment tool offers the possibility to evaluate different criteria (economic, social, ecological, etc.) and aims at organizing information, making the decision process transparent and evaluating the sustainability of the proposed adaptation strategies.

During the whole process stakeholders will be consulted. Policy recommendations will be formulated based on the generated findings.

MONITORING THE EFFECTS OF OFFSHORE WIND TURBINES ON SEABIRDS

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The Belgian Part of the North Sea (BPNS) is of international importance to many seabirds. Meanwhile, the area is heavily exploited in support of the demanding needs of man, as for fishery, sand mining and shipping transport. Added to this, the near future will see large scale exploitation of offshore wind energy. Driven by the need for renewable energy, a large concession zone has been reserved for wind farms, comprising almost 10% of our continental waters. Currently, one offshore wind farm is being built at the 'Thorntonbank', and two others have been licensed.

The Research Institute for Nature and Forest (INBO) investigates the impact of offshore wind farms on seabirds according to a Before-After/Control-Impact design (BACI). Hence we compare seabird densities before and after the wind farms become operational, in the wind farm area itself as well as in a control area. Based on our current knowledge on the distribution of seabirds on the BPNS, suitable control areas have already been delineated for the future wind farms at the 'Thorntonbank' and 'Blighbank'. Each month, INBO performs seabirds counts from the research vessel 'Zeeleeuw' along three monitoring routes through these areas.

In 2008, C-Power started up the construction of the wind farm at the 'Thorntonbank', and currently six wind turbines are in operation. We investigated if we could already discern effects on the occurrence of seabirds. The research results showed a strong decrease of auks in the impact area. However, a comparable change was seen in the control area. The opposite was true for Little gull. In both the impact and control area Little gulls appeared to be more common in 2008 compared to the reference period 2005-2007. We conclude that the observed changes are not induced by the presence of the wind turbines, but result from a natural interannual variation in seabird densities.

While this part of our research focuses on displacement and disturbance effects caused by wind turbines, in upcoming years we will also study the collision risk. Through radar research we will be able to accurately assess the number of birds flying through the wind farm. Combined with modelling, this will allow us to make estimations of the number of collision victims.

DESIGN OF RUBBLE MOUND BREAKWATERS – MODELLING OF WAVE-INDUCED FLOW IN A POROUS STRUCTURE

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Permeable coastal structures such as rubble mound breakwaters are of great interest in coastal and harbour engineering. These structures are capable of protecting a coastal area from excessive wave action by dissipating the incident wave energy through friction inside the porous body of the structure. When studying the structural response of rubble mound breakwaters to wave loading, the knowledge of pore pressures and related wave attenuation inside the porous structure is important since the pore pressures affect most responses, such as wave run-up, wave overtopping, reflection, transmission and the hydraulic and geotechnical stability of the breakwater. Although designing and constructing a stable rubble mound structure continues to rely heavily on past experience and physical modelling, the development and use of numerical models to analyze the structural response of the breakwater to wave loading is growing rapidly nowadays. The main part of the present work consists of the development of a numerical wave flume, using a general Applicable CFD-solver (FLOW-3D®), customized with newly developed modules for wave generation and wave absorption at the boundaries of the flume. To validate the performance of the numerical wave flume with regard to the interaction of the porous structure with waves, reliable pore pressure data are needed, either from prototype measurements or from physical model tests. In the scope of this work, the pore pressure distribution has been determined within the core of a physical model, built at scale 1:30 in the wave flume of Ghent University. The model is a typical example of a conventional layered breakwater, consisting of a core, a filter and an armour layer. In this model, pressure gauges were installed at several locations throughout the cross section. An important outcome from the pressure measurements concerns the pressure decrease through the armour and the filter layer. The degree of dissipation can be represented by the dimensionless 'reference pressure', the ratio between the pressure height oscillation and the incident wave height. From large-scale (1:5) experimental tests (Oumeraci and Partenscky, 1990) it was concluded that the reference pressure can be regarded as approximately constant along the interface core-filter and independent of the wave steepness (i.e. the ratio of wave height to wave length). The present tests provide more detailed data and show a stronger correlation between the reference pressures and the wave steepness. A first preliminary comparison with numerical simulations of the same test setup confirms this and suggests that scale effects play a role. The dissimilarity between the different models regarding air entrainment (turbulent flow dissipation) and viscous forces affects the energy dissipation through armour and filter layer, causing a different value of the reference pressure in both scale models.

An exponential decrease in pressure oscillation along the direction of wave incidence was observed, confirming the applicability of the theoretical model (Burcharth *et al*. ,1999) which accounts for the pressure distribution.

Future work will consist of further development of the numerical model and an extensive validation with results from physical model tests and prototype measurements performed at the Zeebrugge western breakwater (Troch, 2000).

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IDENTIFICATION OF THE MATING TYPE LOCUS IN PENNATE DIATOMS

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Diatoms form one of the most diverse and productive groups of algae, with an estimated 200,000 species responsible for more than 1/5 of the worlds primary production. They are also very interesting from a biotechnological point of view, with huge potential for the production for high-value bioproducts such as lipids, pigments and biofuels. One of the main bottlenecks for diatom cultivation lies in their life cycle. Diatoms have a unique diplontic life cycle characterized by gradual size reduction which ultimately leads to programmed cell death. The latter, which can lead to loss of strains and cultures, can only be avoided by sexual reproduction, which enables cell size restitution via a specialized type of zygote, called the auxospore. This essential link between the cell size recovery and sexual reproduction is unique for diatoms. Until now however, almost nothing is known about the molecular base of sexual reproduction and sex determination in diatoms. Most sexual determination systems are genetically determined by a specific region, the so-called mating type (MT) locus.

We are currently identifying the sex determination system and making a genetic map of the pennate diatom *Seminavis robusta* by performing a bulked segregant analysis (BSA) assay in combination with AFLP. So far, we found AFLP markers which were totally and not totally linked to the mating type locus in *Seminavis*. We will also perform a functional characterization of the MT genes by RT-PCR and genetic transformation. The evolution of the selected MT locus genes will be studied in related diatom species.

A PROTOCOL FOR CLASSIFYING ECOLOGICALLY RELEVANT MARINE ZONES, A STATISTICAL APPROACH

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Mapping ecologically relevant zones in the marine environment has become increasingly important. Biological data are however often scarce and alternatives are being sought in optimal classifications of abiotic variables. The concept of 'marine landscapes' is based on a hierarchical classification of geological, hydrographic and other physical data. This approach is however subject to many assumptions and subjective decisions.

An objective protocol for zonation is being proposed here where abiotic variables are subjected to a statistical approach, using principal components analysis (PCA) and a cluster analysis. The optimal number of clusters (or zones) is being defined using the Calinski-Harabasz criterion. The methodology has been applied on datasets of the Belgian part of the North Sea (BPNS), a shallow sandy shelf environment with a sandbank-swale topography.

The BPNS was classified into 8 zones that represent well the natural variability of the seafloor. The internal cluster consistency was validated with a split-run procedure, with more than 99% correspondence between the validation and the original dataset. The ecological relevance of 6 out of the 8 zones was demonstrated, using indicator species analysis.

The proposed protocol, as exemplified for the BPNS, can easily be applied to other areas and provides a strong knowledge basis for environmental protection and management of the marine environment. A SWOT-analysis, showing the strengths, weaknesses, opportunities and threats of the protocol was performed.

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GENETICS IN MARINE ECOTOXICOLOGY: A NORTH SEA SHRIMP (*CRANGON CRANGON* L.) DNA MICROARRAY

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C. crangon (Crustacea; Decapoda; Caridea) is one of the most common and economically important crustacean species of the European coastal waters and estuaries. While crustaceans are believed to be extremely sensitive towards xenobiotic endocrine disruption, practically no scientific effort has focused on the effects of pollution on brown shrimp. Generally, investigation of endocrine disruption in natural populations is hampered by the high diversity of potential endocrine disrupting compounds (EDCs), which may have synergistic as well as individual physiological effects, and the complexity of the endocrine system itself. Currently, ecotoxicological research has placed its hope in the tremendous potential DNA microarray technology for screening EDCs and their effects on biota. A DNA microarray consists of an arrayed series of generally thousands of microscopic spots of gene specific DNA fragments (probes) that are used to hybridize the fluorescent labelled cDNA sample (target). As such, a microarray actually provides a ''snapshot'' of which genes were expressed within the organism (or tissue) at one point in time. As no usable genetic information was available for a *C. crangon* microarray, we opted to isolate gender-specific *C. crangon* cDNA libraries through suppression subtractive hybridization-PCR. Simplified, this technique relies on the removal of dsDNA formed by hybridization between two samples (in this case male and female shrimp cDNA), retaining the differentially expressed genes. Here we report the ongoing isolation and sequencing of these *C. crangon* genes and spotting of the *C. crangon* microarray. Currently, the *C. crangon* genes isolated include genes encoding cuticular and cytoskeletal related proteins (actins, myosin, cathepsins,...), energy metabolism related proteins (cytochrome c oxidase, ATP synthase, sugar binding proteins,...), antimicrobial proteins (crustin, carcinin,..) and reproduction related proteins (vitellogenin, male reproductive related protein a,...). In the immediate future this molecular tool will be used to screen for a broad range of endocrine disrupting effects in laboratory exposed as well as wild-caught shrimp.

COASTAL ANTARCTIC LAKES: MICROBIAL BIODIVERSITY HOTSPOTS AND ARCHIVES OF PAST ENVIRONMENTAL CHANGES

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Antarctic oases are relatively small ice-free regions situated at the boundary between the continental ice sheet and the Southern Ocean. With a few exceptions, Antarctic lacustrine ecosystems are largely confined to these oases. Over the past 10 years, we studied the microbial biodiversity in coastal Antarctic lakes and used biological and geochemical proxies in their sediments to study past changes in climate along a latitudinal gradient, ice sheet and sea-ice dynamics, and relative sea level.

Microscopy and the application of molecular-phylogenetic techniques to cultured and uncultured diversity revealed a high number of endemics among cyanobacteria, bacteria, green algae, and diatoms. Calibration of molecular phylogenies also suggested that several clades have an ancient evolutionary history within the Antarctic continent, possibly dating back to 330 Ma. In a broader context, this work has at least two important implications. First, it refutes the long-standing 'ubiquity hypothesis', which states that for microorganisms 'everything is everywhere but the environment selects'. Factors regulating the distribution and taxonomic turnover amongst microorganisms are thus not very different from those shaping communities of higher organisms, implying that microbial ecology further converges with the general ecological theory. Second, these results contradict the 'recolonization hypothesis' which states that expanded ice-cover during Neogene and Late Pleistocene glaciations has resulted in an almost complete extinction of biota in Antarctica, followed by extensive colonization after glacial maxima. In contrast, our findings are consistent with the 'glacial refugia hypothesis' and call for a revision of the existing ice sheet models, which suggest that most or all currently coastal ice-free sites were covered with ice during glacial maxima.

Paleolimnological analysis of sediment cores from several coastal ice-free regions revealed the presence of two distinct warm periods during the past 10,500 years BP. An Early Holocene warm period is coincident with the retreat of the ice sheet from the continental shelf in several areas of around Antarctica. During the Mid Holocene a marine climate optimum with less extensive sea ice cover is present in records from Maritime Antarctica and some east Antarctic records. This Mid Holocene Warm period is clearly out of phase with a well-defined temperature excursion in terrestrial records from Maritime Antarctica during the late Holocene. An inventory of the autotrophic community structure using microscopy, fossil pigments and fossil DNA in sediment cores indicates that the recent anomalies have already affected Antarctic aquatic ecosystems and their biota. In some regions, the taxonomic turnover during the past few decades passed the threshold of natural variability experienced over the past 6000 years. Dating the transitions in sediment cores from isolation lakes allowed us to develop relative sea level curves (RSL) for different regions in East and West Antarctica. These RSL are used to calculate the contribution of the Antarctic ice sheets to post glacial sea level rise. Our results indicate the East Antarctic Ice Sheet – the largest remaining ice sheet on Earth - reacted to Holocene climate variability, making it a likely contributor to future global sea level changes.

HOVERCRAN – HOVERING PULSE TRAWL FOR SELECTIVE *CRANGON* FISHERY

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The brown shrimp (*Crangon crangon*) fishery is a widespread human activity in the coastal zones of the North Sea. The popularity of the brown shrimp as a delicacy makes this fishery and its related food processing industry of great commercial importance. The fishery itself is carried out by an international fishing fleet of approximately 600 vessels, operating mainly off the coasts of Denmark, Germany, the Netherlands, Belgium and the east of England. Total landings can mount up to 35,000 tons a year. The discarding practices associated with the brown shrimp fishery have been regarded as a problem for many years. The poor selectivity of the small meshed nets produces very high amounts of unwanted by-catch. The fact that the fishery itself is carried out in vulnerable areas like coastal zones and estuaries, often important nurseries for a wide range of marine species, intensifies this problem. Especially the by-catch of young flatfish, like sole and plaice has a significant influence on the commercial fish stocks. An additional problem facing the fishery is the bottom contact caused by the heavy bobbin rope used to startle the shrimp.

Current technical modifications for by-catch reduction in the *Crangon* fishery, like sieve nets, focus on catch separation or filtering after species have entered the trawl. Damage incurred by contact, or stress caused during the capture and escape process may lead to higher discard and escapee mortality. Sieve nets are satisfactory effective at reducing by-catch of relatively large fish of all species, but less so at reducing 0 group plaice and sole, which make up a large fraction of the by-catch. Because of these drawbacks alternative measures are needed.

The HOVERCRAN is a new type of fishing gear that aims at stricter selectivity and reduced seabed contact. The fundamental idea is to replace the heavy bobbin rope with electrodes, in order to use electrical pulsation as a stimulation alternative. Research by ILVO showed that the use of a specific electric field close to the sea floor induces a startle response in shrimp and leaves other organisms untouched. Herein lays the selective fishing potential of this alternative technique. In addition, exposure and survival experiments, carried out in cooperation with the Ghent University, have shown that the use of these pulses, low in frequency and voltage, has no significant effects on fish and invertebrate species.

Preservation of the commercial catches and the reduction of discards and seabed contact are the decisive criteria in the evaluation of the HOVERCRAN. Extensive testing of the prototype on a commercial shrimp cutter, by direct catch comparison with a standard shrimp trawl, revealed important and hopeful results. First and foremost could be shown that at least as much shrimp can be caught with the new technique in comparison with the traditional gear. On top of that, an average by-catch reduction of 35% in volume is a major step forward in the discard issue of the brown shrimp fishery. Reduction of bottom contact by 75% is a radical change in the environmental impact issue.

ELECTRIC POWER FROM OCEAN WAVES – IMPROVING THE PERFORMANCE OF OVERTOPPING DEVICES

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The global economy is growing rapidly, involving an increased energy demand. Conventional energy sources are limited and imply CO2-emissions that are harmful for the natural environment. A global revolution in the use and supply of energy is required (International Energy Agency, 2008). Wave energy - i.e. energy from ocean waves - is not yet economically competitive although it holds the same possibilities as hydropower and wind energy (Pontes *et al.*, 1998; Brooke, 2003). Extensive research is required to improve the performance of wave energy converters (WECs) (Brooke, 2003).
One basic type of WECs links up with the expertise of the Department of Civil Engineering at Ghent University on breakwaters: overtopping devices. These are based on wave run-up on a slope and overtopping into a reservoir that is emptied into the sea through a turbine. Both floating structures for deeper water (e.g. Wave Dragon, Denmark) and fixed constructions nearshore [e.g. built in a breakwater, Seawave Slot-Cone Generator (Norway)] are under development. For overtopping WECs, the physical process of wave overtopping determines the efficiency of the energy conversion. When the volume that overtops into the reservoir - wave by wave - is known, the turbine/control strategy can be adjusted accordingly to achieve an optimal efficiency of the device. A time-domain approach is required to predict the overtopping volumes wave by wave, based on real-time measurements of parameters of incident waves in front of the device.
Physical experiments have been carried out by the first author in a wave flume at Aalborg University. The tested device consists of a fixed single slope extending to the bottom of the flume, with low crest freeboards. The experimental test set-up was specifically designed so that derivation of individual overtopping volumes from waves was possible. The results for the average overtopping discharges are in good agreement with the state-of-the-art empirical formulae and small adjustments have been proposed. The results for the individual overtopping volumes are gathered and a first comparison with the numerical results shows the numerical tool gives realistic results for the overtopping volumes (Victor *et al.*, 2009). This numerical tool consists of a numerical wave flume in FLOW3D® (www.flow3d.com), a general applicable CFD-solver, which is based on the Navier-Stokes equations and incorporates a Volume Of Fluid (VOF) method to track the free surface. The code is customized by adding code for wave generation and wave absorption. The numerical wave flume gives promising results, and is under further development (wave generation). Many different geometries can be easily tested with this numerical tool in order to set up the prediction strategy for a variety of structures. Currently, digital filter techniques are investigated to link the incoming wave characteristics to individual overtopping volumes based on the physical experiments.

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MODELING FLOCCULATION PROCESSES: CONTINUOUS PARTICLE SIZE DISTRIBUTION METHOD

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The flocculation process of cohesive sediment suspended in water consists of aggregation of the fine particles and breakup of the large flocs. The population balance equation (PBE) is a statement of continuity for particulate systems, and it is used to model the flocculation process and predict the particle size distribution (PSD). Different numerical methods are developed to solve the PBE, however most of the methods have difficulties in representing the continuous PSD or improving computational efficiency. In this research, the B-spline FEM and Galerkin FEM are studied to simulate the continuous PSD. The B-spline FEM solves the PBE over the whole domain, which is truncated to finite domain; the open non-uniform B-splines are used as basis function to approximate the PSD; the curve of PSD is required to be smooth enough. The Galerkin FEM discretizes the PBE on each sub-domain (the whole domain is split to several sub-domains), and it is used to solve less-smooth problems. The adaptive technique is applied to readjust the computational grid (particle size domain) to improve computational efficiency and the accuracy, and it is also applied in varied time step to get suitable time step to improve the stability. The analytical solutions of the PBE in special conditions and the experimental data are used to validate both B-spline FEM and Galerkin FEM, and the results are compared with that of the classical DPBE method. It shows that both B-spline FEM and Galerkin FEM can solve the PBE and simulate continuous PSD accurately and efficiently.

TOP-DOWN CONTROL CAUSES COLLAPSE OF A SELF-ORGANIZED LANDSCAPE ON INTERTIDAL MUDFLATS

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During spring, intertidal flats can exhibit strikingly regular spatial patterns of diatom-covered hummocks alternating with almost bare hollows. These patterns develop due to a strong interaction between diatoms and sedimentary processes and are a seasonal phenomenon. Previous research showed that intertidal flats exhibiting spatial patterns have higher diatom concentration and more sediment accretion compared to intertidal flats lacking spatial patterns. Patterns are being most prominent during April and May, followed by a relatively sudden collapse in June to a homogeneous tidal flat characterized by a much more erosive regime. This rapid shift co-occurs with a gradual increase in herbivore numbers. We hypothesize that herbivore grazing later in the season disrupts diatom-silt interaction and leads to a collapse of these self-organized patterns. Field experiments confirmed the hypothesis that the collapse of this self-organized landscape is driven by benthic macrofauna that disrupt the interaction between diatoms and sediment dynamics. Our results show that benthic herbivores affect the formation of the geomorphological landscape of intertidal flats. Moreover, herbivores rapidly shift the self-organized system from a spatially patterned state, which is highly productive, into an erosive state with almost bare sediment. Therefore, benthic macrofauna not only affect landscape formation on intertidal flat, but also changes ecosystem functioning on the entire intertidal flat.

PHYSIOLOGICALLY BASED PHARMACOKINETIC MODELS FOR LIFETIME EXPOSURE TO PERSISTENT ORGANIC POLLUTANTS BY HARBOUR PORPOISES (*PHOCOENA PHOCOENA*): DATA FROM THE PAST, MODELS FOR THE FUTURE?

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Physiologically based pharmacokinetic (PBPK) models are a mathematical and computational approach of reality. Based upon the physiology of the organism and the biochemical properties of the selected compound, these models provide insights into processes such as the absorption, distribution, metabolism and excretion (ADME) of the chemical. PCBs (polychlorinated biphenyls) are banned since the 1970s, but are still a threat to wildlife, including marine mammals, because of their persistence in the environment. PBPK models for PCBs have been developed for rats, mice and humans, but are scarce for marine mammals and no PBPK models are available for any chemical in harbour porpoises (*Phocoena phocoena*) so far.

Harbour porpoises are common cetaceans in European waters. In the last decade, observations showed that harbour porpoises are moving from more northern waters (Norway) to the south, reaching high densities in the North Sea (Belgium, Germany, the Netherlands, UK). They are known to accumulate high concentrations of chemicals because of their long life spans and their top position in the food chains. These animals are suggested to have low metabolic capacities for PCBs (and possibly other chemicals as well) compared to other top predators, such as the harbour seals. This makes them particularly vulnerable and sensitive to pollution. All these factors require regulations about the use, production and release of chemicals, in order to maintain the current population of harbour porpoises in the North Sea. Assessing the health situation of harbour porpoises in the North Sea (and other parts of the world) now and in the future requires a more profound knowledge about the kinetics of chemicals inside their body. In the present study, a preliminary PBPK model for CB 153, as one of the best known pollutants in marine mammals, in harbour porpoises was developed and evaluated. The model consists of 4 compartments, namely liver (metabolism), blubber or adipose tissue (storage), kidney, and brain (neurotoxicity) and was developed using Berkeley Madonna software. All physiological/biochemical parameters were found in the literature. The intake of CB 153 was from milk from birth to 6 months and after weaning, principally from fish as a food source. The model was evaluated using existing datasets from the literature and data from own analyses performed with GC-MS. Preliminary computer simulation results were consistent with the available data so that this PBPK model is capable of simulating the bioaccumulation of CB 153 during the entire life span of approximately 20 years of the harbour porpoises. It is believed that a well constructed PBPK model is a good reflection of reality and that the model can be used as a non-invasive and non-destructive tool for predicting pollution in harbour porpoises or perhaps in marine mammals in general.

THE FIN WHALE FROM ANTWERP: A TOXICOLOGICAL PERSPECTIVE

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Although fin whales (*Balaenoptera physalus*) are more common in the open seas throughout the globe, occasional stranding events of individuals may occur in the North Sea. On Monday September 21st, 2009, a fin whale was dragged in to the harbour of Antwerp after a ship collision. The whale was an adult female of about 20 metres long and she was the main talk of the town for more than two days. Hundreds of people went down to the beach of St. Anna to take a glimpse of the giant animal. However, some things were not visible from the outside. For fin whales, maximum ages of up to 80-90 years have been reported. They feed on a wide variety of organisms, depending on availability, season and locality. In the Northern Hemisphere, they are known to prey upon krill, fish (such as herring, mackerel and whiting) and sometimes even small squids. In marine mammals in general, the principal source of input of contaminants, such as PCBs (polychlorinated biphenyls), PBDEs (polybrominated diphenyl ethers, pesticides (DDT and metabolites) and metals (mercury, cadmium,...), is fish and concentrations of pollutants tend to increase with age. Data of chemicals in fin whales are scarce. Harbour porpoises however, with a maximum age of 20 years and maximum size of 2 metres, accumulate considerable and maybe even toxic loads of pollutants in their bodies. So what about the toxicological condition of an adult whale of 20 metres long? To find an answer to this question, the present study aimed to analyse persistent organic pollutants, such as PCBs, PBDEs and pesticides (DDT and metabolites), in tissues of the adult female fin whale from Antwerp.

OCCURRENCE OF PERFLUORINATED COMPOUNDS IN WATER, BIOTA AND SEDIMENT IN THE BELGIAN MARINE ENVIRONMENT

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Perfluorinated compounds (PFCs) are an important new class of global environmental contaminants. Due to their specific surfactant properties, PFCs have been extensively used in the past in a wide variety of applications. Consequently, recent monitoring studies have reported their widespread occurrence in the environment. The objective of this study was to quantify the occurrence of thirteen PFCs in water, sediment and biota samples from the North Sea and Scheldt Estuary. In the water samples, perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) were found to be the most abundant PFCs with levels up to 24 and 39 $ng.l^{-1}$. Five different PFCs were found in blue mussels (*Mytilus edulis*) and Pacific oysters (*Crassostrea gigas*) used in (exposure) cage experiments in Belgian coastal harbours: PFOS was measured in most samples at concentrations up to $19ng.g^{-1}$ while PFOA, perfluorodecanoic acid (PFDA), perfluorohexanoic acid (PFHxA) and perfluorooctane sulfonamide were found at concentrations lower than $5ng.g^{-1}$. Similar results were obtained from analyses of the brown shrimp (*Crangon crangon*) collected in the North Sea. Analysis of sediment and suspended matter resulted in the detection of seven different PFCs at concentrations below $20ng.g^{-1}$. This study confirms the ubiquitous character and occurrence of PFCs in the various environmental compartments of the Belgian coastal system.

WAVE FLUME AND WAVE BASIN DESIGN OF COASTAL STRUCTURES IN FLANDERS

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The hydraulic design of coastal structures is a complex task. In the past decades physical scale models often were the only possibility to verify the design. Nowadays computer models are very powerful but some physical processes still cannot be calculated accurately. Therefore physical scale models are still intensively used as design tools in almost all major coastal engineering projects.

Since the 80's of the previous century Flanders Hydraulics Research has invested in 3 wave facilities: two wave flumes for two-dimensional scale models and one wave basin for three-dimensional scale models. The dimensions (L x W x D) of the small wave flume are 41mx0.7mx0.86m, the large wave flume 70mx4mx1.4m and the wave basin 17.5mx12.2mx0.45m.

Flanders Hydraulics Research has performed a lot of studies in the past decades. This abstract and the accompanying poster give a limited overview of some scale models dealing with research on coastal structures:

- Stability of the Zeebrugge breakwaters.
- Stability of 'Binnenrede' in port of Zeebrugge.
- Wave forces on wind turbines on top of the Zeebrugge breakwater.
- Wave run-up at Zeebrugge breakwater (Opticrest – optimisation of crest level design).
- Hydraulic stability of the beach of Oostende.
- Current velocities at the entrance of the port of Oostende.
- Hydraulic stability of a new breakwater in Oostende.
- Wave overtopping at a new seadike in Oostende.
- Wave forces on a piled pedestrian walkway on top of the new breakwater in Oostende.
- Wave penetration in the port of Oostende.
- Wave overtopping at Zeeheldenplein Oostende.
- Hydraulic stability (waves + current) of beach profiles in Knokke-Zoute.
- Comparative research on the hydraulic stability of different armour units.
- Wave forces on underwater screens.
- Wave overtopping at Ostia yacht harbour (Clash – crest level assessment of coastal structures).
- Wave overtopping at sea dikes with broad crest, crest with roughness, crest with broad sand berm in front.

EFFECTS OF DREDGED MATERIAL DISPOSAL ON BENTHIC AND DEMERSAL FAUNA

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Continuous dredging is needed to conserve the maritime access channels to the Flemish harbors and to maintain the shipping depth in these harbors. The dredged material that fulfils a number of sediment quality criteria (varying between 8 and 15 million tons dry matter per year the last decennium) is disposed at 5 dumping sites within the shallow Belgian coastal zones: S1, S2, Zeebrugge Oost, Oostende and Nieuwpoort.

Within the framework of an ongoing monitoring and research program, the impact of dredge disposal on the bottom fauna (macrobenthos, epibenthos and demersal fish) and the physical and organic composition of the sediment is evaluated.

Results for the period 2007-2008 indicate a negative impact on the different components of the macrobenthic communities, mainly correlated with the intensity of dumping. At dumping sites S1 and Zeebrugge Oost, where >80% of the dredged material is dumped, the benthic characteristics were significantly different from the control zones. Dumping site S1 is characterized by a large heterogeneity in sediment characteristics (mud, fine and coarse sand in different proportions), partly as a result of the intensive dumping activities in that area. However, the observed differences between the control and impact zones for dumping site S1 are hampered by the natural heterogeneity in the sediment related to the depth gradient in and around that area. Dumping site Zeebrugge Oost and its control area are both characterized by very poor benthic communities. Still, the impact of the dumped material on the macrobenthos is temporal and not necessarily irreversible. At the other sites (S2, Oostende, Nieuwpoort) the macrobenthic communities showed no clear impact.

So far, no significant correlations were found with the dumping activity when looking at the species composition of the epibenthos and demersal fish communities for the period 2007-2008. A negative impact cannot be shown or is largely obscured by the difference in geographical location of the 5 dumping sites, which is the main structuring factor for these faunal components.

HOW OLD ARE YOU?

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To determine the status of the stock and formulate the advice for ICES and the European Commission, the scientists need to know the age of the fish and the age composition of the stock. The age of a bony fish can be determined using their otoliths. Otoliths are calciferous structures which keep growing throughout the life of the fish. During summer they grow faster than during winter. As a result, the otoliths grow a small, translucent ring during winter and a thick, opaque ring during summer. By counting the opaque rings, an estimation of the age of the fish can be made! Practically, the sagittae are used for age determination as they are the biggest of the 3 types of otoliths. These otoliths, 2 per fish, each lie in a fluid filled chamber in the back of the fish's head, under the ear. Once dissected out of the fish and arrived in our lab, the otoliths are cleaned in water. The otoliths of *Pleuronectes platessa* (European plaice) are read at this stage as a whole otolith, but for other species of fish, the otoliths need further treatment to distinguish the difference between the winter and summer rings more easily. *Solea solea* (sole), *Psetta maxima* (turbot), *Scophthalmus rhombus* (brill), *Gadus morhua* (cod) and *Merlangius merlangus* (whiting) are the other species read as they are the most important commercial species for the Belgian fisheries. One of the sagittae of fish from these species, is embedded in black resin. The embedded otoliths are cut through the nucleus in very thin sections of 0.5mm thickness, using a diamond cutting machine. Depending on the species, the sections might need to be coloured with neutral red before they are fit for reading. The sections (or whole otoliths in the case of plaice) are then placed under a binocular microscope and digitalized, after which the digital images are marked and analysed. All calcified structures are archived, as well as the interpreted images. These are referenced in a national database, recording all data related to the fish and its capture.

THE PROCEDURE OF DETERMING AGE IN FISH

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In studying the population dynamics of fishes, the age estimation of a fish is one of the most crucial parameters to be able to estimate the status of a stock. To know more about the population dynamics of a stock, knowledge about the age structure in the stock is required. As the spawning period is known, fishes can be classified into certain age groups (age 0, age 1, age 2, age 3, ….). In order to be able to exploit the stocks in a sustainable way, the European Commission requires a huge set of data supplied by all member states with an active fishing sector. This data collection is described in the Data Collection Framework (DCF) EC no. 199/2008. As such, according to the Belgian data collection program, an average of 25,000 otoliths are analyzed on a yearly basis in the otolith lab of ILVO.

At the otoliths laboratory of ILVO, the age of individual fish is determined for 7 commercially important species for the Belgian fisheries sector i.e. *Pleuronectes platessa* (European plaice), *Solea solea* (sole), *Psetta maxima* (turbot), *Scophthalmus rhombus* (brill), *Gadus morhua* (cod) and *Merlangius merlangus* (whiting), *Melanogrammus aeglefinus* (haddock). Plaice and sole are the main target species for the Belgian fleet. The age reading procedure is specific for each species although they follow a general basic principle: counting the annual rings on the otoliths. In the process of establishing a uniform quality control system and implementing the ISO norm 10725, protocols are developed per species in order to optimize the technique of preparation as well as the analysis of ages. These protocols describe every step in the process: from cutting out the otoliths up to analyzing the data. In this poster, the characteristics and techniques for age determination of these species are explained. The otoliths of each species are also portrayed which shows the wide variety in size, shape and nature of the ring pattern.

APPLICANTS
VLIZ Thesis Awards Marine Sciences 2009

GEMENGDE BEGRAZING MET EEN GRAZER (PONY) EN EEN VARIABELE ETER (GEIT): WAT IS HUN FOERAGEERSTRATEGIE IN EEN OMGEVING GEDOMINEERD DOOR STRUIKGEWAS?

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Verruiging is een algemeen probleem in duingraslanden aan de Belgische kust (Provoost *et al.*, 2002; Hoffmann *et al.*, 2005;). Dit kan leiden tot een verlies van biodiversiteit omwille van de dominantie van enkele grassoorten of door een dichte begroeiing van struiken (Veer en Kooijman, 1997; Isermann *et al.*, 2007). Verschillende grote grazers werden ingezet in een poging deze expansie van dominante soorten tegen te houden en een structurele diversiteit in de vegetatie te bekomen (Hoffmann *et al.*, 2005). Er is echter nood aan kennis over welke diersoorten geschikt zijn voor de gestelde beheerdoelstellingen (Milotic *et al.*, 2008). Een aantal monitorprojecten zijn reeds achter de rug maar een probleem hierbij is dat de herbivoren vaak geplaatst zijn in verschillende duingebieden en de resultaten dus niet objectief vergelijkbaar zijn. Eén uitzondering aan de Belgische kust betreft de Westhoek, waar men koos voor een gemengde begrazing met pony's en runderen (Lamoot *et al.*, 2005). Deze combinatie van herbivoren voldeed nog niet aan de verwachtingen aangezien ze enkel geschikt bleken om de verruiging met dominante grassen in te tomen maar niet de opslag van struiken. Echter, omwille van hun verschillend foerageergedrag ontstond er meer nood aan resultaten over niche differentiatie tussen verschillende grote herbivoren. Deze opportuniteit ontstond in het VNR 'de Zwinduinen en –polders'. Dit reservaat kampt eveneens met verruiging van gras en struweel waardoor besloten werd pony's en geiten in te zetten (Zwaenepoel *et al.*, 2007).
Er werd verwacht dat beide soorten differentiatie in gedrag zouden vertonen omdat pony's beschreven worden als colon fermenterende grazers en geiten als herkauwende variabele eters, beide een verschillend foerageerstrategie vertonend (Hofmann, 1989). In deze studie werd onderzocht of beide herbivoren verschillen in i) tijd budget in foerageergedrag ii) gebruik van habitattypes (grasachtige habitat, struweel en bos), iii) gebruik van vegetatie-eenheden binnen de grasachtige habitat iv) dieetsamenstelling en of er een verschil optreedt doorheen de dag en tussen seizoenen in voorgaande punten.

Het foerageergedrag van de dieren werd bestudeerd door 'instantaneous sampling' waarbij elk dier om de 15min geobserveerd werd. Anderzijds werd 'continuous sampling' toegepast op niet graasgedrag. Hierbij werd het optreden van het betreffend gedrag continu genoteerd. Deze methodes zijn gebaseerd op Altmann (1974) en Lamoot *et al.* (2005). Voor de habitattypes werd een onderscheid gemaakt tussen: 'grasachtige habitat', 'struweel', 'bos' en ' ander'. Binnen de grasachtige habitat werd 'grasland', 'mosduinen en open vegetatie', 'ruig grasland' en 'grasland met struweelinvasie' onderscheiden. Plantensoorten tenslotte, werden onderverdeeld in: 'kruiden', 'grassen', 'houtige planten', 'ander' of 'mix'.

Data werden verzameld bij daglicht in de herfst (september/oktober/november) en in de winter (december/januari/februari). Observatieperiodes van 2x4u per sessie werden uitgevoerd. In totaal werden 29 sessies in de analyse opgenomen, 16 in de herfst en 13 in de winter. Data werden bijeengebracht in een bestaande MS Access 2003 database van het Instituut voor Natuur- en Bosonderzoek en die specifiek ontwikkeld werd voor dit type van diergedragwaarnemingen in functie van begrazingsbeheer. Deze data werden verwerkt met SAS 9.2 en Statistica 7. Hierbij werden alle proportionele data geanalyseerd met een veralgemeend lineair gemengd model (GLMM) met 'individu' telkens als random factor; voor continue data werd gewerkt met een algemeen lineair model. Data voor graasgedrag in een bepaalde habitat of vegetatietype werd getransformeerd, gebruikmakend van 'Jacobs' (1974) index of selection' en geanalyseerd met een GLMM. Deze index geeft aan of een diersoort een preferentie of aversie vertoont voor deze habitat of vegetatietype. Voor dieetsamenstelling werd een DCA toegepast met behulp van Canoco for Windows 4.5. Positionele data werden verwerkt met ArcGIS 9.2. Tenslotte werden Simpson's diversity index (niche breedte) en Kulczinski's index (niche overlap) berekend, gebaseerd op Lamoot *et al.* (2005) en Menard *et al.* (2002).

Geiten foerageerden proportioneel langer dan pony's ten opzichte van andere activiteiten maar beide diersoorten spendeerden gemiddeld meer tijd aan foerageren in de winter dan in de herfst. Indien een onderscheid werd gemaakt tussen voor- en namiddag dan trad er geen verschil op voor

geiten. Pony's graasden meer in de voormiddag en minder in de namiddag in de winter vergeleken met de herfst.

Het graasgedrag in een bepaalde habitat of vegetatietype werd bestudeerd ten opzichte van de beschikbaarheid van de betreffende habitat of vegetatietype om vergelijkbare resultaten met andere studies te bekomen. Daarvoor werden deze data getransformeerd, gebruikmakend van Jacob's index van selectie. Deze index gaf aan dat de pony's duidelijk een preferentie vertoonden voor de grasachtige habitat in beide seizoenen terwijl de geiten deze habitat enkel verkozen in de herfst, in de winter foerageerden de geiten liever in het bos. Dit gaf al een eerste aanwijzing naar het flexibel graasgedrag van een variabele eter naargelang de omstandigheden. Binnen de grasachtige habitat verkozen beide diersoorten duidelijk het ruig grasland en was er aversie voor de andere vegetatietypes, behalve voor graslanden begraasd door de pony's in de herfst. Het is niet duidelijk waarom er bijvoorbeeld een afkeer optreedt voor graslanden aangezien deze habitat duidelijk verkozen wordt door pony's in andere studies (Lamoot en Hoffmann, 2004, Lamoot *et al.*, 2005). Echter, er dient opgemerkt te worden dat elk studiegebied gekenmerkt wordt door specifieke duinhabitats en ruimtelijke heterogeniteit waardoor de beschreven habitat- of vegetatietypes niet noodzakelijk precies dezelfde floristische samenstelling vertonen.

Wanneer dieetsamenstelling bestudeerd werd, trad er eveneens een verschil op tussen beide diersoorten. Zoals reeds bevestigd in andere studies, zijn pony's grazers en voeden ze zich voornamelijk met grasachtige planten (Cosyns *et al.*, 2001; Hoffmann *et al.*, 2005; Lamoot *et al.*, 2005,). Opnieuw was er een indicatie van het variabeler foerageergedrag van geiten. Geiten aten min of meer een gelijke hoeveelheid kruiden en grasachtige planten maar ook houtachtige planten vormden een belangrijk aandeel van hun dieet. Dit was verder afhankelijk van het habitattype waarin ze foerageerden. Zoals andere studies reeds bevestigden, suggereren we dat geiten hun foerageergedrag aanpassen naargelang de beschikbaarheid en kwaliteit van de vegetatie (Barosso *et al.*, 1995; Odo *et al.*, 2001; Aharon *et al.*, 2007, Celaya *et al.*, 2007).

Algemeen was de nichebreedte van beide diersoorten laag, wat een homogeen habitatgebruik aangeeft, te wijten aan de lage habitatdiversiteit in het studiegebied. Echter, niche overlap was ook meestal laag, wat dan weer een indicatie is voor een verschillend habitatgebruik en foerageergedrag van beide herbivoren.

Gebaseerd op voorgaande resultaten, suggereren we dat er een verschil is in foerageergedrag tussen de pony's als colon fermenterende grazers, en geiten, als variabele eters en herkauwers. Echter, er is een gebrek aan kennis over de beschikbaarheid van de vegetatie op soortniveau. Dit kan bovenstaande uitkomsten beïnvloeden aangezien er wel aangetoond wordt hoeveel een diersoort van een bepaalde plantensoort zal eten maar dit geeft geen informatie over de preferentie voor deze plantensoort of de impact erop. Daarenboven zouden additionele observaties, en met name lente en zomersessies, nog beter het verschil in foerageergedrag tussen beide diersoorten uitwijzen. Bovendien zou verder monitoren een besluit kunnen vormen over de impact van gemengde begrazing met een colon fermenterende grazer en een variabele eter en herkauwer op een omgeving gedomineerd door struikgewas.

MONITORING WETLANDS ALONG THE WESTERN-GREEK BIRD MIGRATION ROUTE USING LANDSAT AND ASTER SATELLITE IMAGES – AMVRAKIKOS GULF (GREECE)

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De westkust van Griekenland is een belangrijke migratieroute voor Afrikaans-Aziatische migrerende watervogels, aangezien ze deel uitmaakt van de Zwarte-Zee/ Mediterrane vliegroute. De wetlands langs deze kust zijn belangrijke tussenstopplaatsen tijdens de migratie van vogels tussen hun overwintering- en broedplaatsen. De populatie van langeafstandstrekvogels gaat er sterk op achteruit, maar in veel gevallen zijn de oorzaken voor deze achteruitgang niet voldoende gekend om gepaste beheersmaatregelen voor te stellen of uit te voeren. De hoofdvraag van dit onderzoek is 'Welke veranderingen in wetland habitat zijn belangrijk voor migrerende watervogels?' Hoewel veel wetlands langs de 'Western-Greek bird migration route' beschermd zijn als Ramsar sites, Important Bird Areas (IBAs), Natura 2000 sites, Greek National Parks, etc., worden veel van de nodige beschermingsmaatregelen niet uitgevoerd en gaan veel wetlands er duidelijk op achteruit. Dit is gedeeltelijk te wijten aan een gebrek aan geschikte informatie. Arbeid- en kostefficiënte methoden zijn nodig om het aantal, de oppervlakte en de kwaliteit van deze wetlands te controleren.

De hypothese die geleid heeft tot dit onderzoek is dat het verlies en/of de achteruitgang van aantal, oppervlakte en kwaliteit van wetlands langs de westkust van Griekenland kan leiden tot een gebrek aan geschikte tussenstopplaatsen voor trekvogels. Het gebruik van remote sensing methoden voor het in kaart brengen van tussenstopplaatsen voor trekvogels langs de westkust van Griekenland en voor het nagaan van veranderingen in deze habitats werd onderzocht. De gebruikte methoden en de resultaten zouden een basis moeten vormen voor verder onderzoek in dit aspect en in dit gebied. Post-classificatie veranderingsdetectie werd uitgevoerd over een tijdsperiode van 15 jaar (1989-2004). Verandering in de hoeveelheid fragmentatie en in de ruimtelijke schikking van habitat voor migrerende watervogels werd eveneens onderzocht. Additionele gegevens werden gebruikt om deze veranderingen te verklaren.

De Golf van Amvrakikos, een wetlandcomplex langs de westkust van Griekenland, werd geselecteerd als studiegebied. Landsat TM (1989) en ETM+ (2000) beelden en ASTER VNIR beelden (2002 en 2004) werden gebruikt. Het conceptueel model van Phinn werd gebruikt om de efficiëntie van deze beelden voor dit onderzoek na te gaan. Er werd een inventaris gemaakt van alle al benoemde wetlands van het studiegebied en van alle kleinere 'ongekende' wetlands die herkend werden op de satellietbeelden. In het studiegebied bevinden zich 25 benoemde wetlands gesitueerd binnen de beschermingszone van de Amvrakikos Gulf, maar in praktijk zijn de meeste niet beschermd. De satellietbeelden worden als zeer efficiënt beschouwd om een nauwkeurige, bijgewerkte inventaris van het volledige wetlandcomplex te ontwikkelen en kunnen nuttig zijn om de nodige informatie te bekomen voor het beheer van deze wetlands. Om alle wetlands of tussenstopplaatsen langs de 'Western-Greek bird migration route' te beschermen zou een inventaris moeten gemaakt worden van alle wetlands langs de westkust van Griekenland.

Een classificatieschema werd ontwikkeld, gebaseerd op het MedWet classificatiesysteem. Aanpassingen aan dit classificatieschema werden gemaakt om overeen te stemmen met de onderzoeksdoelstellingen, rekeninghoudend met de informatie beschikbaar van satellietbeelden. Het ontwikkelde classificatieschema wordt als voldoende beschouwd om in te brengen in verdere inventarisatie van wetlands langs de westkust van Griekenland en voor verdere controle van wetlands in functie van migrerende vogels, dit vooral bij het gebruik van Landsat en ASTER beelden. Dit classificatieschema bevat de klas 'Moerassen, slikken, modderbanken', wat beschouwd wordt als een belangrijk habitat voor migrerende watervogels. Beelden met meer banden en betere spectrale resolutie zouden het gebruik van een meer gedetailleerd classificatieschema kunnen mogelijk maken, met misschien een betere herkenning van verschillende vegetatietypes.

Elk beeld werd afzonderlijk geclassificeerd in ERDAS IMAGINE, gevolgd door een pixel-tot-pixel vergelijking van de beelden. Google Earth en topografische kaarten van Árta (1986) en Vónitsa (1987) werden gebruikt als referentie. Een 'unsupervised ISODATA' (Iterative Self-Organizing Data Analysis) classificatie werd uitgevoerd, gevolgd door 'signature editing', 'supervised' classificatie en

een nauwkeurigheidsbepaling van de classificatie. De post-classificatie vergelijking werd uitgevoerd aan de hand van een matrixanalyse van verschillende paren van beelden: 1989-2000, 2000-2002, 2002-2004 en 1989-2004. Tijdens de 15 jaar die bestudeerd werden, was er een vermindering in de oppervlakte van moerassen, slikken en modderbanken van 32%, 25% van deze klasse veranderde naar wateroppervlakte en 7% naar vegetatie. Deze vermindering vond voornamelijk plaats tussen 1989 en 2000. Van 2000 tot 2004 waren er slechts enkele dynamische veranderingen van wateroppervlakte naar moerassen, slikken en modderbanken en terug. Het systeem leek te fluctueren rond een constante waarde, althans wat de belangrijkste landbedekkingscategorieën betreft.

FRAGSTATS werd gebruikt om verandering in de hoeveelheid fragmentatie en in de ruimtelijke schikking van habitat van migrerende vogels te bestuderen. Een binaire 'patch' structuur werd gebruikt waarin de bestudeerde fragmenten zich bevinden in een neutrale matrix. Patronen in het landschap, zoals het aantal en de oppervlakte van de fragmenten, werden berekend. Enkele meer ruimtelijke berekeningen, zoals afstand tussen fragmenten, werden gebruikt voor het meten van contextuele informatie. De hoeveelheid fragmentatie van habitat voor trekvogels steeg van 1989 tot 2004. Deze fragmentatie is meer uitgesproken wanneer ze samen gaat met een verlies in totale oppervlakte (van 1989 tot 2000). Er vond nog steeds fragmentatie plaats van 2000 tot 2004, maar de fragmenten bleven gegroepeerd en er was geen verlies in totale oppervlakte.

We kunnen besluiten dat de kwaliteit van habitat van trekvogels (hier moerassen, slikken en modderbanken) nog verminderde sinds 1989. De totale oppervlakte verminderde en de fragmenten werden kleiner en meer gefragmenteerd, wat ze kwetsbaarder maakt voor externe verstorende invloeden (mensen, wegen,...). Het gebruikte materiaal en methoden worden als efficiënt beschouwd voor verdere opvolging van de Golf van Amvrakikos en de volledige westkust van Griekenland. Ze worden voorgesteld als een nuttige methode voor verder onderzoek van wetlands. Het gebruik van Landsat en ASTER satelliet beelden zou nuttig kunnen zijn voor beleidsmakers en beheerders, aangezien ze gemakkelijk veranderingen in wetlands kunnen herkennen en opsporen en op deze manier de efficiëntie van de beschermings- en beheermethoden die elk land, en in ons geval Griekenland, toepast op zijn wetlands kan evalueren. Ze zijn gemakkelijk te verkrijgen, betrouwbaar en niet duur, hoewel verder onderzoek nodig is om de ecologische resolutie te verbeteren (verdere karakterisatie van biotopen en habitat types).

VERVUILING IN KUSTHAVENS, TOEPASSING VAN BIOMERKERS EN BIOMETRISCHE KARAKTERISTIEKEN IN *MYTILUS EDULIS* KOOI EXPERIMENTEN

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Doordat havens half ingesloten structuren zijn, accumuleren ze grote hoeveelheden polluenten afkomstig van rivieren, landbouwgronden, afvalwaterlozingen, schepen en atmosferische depositie. Door het voorkomen van micropolluenten zoals organochlorine pesticiden, polyaromatische koolwaterstoffen (PAKs), organohalogenen en endocriene verstoorders is er een verhoogde nood om hun potentiële effecten op de gezondheid van het mariene ecosysteem te bepalen (Janssen *et al*., 2006; Janssen *et al*., 2007). Bijgevolg werd het INRAM project (*Integrated Risk Assessment and Monitoring of Micro-Pollutants in the Belgian Coastal Zone*) ingevoerd om de concentraties, ecologische effecten en transfers van micropolluenten langsheen de Belgische kustzone te bestuderen.

Als onderdeel van het INRAM project werd de inheemse mosselsoort *Mytilus edulis* L. geïntroduceerd als bio-indicator ten einde de effecten en concentraties van micropolluenten in Belgische kusthavens te bepalen. Mosselen werden in vorige studies vooral gebruikt om op organisme niveau de effecten van polluenten na te gaan met behulp van biometrische karakteristieken zoals groeisnelheid, conditie-index en gonadeontwikkeling. Het gebruik van deze biometrische karakteristieken is echter zeer tijdrovend aangezien de effecten pas na langere perioden van blootstelling ontstaan, namelijk ca. drie maanden. Snelle, efficiënte en kosteffectieve technieken moesten daardoor ontwikkeld worden aangezien vele onderzoeksprojecten gelimiteerd zijn door tijd en budget. In de laatste decennia werden dus moleculaire en cellulaire biomerkers ontwikkeld die als 'early warning signals' functioneren.

Twee cellulaire biomerkers werden in dit onderzoek toegepast waaronder een stress (Lysosomale Membraan Stabiliteit) en een exposure biomerker (Alkali Labile Phosphate analysis). Twee transplantatie-experimenten werden op korte termijn (zes weken) uitgevoerd om het gebruik van deze twee cellulaire biomerkers als monitoringinstrumenten in de Belgische kustzone te onderzoeken.
Tijdens het eerste experiment (najaar 2008) werden mosselen getransplanteerd vanuit de Oosterschelde. Vermits er hier geen referentiesituatie mogelijk was werden mosselen tijdens het tweede experiment (voorjaar 2009) getransplanteerd vanuit de aquacultuurmosselkooien dichtbij de Nieuwpoort Bank. Vervolgens werden deze mosselen overgebracht naar vier havenstations om verschillende soorten antropogene en natuurlijke input van micropolluenten op te nemen in het onderzoek. De havens van Oostende (OO) en Nieuwpoort (NP) werden als jacht- en visserijhavens gekozen met een zoetwaterinvoer van respectievelijk het Kanaal Brugge-Oostende en de IJzer. De jachthaven (ZB_2) en buitenhaven van Zeebrugge (ZB_1) werden geselecteerd om de effecten van scheepvaart in te brengen. Bovendien werd de buitenhaven van Zeebrugge gekozen als een mogelijk minder gecontamineerd station vergeleken met de drie andere locaties.
Daarenboven werden de twee cellulaire biomerkers parallel uitgevoerd met drie biometrische karakteristieken op organismeniveau (groeisnelheid, conditie-index en gonadeontwikkeling) die significante resultaten vertoonden na een langetermijn transplantatie-experiment in 2007-2008 (Janssen *et al*., 2009, in press). Bovendien werd ook de lucht en water temperatuur (°C), saliniteit (PSU), zuurstof (mg/l), SPM (Suspended Particular Matter, mg/l) en chlorofyl a (µg/l) bij de aanvang, het midden en op het einde van elk experiment gemeten.

Als stress biomerker bepaalt de lysosomale membraanstabiliteit (LMS) de reactie van een organisme op fysiologische stress, mogelijks veroorzaakt door vervuiling. Lysosomen spelen een rol in de vertering van macromoleculen en accumuleren bijgevolg verscheidene contaminanten (Moore *et al*., 2004). Deze accumulatie kan leiden tot een instabiliteit, vergroting of zelfs sterfte van de lysosomen. De cytochemische Neutral Red Retention assay (NRR assay) van Moore *et al.* (2004) werd in dit onderzoek toegepast om de lysosomale membraanstabiliteit in de bloedcellen (haemocyten) van *Mytilus edulis* te bepalen na transplantatie in de havens. Als zwakke base kan neutraal rood structurele veranderingen in de lysosomen induceren waardoor een aanvullende stress veroorzaakt wordt. Uit voorgaande studies werd vastgesteld dat gezonde lysosomen het neutraal rood voor

langere perioden (120 minuten) kunnen vasthouden vergeleken met zwakke cellen die al na 15 minuten beschadiging kunnen vertonen (Fig. 1). De tijd waarop meer dan 50% van de cellen een vergroting of beschadiging vertoonden werd de Neutraal Rood Retentie Tijd (NRRT) genoemd. Per station werd de NRRT bepaald voor 15 mosselen (45-50mm in periode 1 en 45-55mm in periode 2) waaruit de gemiddelde NRRT berekend werd.

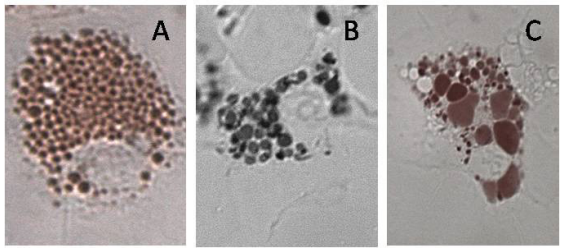

Fig. 1. *Mytilus edulis* haemocyte lysosomen blootgesteld aan neutraal rood. (A) Gezonde cellen na een NRRT van 15 minuten, (B) vergrootte lysosomen en (C) beschadigde lysosomen met een lekkage van neutraal rood naar het cytosol. (Totale vergroting x1000).

De Alkali Labile Phosphate (ALP) analyse werd als een exposure biomerker toegepast om indirect de effecten van endocriene verstoorders op de vitellogenese van *Mytilus edulis* te bepalen. Vitellogenese is de synthese van vitellogenin, de voorganger van vitellinen of eidooierproteïnen die een ontwikkelend embryo van de nodige energiereserves voorziet (Matozzo *et al.,* 2008). Op natuurlijke wijze worden de vitellogeninproteïnen geïnduceerd door het vrouwelijk hormoon estradiol. Maar endocriene verstoorders zoals tributyltin (TBT) of de synthetische ethinylestradiol kunnen de vitellogeninniveaus sterk verhogen in vrouwtjes en traceerbare niveaus produceren in mannetjes. In dit onderzoek werd de ALP methode, beschreven door Ortiz-Zarragoitia and Cajaraville (2006), toegepast om indirect de vitellogenineniveaus in de gonaden van *Mytilus edulis* te meten. Na beide transplantatie-experimenten werden de fosfaat- en proteïneniveaus in de gonaden of mantels van 10 vrouwtjes en 10 mannetjes (45-50mm in periode 1 en 45-55mm in periode 2) geanalyseerd. Daaruit werden twee verhoudingen gevormd om de ALP niveaus te normaliseren. Vooreerst werd een verhouding gevormd van de fosfaten (µg) over het gonade of mantel nat gewicht (g) en vervolgens een verhouding van de fosfaten (µg) over het corresponderende proteïneniveau (mg) om variaties in biomassa te minimaliseren (Matozzo *et al.*, 2008). Aangezien het eerste experiment uitgevoerd werd in november was er een sterk vermoeden dat de mosselen zich in een vroeg ontwikkelingsstadium gingen bevinden waardoor het onmogelijk zou zijn de geslachten microscopisch te bepalen. Dit werd bevestigd na het toepassen van histologische technieken op de gonaden van de mosselen. Daardoor werden de ALP analyses voor het eerste transplantatie-experiment uitgevoerd op de mantels en per station zonder opdeling in geslacht. Bij het tweede experiment waren de mosselen in een gevorderd ontwikkelingsstadium waardoor het geslacht microscopisch kon bepaald worden. Hierdoor werden de ALP analyses tijdens het tweede experiment per geslacht en op de gonaden uitgevoerd.

Na het eerste transplantatie-experiment vertoonden de havenstations OO, NP en ZB_2 hogere stress niveaus met significant ($p < 0.05$) lagere NRRTs in vergelijking met de startsituatie in de Oosterschelde. Daarenboven vertoonde enkel OO een significant lagere NRRT in vergelijking met de referentiesituatie (Sea) na het tweede experiment (Fig. 2).

Aangezien de lysosomale membraanstabiliteit een stress biomerker is kan het beïnvloed worden door zowel micropolluenten als fluctuerende omgevingsfactoren zoals saliniteit en chlorofyl a. Tijdens het eerste experiment werd een lage saliniteit gemeten in OO (1.2 PSU) en NP (3.2 PSU) wijzend op een hogere invoer van zoetwater door onder andere runoff. Na hoge regenval kunnen micropolluenten zoals PAKs, Polychloorbiphenyls (PCBs) en organochlorine pesticiden aanzienlijk verhogen. Daarenboven werden na het tweede transplantatie-experiment, stabielere saliniteiten waargenomen en betere NRRTs wijzend op een lagere invoer van micropolluenten. Toch konden de effecten van lage saliniteit en chlorofyl a concentraties op de lysosomale membraanstabiliteit nog niet uitgesloten worden. Voorgaande metingen van de chemische concentraties in de waterkolom suggereren wel dat OO een algemeen vervuild station is. Hoe dan ook moeten deze resultaten zorgvuldig geanalyseerd worden aangezien concentraties in de waterkolom zeer snel kunnen veranderen door onder andere hoge runoff.

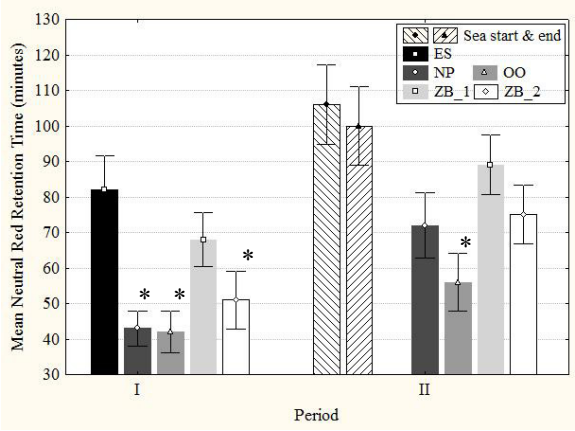

Fig. 2. Gemiddelde Neutraal Rood Retentie tijden (mean ± SE, n = 15) van getransplanteerde *Mytilus edulis* uit de Oosterschelde (ES) in Periode I en de aquacultuurmosselkooien (Sea start & end) in Periode II. Np: Nieuwpoort, OO: Oostende, ZB_1: Buitenhaven van Zeebrugge ZB_2: Jachthaven van Zeebrugge. Verschillen werden met de niet-parametrische Mann-Whitney U-test bepaald en significant bij $p < 0.05$ (aangeduid met *).

Geplande analyses van de chemische concentraties in het mosselweefsel zullen in de nabije toekomst opheldering moeten geven. Daarenboven zou men de effecten van fluctuerende saliniteit op LMS in de toekomst moeten onderzoeken aangezien een goede biomerker ongevoelig moet zijn voor omgevingsfactoren. Dit zou verricht kunnen worden door veld- en laboratoriumexperimenten simultaan uit te voeren met onder andere fluctuerende saliniteiten in het laboratoriumexperiment.

Het haven station NP vertoonde een potentiële endocriene verstoring met significant ($p < 0.05$) hogere ALP niveaus na het eerste transplantatie experiment in vergelijking met ZB_1. Daarenboven vertoonden mannelijke mosselen hogere ALP niveaus in NP en ZB_2 na het tweede transplantatie-experiment.

Resultaten van de vrouwelijke mosselen waren na het tweede experiment niet vertrouwbaar door onverwachte paai activiteiten in enkele transplantatiestations. Het tweede experiment werd immers wegens slechte weersomstandigheden vier weken uitgesteld waardoor de mosselen in een ver gevorderd ontwikkelingsstadium terechtgekomen waren. Onze resultaten vertoonden daardoor een sterke relatie tussen de gonadenontwikkeling en de ALP niveaus gemeten in de gonaden in overeenstemming met vorige studies (Ortiz-Zarragoitia and Cajaraville, 2006). Eerste analyses op de mantels van mosselen gaven verfijnde en betere resultaten. In de toekomst zal er dus verder gewerkt worden met de ALP methode, gebruikmakende van de mantels van mosselen. Daarenboven zullen de metingen van de chemische concentraties in het mosselweefsel ook hier opheldering moeten geven in de nabije toekomst.

Algemeen wordt de relevantie van de ALP methode in vraag gesteld door de grote variatie en lage reproduceerbaarheid tussen studies. Daarenboven is er geen standaard ALP uitdrukking vastgelegd (µg fosfaten/g nat gewicht of µg fosfaten/mg proteïnen) waardoor verschillende studies moeilijk te vergelijken zijn met elkaar. Als snelle en kostefficiënte methode zou ALP in de toekomst als eerste screeningmethode kunnen toegepast worden bij monitoringstudies, naast andere exposure biomerkers.

Deze studie heeft de relevantie van een multi-biomerker aanpak in monitoringstudies aangetoond doordat de resultaten van LMS en ALP niet altijd overeenstemden met elkaar. Voor het INRAM project werden daardoor nog drie andere biomerkers simultaan toegepast door het Laboratorium van Milieutoxicologie en Aquatische Ecologie van de Universiteit van Gent (Partner van het INRAM project).

De cellulaire biomerkers vertoonden meer significante resultaten in tegenstelling tot de simultaan uitgevoerde biometrische karakteristieken op organismeniveau. Daarenboven waren de kortetermijn resultaten van LMS en ALP vergelijkbaar met de langetermijn resultaten van de biometrische karakteristieken in 2007-2008 (Janssen *et al.*, 2009, in press). LMS en ALP kunnen daardoor gesuggereerd worden als mogelijke technieken voor het monitoren van micropolluenten in de Belgische kustzone. Toch vereist vooral de ALP methode verdere 'fine-tuning' en aandacht in de toekomst.

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DE ONTWIKKELING VAN GENOMISCHE TECHNIEKEN VOOR DE KWEEK VAN TONG (*SOLEA SOLEA* L.)

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Inleiding

De visserij van mariene organismen is wereldwijd een onmisbare bron van voedsel die tevens inkomen en werkgelegenheid biedt aan x-aantal vissers. De laatste decennia zijn echter tal van mariene visstocks ineengestort of sterk achteruitgegaan (Myers en Worm, 2003; Mullon *et al.*, 2005) en steeds meer mariene soorten komen terecht op de rode lijst van de World Conservation Union (Kaiser *et al.*, 2005). Oorzaken hiervan zijn overbevissing, vervuiling, introductie van exotische soorten en habitatdegradatie, maar ook klimaatverandering draagt bij tot deze achteruitgang (Dulvy *et al.*, 2003).

Negatieve effecten van visvangst manifesteren zich voor individuele soorten op verschillende vlakken gaande van sterke veranderingen in demografie en populatiestructuur tot evolutionaire veranderingen in levensgeschiedeniskenmerken zoals maturatieleeftijd en -grootte (Heino *et al.*, 2002; Hutchings en Baum, 2005;). Het succes van visserijbeheer kan gedefinieerd worden in termen van biologische, sociale en economische doelstellingen en de politieke besluitvorming speelt een belangrijke rol in het evenwichtig combineren van tegenstrijdige belangen. De meeste visserijen worden echter nog steeds beheerd om uitsluitend tegemoet te komen aan sociale en economische doelstellingen zoals maximale vangst, werkgelegenheid en een goed inkomen. Om natuurlijke visstocks in de toekomst te behouden, zal de visserij op een meer duurzame manier beheerd moeten worden met een grotere nadruk op het biologische aspect (Beddington *et al.*, 2007). Het afbakenen van beheerseenheden die overeenkomen met biologische entiteiten is hierbij van cruciaal belang. Ook het in kaart brengen van de genetische variatie kan belangrijke inzichten opleveren voor visserijbeheer met betrekking tot connectiviteit en de demografische stabiliteit van populaties (Waples, 1998).

Ondanks de vele inspanningen die geleverd worden om de visserij op een meer duurzame manier te beheren, blijft het succes ervan beperkt. Aquacultuur wordt door velen naar voor geschoven als alternatieve voedselbron om het tekort aan voedselproductie uit zee te compenseren (Jennings *et al.*, 2001; Ayer *et al.*, 2009). Hoewel aquatische organismen reeds lang door de mens worden gekweekt (vb. in China sinds 2000 jaar) is de gecontroleerde kweek met productieverhoging tot doel van recente oorsprong (ongeveer 40 jaar). Aquacultuur zorgt voor een gemakkelijke en betrouwbare bron van proteïnen ongeacht de natuurlijke schommelingen in de vangst van wilde organismen (Jennings *et al.*, 2001). Door de stijgende vraag naar aquacultuurproducten is er nood aan efficiënte en ecologische productiesystemen.

Tong (*Solea solea* L., Pleuronectiformes, Soleidae) is een commerciële vissoort die een weloverwogen aquacultuurplan kan gebruiken om natuurlijke populaties te behoeden van overbevissing. Deze platvis heeft een latitudinaal verspreidingsgebeid van Senegal tot Noorwegen en wordt ook aangetroffen langs de kusten van de Middellandse Zee en de Zwarte Zee (ICES-FishMap). Ondanks de lange generatietijd en trage groei, is tong een veelbelovende kandidaat voor aquacultuur. Tong behoort internationaal tot een luxemarktsegment en de huidige marktwaarde in Europa is stabiel en ligt rond 8,5-16,5 euro/kg, afhankelijk van de grootte en het seizoen. De wereldwijde visvangst van tong in 2007 bedroeg 38 392 ton (FAO). 50 procent van de totale vangst van *S. solea* wordt gevangen in de Noordzee (Imsland *et al.*, 2003) en in België is tong de tweede meest belangrijke visserij met een vangst van 5089 ton in 2001 (Facts and figures on the CFP, 2004). Door overbevissing is er echter een dalende trend vastgesteld met een vangst van 4712 ton in 2003 en slechts 3991 ton in 2004 (Facts and figures on the CFP 2006 en 2008). Tong wordt tegenwoordig aan strenge quota onderworpen, maar mogelijk zal dit onvoldoende zijn om de duurzaamheid van de natuurlijke stock te verzekeren. Een grootschalige zelfonderhoudende tongkweek zou een oplossing kunnen bieden om de afnemende wildvangst te compenseren.

Dertig jaar geleden werd tong beschouwd als één van de meest interessante soorten voor mariene aquacultuur in Europa (Howell, 1997). Toch werd tongkweek nooit een groot succes door tal van aquacultuurtechnische problemen (vb."Black Patch" necrose, een aandoening veroorzaakt door de bacterie *Flexibacter maritimus*). Inmiddels wordt gezocht naar efficiëntere kweeksystemen met

betere kweekcondities, voeding en ziekteresistentie. Naast dit onderzoek is het sterk aangeraden om genomische technieken te ontwikkelen die sneller tot een optimalisatie van selectieve kweek met behoud van lange termijn broedstockdiversiteit leiden (Dunham, 2004). Ondanks een reeks initiatieven in Europa, zijn er op dit moment bijzonder weinig genomische bronnen beschikbaar om selectieve kweek van tong tot een goed einde te brengen. Deze masterproef levert hiertoe een eerste bijdrage.

Doelstellingen

De toepassing van moleculaire technieken kan volledig geïntegreerd worden in traditionele kweekprogramma's, wat moet leiden tot een verbetering van het commercieel niveau van tongkweek. Deze masterproef spitste zich toe op twee moleculaire technieken die tot nu toe slechts beperkt toegepast werden in tongkweek, namelijk ouderschapsanalyse en kandidaatgenanalyse.

Ouderschapsanalyse – Om inteelt te vermijden en genetische verarming tegen te gaan, is er informatie nodig omtrent de verwantschap tussen de ouderdieren en hun nakomelingen in het kweeksysteem (Herlin *et al.*, 2007). Het is belangrijk om kruisingen tussen verwante ouderdieren te vermijden, omdat dit de belangrijkste reden is van verlaagde reproductie en overleving in een kweekprogramma (door inteeltdepressie). Gedurende een volledig kweekprogramma is het meestal niet mogelijk om alle vissen individueel te merken (met externe of pit-tags) of om elke familie in een aparte tank te houden. Daarom verschaffen genetische merkers (genetische tags of DNA-sequenties die genetische variatie typeren) de cruciale informatie omtrent verwantschap tussen twee generaties. Vooraleer deze techniek gebruikt kan worden, dient er een panel van merkers ontwikkeld te worden dat voldoende krachtig is om met hoge nauwkeurigheid nakomelingen toe te wijzen aan het juiste ouderpaar (Castro *et al.*, 2006; Herrán *et al.*, 2008). Voor ouderschapsanalyse geven microsatellietmerkers [DNA-fragmenten opgebouwd uit een variabel aantal herhalingen van een kort (2 tot 6 baseparen) motief] de beste resultaten, aangezien genetische variatie tussen individuen zeer hoog is bij deze merkers (Liu en Cordes, 2004; Chistiakov *et al.*, 2006; Wenne *et al.*, 2007).

Kandidaatgenanalyse – Groei en maturatiteit zijn twee belangrijke kenmerken in aquacultuur omdat een snellere groei en gecontroleerde maturiteit een grotere economische winst tot gevolg hebben. Om groei en maturiteit te optimaliseren is een gedetailleerde kennis over de genetische basis ervan cruciaal. Een veelbelovende aanpak om genen te zoeken die in verband staan met specifieke kenmerken is het uitvoeren van een kandidaatgenanalyse. In kandidaatgenen, waarvan vermoed wordt dat ze belangrijk zijn voor groei en maturatie, worden genetische merkers gezocht die een associatie vertonen met deze kenmerken. Indien dan effectief een correlatie wordt aangetoond tussen varianten van deze merkers en het fenotype, bewijst dit dat het gen in kwestie betrokken is bij de genetische controle van het kenmerk. Op basis van deze informatie kan dan veel efficiënter selectie worden uitgevoerd. Er werd gekozen om een nieuwe klasse van moleculaire merkers te gebruiken, namelijk single nucleotide polymorfismen (SNP's), waarbij DNA sequenties slechts verschillen in één basepaar. Het doel is variatie aan te tonen en na te gaan of die in kweekprogramma's gebruikt kunnen worden om de snelst groeiende varianten te selecteren.

Resultaten

Ouderschapsanalyse - Het aantal microsatellietmerkers nodig voor ouderschapsanalyse schommelt naargelang de aanwezige genetische variatie (de graad van polymorfie) in de bestudeerde DNA sequenties. Hoe hoger de graad van polymorfie, hoe krachtiger de merkers zijn voor ouderschapsanalyse. In dit onderzoek werden 15 microsatellietmerkers geanalyseerd waarvan geweten is dat ze efficiënt amplificeren in een PCR reactie. Er werd vertrokken van de genotypes van Noordzee populaties. Uit analyse van de allelfrequenties (frequenties van de verschillende varianten) werd de graad van polymorfie voor elke merker nagegaan. Drie merkers waren ongeschikt voor ouderschapsanalyse. Van de twaalf overige bleken zeven merkers, deze die genetisch het meest variabel zijn, voldoende om een ouderschapsanalyse mee uit te voeren. Een tweede analyse, namelijk een ouderschapssimulatie (die zelf allelfrequenties simuleert) met deze zeven merkers gaf aan dat 99,97% van de nakomelingen betrouwbaar wordt toegewezen aan hun ouders. Alle 12 merkers gebruiken is nauwkeuriger, maar ook duurder en arbeidsintensiever. Voordelig is om enkel die merkers te gebruiken die samen geamplificeerd kunnen worden in één multiplex PCR (Hérran *et al.*, 2008), mits ze voldoende krachtig zijn om de ouderschapstesten op te lossen. Uiteindelijk werden tien merkers geselecteerd op basis van hun amplificatiesucces in één multiplex PCR en hun toewijzingskans.

Kandidaatgenanalyse - De gebruikte tongstalen voor dit deel van het onderzoek werden eerder bemonsterd op verschillende locaties verspreid over Europa, namelijk Skagerrak, Kattegat, Norfolkbank, de Belgische kust, de Ierse Zee, de Golf van Biskaje, Barcelona, Sète (Golf van Lion), Venetië (Adriatische Zee) en Thessaloniki (Egeïsche Zee). Het gebruik van stalen met een grote

geografische spreiding biedt garanties om een groot deel van de natuurlijke genetische variatie terug te vinden. Bij elk individu werd een stukje weefsel van de buikvinnen weggeknipt en bewaard in een 100%-ethanol¬oplossing. Per locatie werden steeds 2 tot 4 individuen geselecteerd waarvan DNA uit de buikvin werd geïsoleerd. De zoektocht naar kandidaatgenen voor groei en maturiteit in de wetenschappelijke literatuur leverde een lijst op met 74 potentiële kandidaatgenen (bijv. De-Santis en Jerry, 2007). Voor 10 van deze kandidaatgenen konden primers ontwikkeld worden op basis van geconserveerde gebieden in kandidaatgensequenties van verwante individuen. In vier genen die verband houden met de kenmerken groei en maturatie [luteïnizerend hormoon β (LHB), oestrogeenreceptor β (ERB), myostatine (MYO) en somatolactine (SL)] kon variatie in microsatelliet- en SNP merkers worden aangetoond in de natuurlijke stalen. In LHB, ERB, MYO en SL werden respectievelijk 4, 11, 6 en 17 SNP's gedetecteerd. In een exonische regio van ERB werd bovendien een microsatellietmerker met trinucleotide-motief opgemerkt en in de MYO intronen twee inserties

Besluit: toekomstperspectieven

In deze masterproef werd een merkerpanel van 10 merkers ontwikkeld voor een betrouwbare ouderschapsanalyse in tong. De eerstvolgende stap is het effectief gebruik van dit panel in een reële ouderschapsanalyse. Het in kaart brengen van familieverbanden is van belang voor de ontwikkeling van een optimaal kweekprogramma waarbij genetische diversiteit behouden blijft.

De zoektocht naar variatie in kandidaatgenen voor groei en maturatie d.m.v. kandidaatgenanalyse was succesvol voor luteïnizerend hormoon β, oestrogeenreceptor β, myostatine en somatolactine. Deze informatie kan in de toekomst gebruikt worden om individuen uit een gecontroleerde kruising te genotyperen voor de gevonden genetische variatie. Een correlatie tussen bepaalde genetische varianten en economisch interessante kenmerken vormt de basis voor merker geassisteerde selectie (MAS) waarbij enkel de beste genotypes worden geselecteerd voor de artificiële kweek. Slechts tien kandidaatgenen voor groei en maturatie werden bestudeerd en in de toekomst kan ook in andere genen en met meer merkers gezocht worden naar variatie. Daarnaast is het eveneens nuttig om kandidaatgenen te bestuderen die belangrijk zijn voor andere relevante kenmerken in aquacultuur zoals ziekteresistentie, de efficiëntie van voedselconversie en de opbrengst en bewaarkwaliteit van visfilets.

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IMPLEMENTATIE EN VALIDATIE VAN GOLFBREKING IN HET NUMERIEKE GOLFVOORTPLANTINGSMODEL MILDWAVE

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Dit artikel beschrijft hoe het fysische proces van golfhoogtetransformatie ten gevolge van dieptegeïnduceerde golfbreking is geïmplementeerd in de mild-slope vergelijkingen van het lineaire golfvoortplantingsmodel MILD¬wave. Verschillende parametrische uitdrukkingen voor de energie¬dissipatie zijn daarbij beschouwd en geëvalueerd. Fysische modelproeven zijn uitgevoerd ter validatie van de numerieke resultaten.
Trefwoorden: windgolven, golfvoortplanting, golfbreking, MILDwave, hyperbolische mild-slope vergelijkingen, parametrisch golfbrekingsmodel, fysische golfgootproeven.

Inleiding

Het gebruik van numerieke golfvoortplantingsmodellen (ook wel refractie-diffractie modellen genoemd) wint steeds meer aan belang bij het ontwerp van waterbouwkundige constructies. Deze golfvoortplantingsmodellen worden in de kustzone toegepast, onder andere om lokale golfkarakteristieken aan de teen van de te ontwerpen constructie te bepalen, vertrekkende van gekende diepwatergolven.
MILDwave is zo'n numeriek model, dat sinds vele jaren in ontwikkeling is binnen de onderzoeksgroep waterbouwkunde van UGent. De zgn. mild-slope vergelijkingen van Radder en Dingemans (1985) beschrijven de fysische transformatieprocessen van refractie, shoaling, diffractie en reflectie van (lineaire of op eerste orde theorie gebaseerde) windgolven die zich in ondieper water voortplanten. Deze vergelijkingen worden in het model MILDwave met behulp van een eindig differentieschema numeriek opgelost. Een gebruikelijke toepassing voor MILDwave is onder meer het berekenen van golfindringing in havens die beschermd worden door golfbrekers.
Het onderwerp van deze scriptie is de implementatie en validatie van een golfbrekingsmodule in MILDwave. Op deze manier is MILDwave – naast andere golftransformatieprocessen – ook in staat rekening te houden met golfhoogteafname ten gevolge van golfbreking in ondiep water. Daardoor wordt het toepassingsgebied van het model aanzienlijk uitgebreid van de kustzone tot in de branding.

Het numerieke model mildwave

Het numerieke golfvoortplantingsmodel MILDwave ontwikkeld door Troch (1998) is gebaseerd op de hyperbolische mild-slope vergelijkingen volgens de formulering van Radder en Dingemans (1985). Het numerieke model lost deze set differentiaalvergelijkingen op via een eindige differentie discretisatie.
De hyperbolische mild-slope vergelijkingen waarmee in MILDwave de verheffing η in functie van tijd *t* en plaats *x* berekend wordt (Troch, 2000), zijn:

$$\begin{cases} \dfrac{\partial \eta}{\partial t} = \dfrac{\omega^2 - k^2 C C_g}{g}\varphi - \nabla \cdot \left(\dfrac{C C_g}{g} \nabla \varphi \right) \\ \dfrac{\partial \varphi}{\partial t} = -g\eta \end{cases} \qquad (1)$$

waarin g de gravitatieversnelling, k het golfgetal, ω de pulsatie, C de celeriteit, C_g de groepssnelheid en φ de snelheidspotentiaal voorstellen.
Zowel regelmatige als onregelmatige golven (Caspeele, 2006) kunnen gegenereerd worden. In het geval van onregelmatige golven is enige aanpassing van de parameters in de mild-slope vergelijkingen vereist (de parameters worden in dit geval berekend met behulp van de piekgolfperiode als representatieve golfperiodemaat).
Het toepassingsgebied van MILDwave verwijst in principe naar golven die aan de lineaire Airy theorie voldoen. Bodemhellingen tot maximaal 1(H):3(V) zijn toelaatbaar.

Golfbreking

Het fysische proces golfbreking

Golfbreking is een niet-lineair en complex verschijnsel dat zowel in diep als ondiep water voorkomt. Het is de hoofdoorzaak van energiedissipatie van watergolven. Specifiek voor MILDwave is de golfbreking in ondiep water (in de kustzone) van belang. Eenmaal golven ondiep water bereiken, ondervinden ze invloed van de bodem. Initieel treedt shoaling op, een verschijnsel waarbij de golfhoogte toeneemt, alsook de golfsteilheid. Bij het bereiken van de maximaal stabiele golfhoogte stort de golf plots in elkaar: de golf breekt. Dit fenomeen gaat gepaard met vele turbulente bewegingen die voor een enorme energiedissipatie zorgen, waardoor de golfhoogte uiteindelijk afneemt.
Dit golftransformatieproces van golfhoogteafname wordt met behulp van een golfbrekingsmodel geïmplementeerd in MILDwave. Zonder ingebouwd golfbrekingsmodel zou de golfhoogte in ondieper wordend water ongestoord blijven toenemen tot onrealistische waarden.

Golfbrekingsmodellen

Het grote voordeel van MILDwave is dat het snel resultaten kan leveren dankzij de (relatief eenvoudige) lineaire differentiaalvergelijkingen waarop het model gebaseerd is. Een zeer belangrijk criterium bij de keuze van het meest geschikte golfbrekingsmodel is daarom dat de toename aan rekentijd beperkt moet blijven na implementatie in MILDwave. Een golfbrekingsmodel gebaseerd op een parametrische benadering van de energiedissipatie ten gevolge van golfbreking blijkt als beste hieraan te voldoen.
In de literatuur zijn verschillende parametrische modellen voor golfbreking beschikbaar. Na een grondige initiële selectie op basis van een literatuurstudie is een aantal van die parametrische modellen geïmplementeerd. Hier worden enkel de meest geschikt bevonden modellen voorgesteld.
De energiedissipatieterm DB voor regelmatige golven (Deigaard *et al.*, 1991), die geïmplementeerd zal worden in de hyperbolische mild-slope vergelijkingen van het model, is:

$$D_B = \alpha \frac{\rho g}{T} \frac{hH^3}{\left(4h^2 - H^2\right)} \qquad (2)$$

waarin α de golfbrekingsintensiteit, ρ de dichtheid van water, *T* de golfperiode, *h* de waterdiepte en *H* de golfhoogte voorstellen.
Deze energiedissipatieterm is opgesteld naar analogie met een hydraulische sprong (Le Mehaute, 1962), waarbij het verval de golfhoogte van een brekende golf voorstelt. De parameter α is toegevoegd om o.a. het verschil tussen een hydraulische sprong en een brekende golf op te vangen. Voor onregelmatige golven is de term D_B (Baldock *et al.*, 1998):

$$D_B = \begin{cases} \alpha \exp\left[-\left(\frac{H_b}{H_{rms}}\right)^2\right] \frac{\rho g\left(H_b^2 + H_{rms}^2\right)}{4T_p} & als \;\; H_{rms} < H_b \\ \alpha \exp[-1] \frac{\rho g 2H_b^2}{4T_p} & als \;\; H_{rms} \geq H_b \end{cases} \qquad (3)$$

waarin H_b de brekingsgolfhoogte, H_{rms} de root-mean-square golfhoogte en T_p de piekgolfperiode voorstellen.
Eenvoudigweg komt vergelijking (3) neer op een energiedissipatie-uitdrukking voor één gebroken golf vermenigvuldigd met de kans op optreden van brekende golven in de branding.
Naast deze golfbrekingsmodellen zijn in de scriptie zelf nog enkele andere formuleringen voor golfbrekingsmodellen uitvoerig getest.
Details van de implementatie worden beschreven in de volgende paragraaf.

Parameters van de golfbrekingsmodellen

Een aantal parameters van deze golfbrekingsmodellen moeten gekalibreerd worden aan de hand van fysische datasets op verschillende schalen om een zo uitgebreid mogelijk toepassingsgebied te verkrijgen. Deze kalibratie werd al uitvoerig in de literatuur verricht. In (Rattanapitikon en Karunchintadit, 2003) en (Rattanapitikon, 2007) worden de waarden voor deze parameters bepaald, respectievelijk in het geval van regelmatige en onregelmatige golven. Deze kalibratie – in het bijzonder voor onregelmatige golven – is uitgevoerd op basis van een groot aantal fysische datasets afkomstig van diverse bronnen. De in de literatuur gekalibreerde parameterwaarden worden opgenomen als de standaardwaarden in de golfbrekingsmodule van MILDwave.
Het betreft de golfbrekingsintensiteit α en de betrokken parameters bij de uitdrukking voor de golfbrekingshoogte H_b.

Implementatie van het golfbrekingsmodel in MILDwave

Toevoegen van de energiedissipatieterm D_B gegeven door vergelijking (2) of (3) in de mild-slope vergelijkingen (1) (Dingemans, 1994), leidt tot:

$$\begin{cases} \dfrac{\partial \eta}{\partial t} = \dfrac{\omega^2 - k^2 CC_g}{g}\varphi - \nabla \cdot \left(\dfrac{CC_g}{g} \nabla \varphi \right) - \dfrac{D_B}{E}\eta \\ \dfrac{\partial \varphi}{\partial t} = -g\eta \end{cases} \qquad (4)$$

waarin E de golfenergie voorstelt.

Implementatie in de code MILDwave is mogelijk na discretisatie in de ruimte en tijdstapping van vergelijking (4). De nieuwe code is uitvoerig getest en werkt naar behoren. Het model is nu geschikt voor de simulatie van dieptegeïnduceerde energiedissipatie door golfbreking op verschillende soorten hellingen.

Fysische modelproeven

Een totaal van 57 fysische modelproeven van golfhoogte transformatie over een bodemprofiel zijn uitgevoerd, op twee verschillende schalen: in de kleine en de grote golfgoot van Afdeling Weg- en Waterbouwkunde (UGent). De gebruikte schaal in de grote golfgoot is dezelfde zoals traditioneel in de literatuur wordt teruggevonden, terwijl in de kleine golfgoot een schaalfactor 0.5 toegepast is, zodat de afmetingen de helft kleiner zijn.

De kleine golfgoot bestaat uit een metalen draagstructuur die een bak in plexiglas ondersteunt. De totale lengte bedraagt 15.0 m met een breedte en hoogte van respectievelijk 35 cm en 60 cm. De grote golfgoot daarentegen bestaat uit beton en een glaspartij, is 30.0 m lang, 1.0 m breed en 1.2 m hoog. Golven worden in beide golfgoten gegenereerd door een golfschot van het piston-type, maar met een beduidend verschil in maximale slaglengte (respectievelijk 28 cm en 1.5 m).

Drie verschillende bodemprofielen werden gebruikt. In beide golfgoten zijn er proeven verricht over een uniforme bodemhelling van 1/20 (waardoor ook schaaleffecten bij de resultaten van de kleine golfgoot konden geëvalueerd worden). Daarenboven zijn een drempel-dal en een trapezium profiel (met hellingen van 1/10) gebouwd in de kleine golfgoot om de nauwkeurigheid van het model bij veranderende topografie te toetsen.

Meting van de golfhoogte per locatie langsheen het bodemprofiel werd uitgevoerd met een golfhoogtemeter van het resistieve type. De opstelling van opeenvolgende golfhoogtemeters werd verricht in een veel dichtere configuratie als gewoonlijk wordt gerapporteerd in de literatuur. Dit zorgt voor een fijnere ruimtelijke resolutie van experimentele meetgegevens van golfhoogtes, zodat meer inzicht wordt verkregen in de evoluties die de golfhoogte ondergaat langsheen het profiel tijdens shoaling, golfbreking, enz.

Vergelijking van de experimentele resultaten met gelijkaardige proefresultaten uit de literatuur wijst uit dat de experimenten correct uitgevoerd zijn en bijgevolg kunnen de data als betrouwbaar beschouwd worden. Een uitzondering daarbij is dat er minder golfhoogtetoename ten gevolge van shoaling waargenomen is in de kleine golfgoot. Gezien de kleinere schaal die gebruikt is in deze golfgoot, worden schaaleffecten als oorzaak verondersteld.

Ook onderling vergelijken van de (verschaalde) resultaten van de kleine golfgoot met die van de grote golfgoot toont aan dat er minder shoaling optreedt op kleinere schaal. Voor het overige worden goede overeenkomsten gevonden tussen beide schalen. Niettemin komen er grotere verschillen voor naarmate de golfperiode wordt opgevoerd. In de kleine golfgoot was de volledige ontwikkeling van de golven niet altijd mogelijk door de tamelijk beperkte aanlooplengte, vooral voor grotere golfperioden.

Validatie van de golfbrekingsmodule

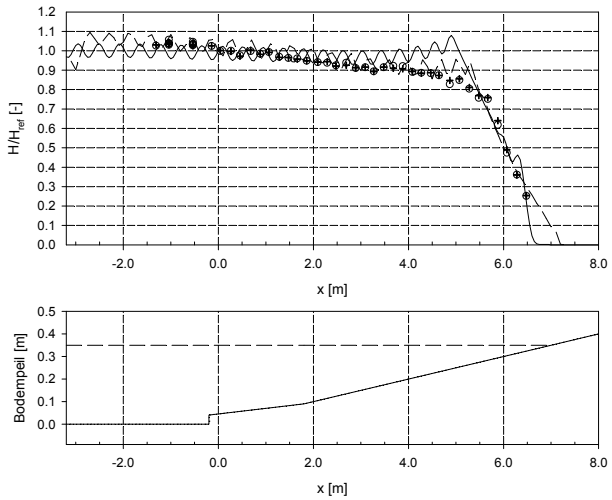
De fysische modelproeven zijn uitgevoerd met als doel de nieuwe MILDwave code met golfbrekingsmodule te valideren. In Tabel 1 worden de golfkarakteristieken van een aantal typerende proeven voorgesteld. De experimentele en numerieke resultaten van deze selectie worden gepresenteerd in Figuren 1-5. Het verloop van de golfhoogte langsheen het bodemprofiel wordt weergegeven.

De waterdiepte en golfkarakteristieken opgelegd bij de numerieke simulaties zijn dezelfde als deze bij de fysische modelproeven met uitzondering van de golfhoogte. De startwaarde voor de golfhoogte is gelijk genomen aan de eerste waarde opgemeten in de golfgoot opdat dezelfde begincondities toegepast worden. De gemeten golfhoogte net na het golfschot was immers dikwijls kleiner dan de golfhoogte opgelegd aan het golfschot (waarde in de tabel).

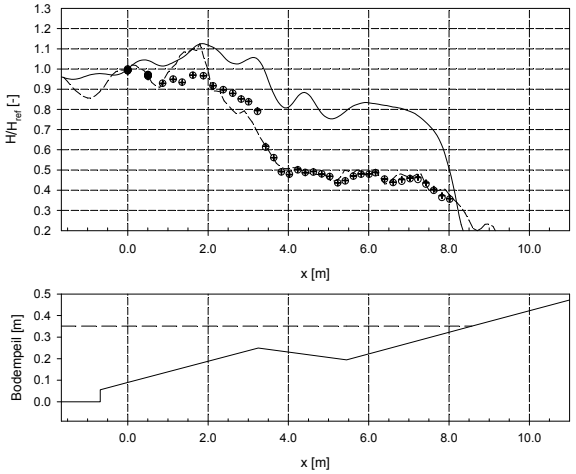
Tabel 1. Golfkarakteristieken van een selectie uit de proevenreeks

Run [-]	d [m]	T(p) [s]	H(s) [m]	Wave Generation [-]	Type [-]
1	0.350	0.75	0.055	regelmatig	spilling
13	0.351	2.20	0.080	regelmatig	spilling
6	0.430	1.50	0.100	Jonswap (γ=3.3)	spilling
2	0.700	2.47	0.120	regelmatig	plunging
9	0.705	1.84	0.204	Jonswap (γ=1.3)	spilling

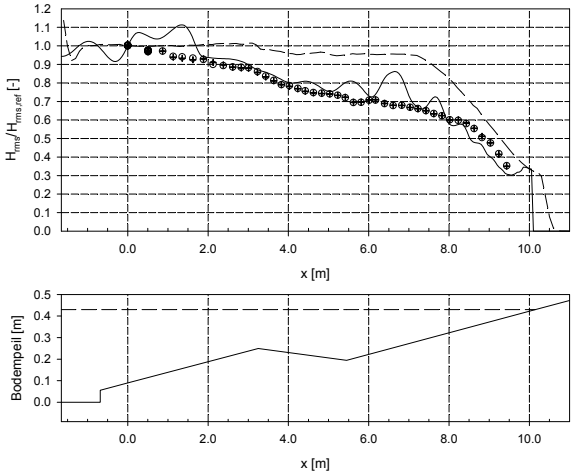
De resultaten van een analoge numerieke simulatie met het meer complex niet-lineaire golfvoortplantingsmodel SimWave staan ook in de grafieken. Dit model is gebaseerd op de Boussinesq vergelijkingen en de simulaties zijn uitgevoerd door Rijckaert (2008). Alle grafieken tonen de golfhoogte berekend in het frequentiedomein en genormaliseerd met een referentie golfhoogte zodat de onderlinge vergelijking tussen alle testresultaten zinvol is.
De experimentele resultaten zijn weergegeven door middel van tekens ('*o*' en '+', in Figuren 1-5), die identieke maar onafhankelijk van elkaar uitgevoerde proeven voorstellen. Onderling vergelijkbare resultaten tonen de goede reproduceerbaarheid van de proeven aan.



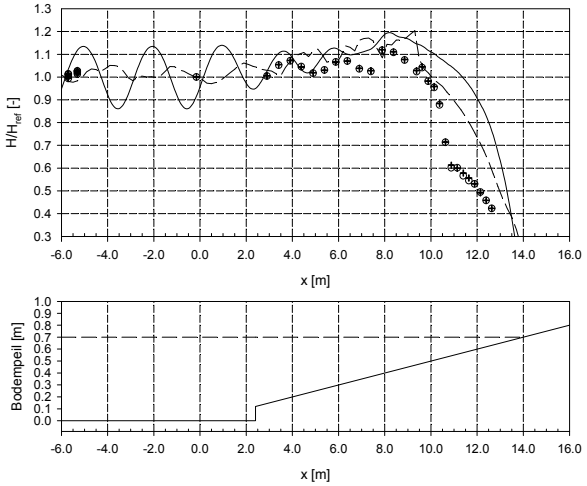
Figuur 1. Run 1 (uniforme helling 1/20, schaal 0.5); (a) experimentele resultaten ('*o*' en '+' tekens), MILDwave resultaten (volle lijn), SimWave resultaten (stippellijn); (b) bodemprofiel.



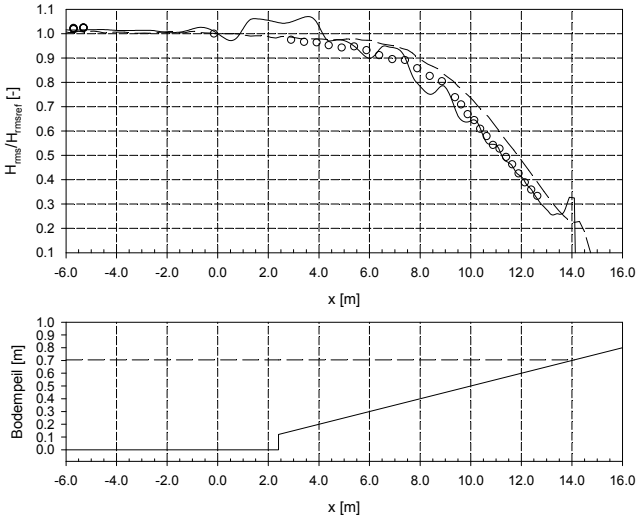
Figuur 2. Run 13 (drempel-dal profiel, schaal 0.5); (a) experimentele resultaten ('*o*' en '+' tekens), MILDwave resultaten (volle lijn), SimWave resultaten (stippellijn); (b) bodemprofiel.



Figuur 3. Run 6 (drempel-dal profiel, schaal 0.5); (a) experimentele resultaten ('*o*' en '+' tekens), MILDwave resultaten (volle lijn), SimWave resultaten (stippellijn); (b) bodemprofiel.



Figuur 4. Run 2 (uniforme helling 1/20, 'ware' schaal); (a) experimentele resultaten ('*o*' en '+' tekens), MILDwave resultaten (volle lijn), SimWave resultaten (stippellijn); (b) bodemprofiel.



Figuur 5. Run 9 (uniforme helling 1/20, 'ware' schaal); (a) experimentele resultaten ('*o*' teken), MILDwave resultaten (volle lijn), SimWave resultaten (stippellijn); (b) bodemprofiel.

Het geïmplementeerde golfbrekingsmodel (Verg. (3)) voor onregelmatige golven blijkt zeer goede overeenkomst te verschaffen met de experimentele data voor de afname van de golfhoogte langsheen het profiel in Figuur 3 en Figuur 5, maar ook bij bijna elke andere test. De relatieve fouten blijven beperkt tot maximaal 5%.
Het golfbrekingsmodel (Verg. (2)) voor regelmatige golven daarentegen produceert eerder zwakke resultaten. Voornamelijk blijken de drempel-dal en trapezium profielen een probleem te vormen voor de golfbrekingsmodule geïmplementeerd in MILDwave voor het geval van regelmatige golven (cf. Figuur 2 voor het drempel-dal geval). Niet-lineaire effecten die optreden in de zones respectievelijk net na de drempel en net na het trapezium, en die niet door de lineaire vergelijkingen kunnen beschreven worden, zijn daarvan de oorzaak. Overstortende brekers (cf. Figuur 4) vertonen bovendien een knik in het verloop van de golfhoogte welke eveneens onmogelijk te modelleren is door het lineaire golfbrekingsmodel.
MILDwave vertoont voor onregelmatige golven een vergelijkbare nauwkeurigheid met het niet-lineaire SimWave model. In sommige gevallen wordt er door MILDwave zelfs grotere nauwkeurigheid bereikt (cf. Figuur 3) met een veel lagere vereiste rekentijd. Regelmatige golven daarentegen worden consequent beter gesimuleerd door SimWave (cf. Figuur 1 en Figuur 2), hoofdzakelijk omdat het Boussinesq-model niet-lineaire effecten wel kan modelleren.
Finaal wordt geconcludeerd dat MILDwave succesvol uitgebreid is met een nieuwe module voor een belangrijk fysisch proces in ondiep water: golfbreking. MILDwave is vanaf heden beschikbaar als een krachtig numeriek instrument voor golfvoortplanting in de kustzone, waarbij (vooral) in het geval van onregelmatige golfvoortplanting op realistische en snelle wijze rekening kan gehouden worden met de golfhoogteafname ten gevolge van dieptegeïnduceerde golfbreking.

Dankbetuigingen

De auteur wil graag prof. dr. ir. P. Troch bedanken voor de begeleiding en ondersteuning bij het tot stand brengen van deze scriptie en R. Rijckaert voor het leveren van de SimWave resultaten en het constructief samenwerken tijdens de fysische proeven.

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EEN STEEKPROEF VAN FOUTEN, DE FOUT IN STEEKPROEVEN

EEN VERGELIJKING VAN VERSCHILLENDE PLOTLOZE STEEKPROEFMETHODEN VOOR HET SCHATTEN VAN DE DICHTHEID EN DE STAMDOORSNEDE-OPPERVLAKTE (BASAL AREA) VAN MANGROVEBOSSEN

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Mangroven

Mangrovebossen groeien wereldwijd aan (sub)tropische kusten. Zij hebben bepaalde fysiologische aanpassingen om zich in het zoute milieu te kunnen handhaven. De mens profiteert van deze opmerkelijke ecosystemen op verschillende manieren; de mangroven bieden economische, ecologische en religieuze mogelijkheden voor de plaatselijke bevolking en verder. Helaas wordt het bestaan van mangrovebossen wereldwijd bedreigd. Alleen al in de laatste helft van de 20e eeuw werd één derde van het totale gebied aan mangrovebossen vernietigd (Alongi, 2002).

Wanneer de kust beschemd is tegen golfslag, door bijvoorbeeld eilanden voor de kust, kan mangrovezonatie voorkomen. Zonatie is de opeenvolging van verschillende zones bestaande uit bepaalde soorten van landwaarts tot aan de kust.

Mangroveonderzoek

Mangroven worden vaak onderzocht voor commerciële en wetenschappelijke doeleinden. Eén van de variabelen die dan gemeten wordt is de dichtheid van het bos, met name het aantal bomen per hectare. Een andere interessante eenheid echter is de stamdoorsnede-oppervlakte (basal area). Dit is de oppervlakte van de doorsnede van alle bomen uitgedrukt in vierkante meter per hectare. Deze eenheid is gerelateerd aan de dichtheid van het bos. Accurate schattingen van deze parameters zijn nodig om trends over langere periodes te kunnen observeren en inzicht te verkrijgen in de interacties tussen verschillende soorten, functionele groepen en mineralenstromen.

In het mangroveonderzoek wordt vaak de *Point Centered Quarter Method* (PCQM of Punt Gecentreerde Vierkantsmethode) gebruikt om de dichtheid en de basale oppervlakte van een bos te bepalen. PCQM is een plotloze methode. Bij plotloze methoden wordt de afstand tussen verschillende punten en een nabije boom gemeten om zo tot een schatting van de dichtheid van het bos te komen. Dit is in tegenstelling tot methoden die verschillende plots leggen waarin het aantal bomen wordt geteld, om dit vervolgens te extrapoleren naar het gehele bos waarin de steekproeven zijn gedaan. Plotloze methoden zijn gemakkelijker in gebruik in schaarse en moeilijk begaanbare bossen, zoals mangroven.

Doelstelling van het onderzoek

De doelstelling van het onderzoek is om de nauwkeurigheid en precisie van verschillende plotloze methoden, waaronder PCQM, te vergelijken.

Materialen en methoden

In deze studie zijn twee verschillende aanpakken gebruikt. Voor de eerste aanpak werden op 4 verschillende plekken in een mangrovebos vlakbij Gazi Bay, Kenia de ruimtelijke coördinaten van alle bomen geregistreerd. Dit gebeurde door het uitzetten van vierkanten met touwen en het meten van de afstanden tussen de stammen van de bomen en de touwen. In de tweede aanpak werden bomenpatronen gesimuleerd *in silico* (MATLAB 7.7.0). Hiervoor werden vanuit de literatuur 6 vegetatiepatronen afgeleid die mogelijkerwijs in mangrovebossen kunnen voorkomen. Beide aanpakken leidden tot datasets waarop de verschillende plotloze methoden konden worden getest. Dit betekent dat de eerste aanpak op echte data gebaseerd was. De tweede aanpak was op een simulatie gebaseerd.

Resultaten

De resultaten van beide aanpakken laten vergelijkbare resultaten zien. Elke geteste methode gaf schattingen met grote fouten, oplopend tot 85%, waarbij de grootte en de variatie van de fout afhangt van én de methode én het vegetatiepatroon. Alle methoden gaven zowel overschattingen

als onderschattingen. Dit betekent dat met de methoden een dichtheid geschat kan worden die tot wel 5 keer lager of hoger kan liggen dan de echte waarde.

De resultaten komen globaal gezien overeen met eerdere onderzoeken, zoals bijvoorbeeld Engeman *et al.* (1994), Steinke en Hennenberg (2006) en White *et al.* (2008). Als toevoeging focuste deze studie op de PCQM en de mangrovezonatie. De resultaten laten zien dat zonatie een onderschatting geeft voor elke methode. Daarnaast valt binnen deze studie PCQM in de groep van de slechtst presterende methoden. De *Variable Area Transect* (VAT of variable oppervlakte doorsnede) methode geeft de beste resultaten als alle plekken en patronen in rekening worden gebracht.

Discussie

Een argument dat vaak aangehaald wordt om het gebruik van een bepaalde methode te verdedigen is het zogenaamde vergelijkingsvoordeel. Als meerdere onderzoekers dezelfde methode gebruiken in hun studies zouden de resultaten beter vergelijkbaar zijn. Dit onderzoek toont echter aan dat zowel een overschatting als een onderschatting van de echte waarde wordt verkregen wanneer de PCQM wordt gebruikt. Dit hangt af van het vegetatiepatroon, maar omdat het patroon aan het begin van het onderzoek nog niet bekend is, kan hiervoor niet gecompenseerd worden. Wanneer dan de dichtheden van twee bossen met verschillende patronen vergeleken worden, gebruikmakend van PCQM, kan de fout verdubbelen.

Waakzaamheid is geboden wanneer plotloze methoden worden gebruikt. Trends kunnen verkeerd geïnterpreteerd worden en vergelijkingen tussen verschillende bossen houden geen stand, zelfs wanneer dezelfde methode gebruikt is. Wanneer ecosysteemdiensten kwantitatief gewaardeerd gaan worden zal dit gebaseerd zijn op schatting van niet alleen bosopppervlakte, maar ook op basis van biomassa. Daar de schatting van biomassa weer gebaseerd is op de schatting van de dichtheid of de stamdoorsnede-oppervlakte van een bos, kunnen fouten opeenstapelen in een ketting van berekeningen. Met de mogelijkheid dat er in de toekomst ook betaald zal worden voor het behoud van bossen tegen de uitstoot van CO2 worden zulke schattingen meer en meer belangrijk. Het kan dan voorkomen dat landen teveel betalen of gemeenschappen te weinig ontvangen voor het behoud van een bos.

Dit onderzoek adviseert de VAT methode voor mangroveonderzoek. Wanneer PCQM toch wordt gebruikt is het beter de afstand tot de tweede boom te meten.

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POPULATIEGENETISCHE STRUCTUUR EN FYLOGEOGRAFIE VAN *DICTYOTA DICHOTOMA* (DICTYOTALES, PHAEOPHYCEAE) LANGSHEEN DE EUROPESE KUST

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In deze studie wordt er een eerste exploratie gemaakt van de genetische populatiestructuur van het bruinwier *Dictyota dichotoma* langsheen de Europese kust. Deze populatiestructuur werd onderzocht aan de hand van een zelf ontwikkelde mitochondriale merker die de intergenische spacer omvat tussen de genen nad 6 en nad 11. Analyse van 281 individuen afkomstig uit 19 staalnamelocaties in de Noordoost-Atlantische oceaan, de Middellandse Zee en Macronesië onthulde een aannemelijke mate van polymorfisme.

De genetische diversiteit blijkt het grootst te zijn in de zuidelijke range van *D. dichotoma*, maar tegen alle verwachtingen in werd er een aanzienlijk aandeel aan private haplotypes gevonden in de Noordoost-Atlantische oceaan. Mismatch distribution analyse toont aan dat Atlanto-Mediterrane populaties sterk gelijkaardig zijn, maar duidelijk verschillend van de populaties in Macronesië.

Indien we tot meer geconsolideerde hypotheses willen komen en de geografische positie van eventuele glaciale refugia willen aanduiden, is het noodzakelijk om de staalname sterk uit te breiden. Dit weerhoudt ons echter niet een voorlopige hypothese te formuleren op basis van de bekomen data. Onze gegevens suggereren een postglaciale rekolonisatie van de Noordoost-Atlantische kust vanuit een mogelijk glaciaal refugium ter hoogte van het Iberische schiereiland.

Sleutelwoorden: *Dictyota dichotoma*; mtDNA merkers; fylogeografie; postglaciale rekolonisatie.

ECOSYSTEM ENGINEERED HABITATS AS A POTENTIAL FOOD RESOURCE FOR SEVERAL JUVENILE FLATFISH SPECIES

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De verspreiding van mobiele organismen, zoals juveniele platvissen, kan verklaard worden door een aantal externe abiotische factoren zoals temperatuur, saliniteit, diepte en de sediment samenstelling (Gibson, 1997; Riou *et al.*, 2001). Tijdens hun leven migreren juveniele vissen van habitat tot habitat, gedreven door de drang om de juiste groei- en overlevingsomstandigheden te vinden. Ze migreren van de broedgebieden (spawning grounds) naar de kweekgronden (nursery grounds), gevolgd met een migratie naar hun adulte habitat (Gibson, 1997).

Biogene structuren in mariene ecosystemen, die een paar centimeter in de waterkolom steken, kunnen een groot effect hebben op de structuur en het functioneren van het mariene ecosysteem. Voorbeelden van dergelijke structuren zijn koraalriffen, kelpwouden, mossel- en oesterbanken en polychaetenkokers (Jones *et al.*, 1994). Deze structuren verschaffen heterogeniteit en structurele complexiteit aan mariene benthische milieus en kunnen functioneren als belangrijke habitat voor verschillende mariene organismen (Turner *et al.*, 1999; Callaway, 2006). Vaak worden de bouwers van deze biogene structuren ook ecosysteemingenieurs genoemd, door hun vermogen, om direct of indirect, de beschikbaarheid van hulpbronnen voor andere organismen te verhogen, door de omgeving te veranderen zowel fysisch, chemisch als biologisch (Jones *et al.*, 1994).

Biogene structuren gevormd door sessiele polychaeten, wonend in een koker die boven het zandoppervlak uitsteekt, kan als een schuilplaats fungeren voor juveniele vissoorten. Daarenboven hebben ze een diverse geassocieerde fauna die als potentiële prooien kunnen dienen (Kaiser *et al.*, 1999). Er worden ecologische eilanden gevormd, die gemiddeld een meer diverse en abundante gemeenschap huisvesten dan omringende zandbodems (Zühlke *et al.*, 1998). In deze studie werden kokerriffen gebruikt die gevormd zijn door *Lanice conchilega* en *Owenia fusiformis*. Deze twee sessiele kokerwormen komen frequent voor in de modderige en fijne sedimenten van de kustzone van de Noordzee.

Lanice conchilega heeft een wereldwijde verspreiding (Hartmann-Schröder, 1996) en leeft in een koker gemaakt van zandpartikels en biogene partikels, dit alles verbonden met een binnenste dunne organische laag. De koker heeft een diameter van 5 mm en kan tot 65 cm lang zijn. De top van de koker steekt 1-4 cm boven het sediment uit en eindigt in een franje van filamenten waarmee partikels in suspensie gevangen worden (Ziegelmeier, 1952). Deze soort is beschreven als een belangrijke ecosysteemingenieur, omdat het zijn omgeving in zo een belangrijke mate gaat beïnvloeden (Rabaut *et al.*, 2007; Van Hoey *et al.*, 2008).

Owenia fusiformis is een polychaete die tot 10 cm kan worden en leeft in taaie, maar flexibele kokers in het zand (Pinedo *et al.*, 2000). De koker, die tot 4 mm diameter kan zijn (Noffke *et al.*, 2009), is samengesteld uit schelpfragmenten die dakpansgewijs boven elkaar zijn gelijmd. De koker is iets langer dan de worm zelf en steekt ongeveer twee centimeters boven het oppervlak. Onlangs is bewezen dat *O. fusiformis* kan gezien worden als een ecosysteemingenieur die zandbanksystemen stabiliseert. Dit heeft duidelijke gevolgen voor de benthische gemeenschap die profiteren van de kleine stabiele niches in een anders sterk dynamische omgeving (Rabaut *et al.*, subm.).

De invloed van beide ecosysteemingenieurs op macrobenthische soorten en hun ecosysteemfunctionering is reeds uitgebreid bestudeerd, hun betekenis voor juveniele platvissen daarentegen is minder goed gekend. In deze thesis ligt de focus op twee veel voorkomende platvissoorten (*Pleuronectes platessa* en *Limanda limanda*). Het doel is om te weten te komen of deze juveniele platvissen actief zullen kiezen voor een habitat waar de ecosysteemingenieurs aanwezig zijn, en of dit gedrag veroorzaakt wordt door hogere densiteiten van potentiële prooien of ten gevolge van de schuilmogelijkheden tussen de kokers en dus minder zichtbaar voor predators.
Twee verschillende geografische gebieden werden geselecteerd. Eén gelegen in het Belgische deel van de Noordzee (BDNZ), dat gedomineerd werd door *O. fusiformis* als ecosysteemingenieur. Het andere gebeid was gelegen in het Nederlandse deel van de Wadden Zee (NDWZ), waar *L. conchilega* de meest voorkomende ecosysteemingenieur was. In beide geografische gebieden werden twee

subzones aangeduid, gebaseerd op de densiteiten van de aanwezige ecosysteemingenieurs (zones waar hoge densiteiten aanwezig waren en zones waar de ecosysteemingenieur in veel lagere densiteiten/niet aanwezig was). De platvissen gevangen in beide gebieden werden onderverdeeld in twee leeftijdscategorieën: leeftijdsklasse 0 bevat individuen tussen 5 en 9 cm en leeftijdsklasse 1 bevatte dan weer individuen tussen 9.1 en 13 cm (Beyst *et al*., 1999; Amara *et al*., 2001). In leeftijdsklasse 0 werden er geen individuen kleiner dan 5 cm geanalyseerd, omdat deze kleinere individuen afhankelijk zijn van meiobenthos als voedselbron, terwijl grotere individuen gaan overschakelen op macrobenthossoorten (Aarnio *et al*., 1996). In het labo werden per geografisch gebied, per habitatzone en per leeftijdsklasse van *P. platessa* en *L. limanda* 10 individuen geselecteerd voor verdere maaganalyses (Rijnsdorp *et al*., 2001). Alle prooiorganismen gevonden in de maag en het darmkanaal werden indien mogelijk tot op soortsniveau gedetermineerd. De biomassa (mg AFDW) alsook het aantal prooien gevonden in het spijsverteringskanaal werden bepaald.

De densiteiten van de gevangen platvissen (per 100m²), per gebied, per zone en per leeftijdsklasse werden geanalyseerd met een algemeen lineair model. De densiteiten en biomassa's van de verorberde organismen werden geanalyseerd met zowel univariate als multivariate methodes.

Pleuronectes platessa leeftijdsklasse 0 (NDWZ) werd in hogere densiteiten gevangen in de zones waar *L. conchilega* aanwezig was als ecosysteemingenieur, in deze zones bleken de platvissen ook een significant hogere fullness index te hebben. Deze significante indicatie was ook te zien in de biomassa van de soorten gevonden in het spijsverteringskanaal. De densiteiten, daarentegen, vertonen een tegenovergestelde trend. De hoge biomassa's die *P. platessa* had verorberd in het NDWZ was bijna volledig te wijten aan predatie op de ecosysteemingenieur, *L. conchilega*. Het hogere aantal verorberde prooien in de zones zonder ecosysteemingenieur was dan weer ten gevolge van *Spio* spec., een kleine polychaete. Blijkbaar gaat *P. platessa* bij de afwezigheid van *L. conchilega* zich vooral richten op kleinere polychaeten, die in grote densiteiten aanwezig zijn, hier *Spio* spec. Voor *P. platessa*, leeftijdsklasse 1 gevangen in de Nederlandse Wadden Zee was een gelijkaardige trend gevonden als bij leeftijdsklasse 0.

Pleuronectes platessa leeftijdsklasse 1 was in significant hogere densiteiten gevangen in de zones waar *O. fusiformis* aanwezig was als ecosysteemingenieur. In tegenstelling tot dit gegeven staat dat zowel de fullness index als het aantal en de biomassa van de verorberde soorten hoger was in de zones waar geen ecosysteemingenieur aanwezig was. In aantal lijkt *L. conchilega* een belangrijke prooisoort buiten het habitat van *O. fusiformis*, terwijl *Caprellidae* spec. zowel in aantal als in biomassa de belangrijkste prooisoort was in de zone waar de ecosysteemingenieur aanwezig was. *Owenia fusiformis* was niet gevonden als belangrijke prooisoort, wat mogelijks te wijten is aan de kokerstructuur. *Caprellidae* spec., daarentegen, is wel een belangrijke prooi en zijn aanwezigheid is volledig ten gevolge van de ecosysteemingenieur, omdat deze amphipoden zich via aanhangsels vastklampen aan kokers en andere structuren (Guerra-Garcia *et al*., 2002).

Juveniele *L. limanda* leeftijdsklasse 0, BDNZ, is significant in hogere densiteiten gevangen in de zone waar de ecosysteemingenieur, *O. fusiformis*, aanwezig was. Zoals *P. platessa* leeftijdsklasse 1, is ook hier de fullness index, het aantal en biomassa van de verorberde prooisoorten hoger in de zone waar de ecosysteemingenieur afwezig was. Deze inverse trend is vooral veroorzaakt door *Caprellidea* spec. en *Hydrozoa* spec.

Juveniele platvissen van zowel *P. platessa* als *L. limanda* gaan actief selecteren voor een habitat dat gedomineerd werd door ecosysteemingenieurs. Deze keuze kan deels verklaard worden door het voedselvoordeel, dit is zeker het geval voor *P. platessa* die gevangen zijn in de gebieden gedomineerd door *L. conchilega*. In de *O. fusiformis* habitats was voor *P. platessa* geen dergelijke relatie zichtbaar. De significant hogere densiteiten van *L. limanda* in de gebieden van *O. fusiformis* werden niet verklaard door een verhoogd voedselvoordeel. Deze juveniele platvissen hebben dus een ander voordeel voor zich in deze habitat te bevinden. Wij suggereren dat de platvissen deze habitat als schuilplaats gebruiken tegen potentiële predators, en prefereren zich te voeden buiten deze habitats.

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ADAPTATIE OP HET RODOPSINE GEN IN DE ZANDGRONDELGROEP OP FYLOGENETISCH EN POPULATIEGENETISCH NIVEAU

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Ondanks het grote potentieel voor genmigratie en het gebrek aan fysische barrières in het mariene milieu, lijkt een steeds groeiend aantal studies aan te tonen dat lokale adaptatie wel degelijk mogelijk is in mariene organismen. Om deze processen van selectie en lokale adaptatie goed te begrijpen, is er nood aan meer onderzoek en vooral aan goede modelsystemen. Een goed modelsysteem om deze processen te onderzoeken, is het mechanisme van spectrale fijnregeling van visuele pigmenten. Visuele pigmenten zijn gelegen op de staafjes en kegeltjes van het netvlies en zorgen voor de lichtcaptatie. Mariene organismen gebruiken hun zicht bij het zoeken van partners, voedsel en goede nestplaatsen en bij het migreren en het ontwijken van predatoren. Het is dan ook belangrijk dat ze hun visuele pigmenten kunnen aanpassen aan de heterogene lichtcondities die te vinden zijn binnen het mariene milieu.
Een goed visueel systeem om lokale adaptatie te bestuderen, is te vinden bij het dikkopje *Pomatoschistus minutus*. Het dikkopje maakt deel uit van de zandgrondelgroep. Dit is een groep van verwante soorten behorende tot vier genera (*Pomatoschistus*, *Gobiusculus*, *Knipowitschia* en *Economidichthys*) die diverse habitatten (zoet, brak en zout) benutten met verschillende lichtcondities. Omdat deze soorten vooral 's nachts actief zijn, is het rodopsine gen (*RH1* gen) het beste kandidaat-gen om selectie te bestuderen. Binnen deze thesis werd een combinatie gemaakt tussen een fylogenetische en populatiegenetische benadering. In een eerste deel werd op fylogenetisch niveau de vraag gesteld of selectie op het rodopsine gen een rol heeft gespeeld in de soortvorming van deze negen nauw verwante soorten uit de zandgrondelgroep. Om een beter inzicht te verkrijgen in hoe soortvorming binnen de zandgrondelgroep tot stand gekomen is, kan het interessant zijn te kijken welke rol selectie op het rodopsine gen speelt of gespeeld heeft op populatiegenetisch niveau. Het tweede deel van deze thesis onderzocht dan ook de populatie differentiatie van *P. minutus* op microschaal. Als studiesystemen werden hiervoor twee microsystemen gekozen namelijk de Nederlands-Belgische kust en de Baltische zee. Verder werden ook stalen uit de noordelijke Noordzee en Kattegat genomen om zo een overgang tussen beide systemen te kunnen maken. Het doel van dit onderdeel was het onderzoeken of adaptatie op het *RH1* gen mogelijk is binnen een marien systeem en hoe diverse mariene systemen van elkaar verschillen. Om de verschillende onderzoeksvragen te kunnen beantwoorden, werd een sequentieanalyse uitgevoerd op het *RH1* gen.
Uit de analyse van het eerste deel kon positieve selectie aangetoond worden op het *RH1* gen op fylogenetisch niveau en bleek verder dat de verschillende soorten goed aangepast lijken aan de verschillende lichtcondities van het specifieke habitat. Verder werden nieuwe potentiële aminozuren aangeduid die de spectrale fijnregeling van het rodopsine kunnen beïnvloeden. Een laatste belangrijk besluit dat genomen kon worden in dit deel is dat rodopsine best niet als neutrale merker kan gebruikt worden in neutrale fylogenetische analyses. Op populatiegenetisch niveau werden de ruimtelijke en temporele kenmerken van lokale adaptatie binnen één van de vertegenwoordigers van de zandgrondelgroep, namelijk *Pomatoschistus minutus*, onderzocht. Op basis van neutrale en selectiemerkers werd een verschil gevonden tussen de verspreidingspatronen wat een indicatie geeft dat selectie een rol heeft gespeeld op het *RH1* gen. In de Noordzee werden indicaties voor balancerende selectie op het *RH1* gen aangetoond. Er werd een hoog polymorfisme vastgesteld op het *RH1* gen wat verklaard kan worden door de heterogene lichtomgeving waarin *P. minutus* leeft of door de verschillende habitatten die het dikkopje benut binnen zijn levenscyclus. Bovendien werd een trend waargenomen dat dikkopjes die migreren naar de estuaria rodopsine variaties bezitten die een beter zicht verzekeren in het brakwater. In de Baltische Zee werden indicaties voor positieve selectie waargenomen op functioneel belangrijke aminozuren. De individuen van de verschillende locaties lijken dus aangepast aan de heersende lokale lichtomstandigheden.

Deze thesis toont aan dat natuurlijke selectie zowel een rol speelt in de soortvorming als in de evolutie binnen een soort. Hierdoor werd aangetoond dat lokale adaptatie wel degelijk mogelijk is in soorten binnen het mariene milieu, dit ondanks het grote potentieel voor genmigratie en het gebrek aan fysische barrières.

EEN GEZONKEN LEEFWERELD: DE PROBLEMATIEK VAN DE IDENTIFICATIE EN INTERPRETATIE VAN SCHEEPSVONDSTEN VAN DE S.S. LEERDAM, W.A. SCHOLTEN, S.M.S. PRANGENHOF, S.S. KILMORE, EN QUEEN OF THE CHANNEL: TESTSTUDIE IN DE ONDERWATERARCHEOLOGIE

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Inleiding

Het onderzoek start vanuit 15 artefacten van de S.S. Leerdam, 40 van de W.A. Scholten, 79 van de S.S. Kilmore, 39 van de S.M.S. Prangenhof en 5 van de Queen of the Channel (hierna respectievelijk: Leerdam, Scholten, Kilmore, Prangenhof & Queen). Om de identificatie en de interpretatie van de artefacten beter te begrijpen, wordt eerst de historische situering van de schepen geschetst. We moeten tevens in gedachten houden dat de artefacten al een traject hebben afgelegd alvorens ze in dit onderzoek terechtkwamen. De resultaten beschreven in dit artikel zijn dan ook zonder twijfel door het eerdere life trajectory van de artefacten beïnvloed. Bovendien zal van niet elk object dit traject volledig achterhaald kunnen worden.
In het kader van dit artikel wordt getracht representatieve voorbeelden aan te halen van elk typisch probleem waarmee men bij de identificatie en interpretatie geconfronteerd wordt. We onthouden wel dat elk wrak initieel met elk van deze problemen, zoals de identificatie van het wrak, te maken heeft. Voor de interpretatie combineren we de functie van de artefacten met de historische situering van het wrak en met het interieur van het schip. Concreet proberen we na te gaan hoe de identificatie van de artefacten past binnen de ruimte van de schepen en of de tijdsgeest overeenkomt met de functie en vormgeving van elk artefact.

De wrakken

Scholten en Leerdam

Beide wrakken behoorden tot de *Nederlandsch-Amerikaansche Stoomvaart Maatschappij* (voortaan: NASM). De geschiedenis van deze maatschappij begon in 1850 naar aanleiding van de verhoogde vraag naar transport van passagiers en vracht over de Atlantische Oceaan naar Amerika (GUNS 2004: 9). Pas bij de derde poging tot oprichting werd in 1870 de NASM opgericht. Het derde schip dat de NASM in bezit nam, was de Scholten. Voor de aankoop van dit schip werd in 1873 de goedkeuring gegeven (GUNS 2004: 11). In 1887 kwam de Scholten in aanvaring met het Engelse stoomschip de Rosa Mary en zonk ten gevolge van de opgelopen schade. Het stoomschip de Leerdam werd in 1881 gebouwd. (GUNS 2004: 17). Het schip werd vanaf 1882 gehuurd en pas in 1889, het jaar dat het schip zonk, verwierf de NASM er de volledige eigendom van (GAR : inv. nr. 318.16-57).

Kilmore

Voor wat betreft het vrachtschip de Kilmore werd minder informatie gevonden. In dit geval volgt het gebrek aan bronnen vermoedelijk uit het feit dat het schip, in tegenstelling tot de twee vorige schepen, geen deel uitmaakte van één of andere grote en belangrijke organisatie. De Kilmore werd door Wm. Johnston & Co. in het jaar 1890 gebouwd voor de kleine rederij Edwards' S.B. Co. Er wordt ook vermeld dat het schip gezonken is nabij West Hinder op 29 juli 1906 na een aanvaring met het Britse stoomschip de Montezuma op het traject Antwerpen-Liverpool met een grote, maar niet gespecificeerde, lading (Hocking 1989: 283).

Prangenhof

Bij de meeste wrakken is de identiteit ervan bij de vondst niet gekend. Meestal wordt er dan gezocht naar een herkenning via de naam op de romp van het wrak of via bouwplaten die onthullen wanneer en door wie een onderdeel gemaakt werd. De naam Prangenhof werd via een bouwplaat teruggevonden. Deze vermeldt dat het schip in 1902 gebouwd werd door een zekere J.H. Techlenborg in Bremershaven-Geestemunde (Termote, 2003: 88). Zo werd de naam Prangenhof succesvol gelinkt aan het wrak.
De datering van de Prangenhof gebeurde ook via een aantal andere elementen, waaronder de munitie. De dateringen hiervan lopen van het einde van de negentiende eeuw tot en met 1914 (Termote, 2003: 38). Dit geeft geen zekerheid over de exacte zinkdatum van het schip maar als *terminus post quem* betekent dit uiteraard wel dat het schip na het einde van de negentiende eeuw gezonken moet zijn. De Prangenhof was een vissersboot die pas laat is toegetreden tot de

Vorpostenflottille Flandern. Op vier april 1916 liep ze vast op een zandbank en werd ze achtergelaten (Termote, 2003: 115).

Queen of the Channel
Het passagiersschip de Queen werd in het jaar 1935 gebouwd in Dumbarton door de fabriek William Denny & Brothers Ltd (Hocking, 1989: 573). De eerste eigenaar van het schip was de *New Medway Steam Packet Company Ltd* (voortaan: NMSC). Later kwam deze maatschappij in handen van de *General Steam Navigation Company* (Lee, 2008).
Op 28 mei 1940 is het schip gezonken in de Noordzee. Het maakte op dat moment deel uit van de vloot die de Britse troepen evacueerde vanuit Duinkerke (Hocking, 1989: 573). Aangezien ze ter hoogte van Nieuwpoort zonk, weten we dat ze langs route Y evacueerde, één van de drie uitgetekende routes om Duinkerke te evacueren (Ellis, 1954: 185).
De historische achtergrond van de Queen binnen de *General Steam Navigation Company* begint met de *Medway Steam Company* (voortaan: MSC). Deze maatschappij werd opgericht in 1837. Een tweede MSC werd opgericht in 1881. De NMSC werd uiteindelijk door overname gevormd in 1919. Omstreeks 1924 werd ze de *Queen Line* genoemd. In deze hoedanigheid werd in 1935 ook de Queen aangekocht.[1]
In 1824 werd de *General Steam Navigation Company* (voortaan: GSNC) gesticht. De GSNC werd in 1920 zelf overgenomen door de *Peninsular & Oriental Steam Navigation Company*. Het bestuur van de maatschappij bleef ongewijzigd. Na de overname door de NMSC in 1936 van de GSNC werd deze naam echter nog een aantal jaren verder gebruikt (Boyle, 2007).

Identificatie van de artefacten
Voor wat betreft de identificatie van de artefacten zijn slechts een aantal uitzonderlijke artefacten geselecteerd voor deze samenvatting. Voor wat betreft de beschrijving van de andere artefacten (Verrijken, 2008: 41-79) en de catalogus (Verrijken, 2008: 125-299) wordt doorverwezen naar de scriptie.

Artefacten van de Scholten
Porselein
Uit het onderzoek van 2007 zijn er drieëndertig stukken porselein afkomstig van de Scholten. Van deze drieëndertig porseleinen artefacten zijn er twaalf ondertassen en negentien kopjes met identiek dezelfde vorm, één kom en één bord. De stukken porselein werden gemakkelijk geïdentificeerd aan de hand van het merkteken aan de onderkant: "P.REGOUT&C° MAASTRICHT"[2] Met een merkboekje van Polling (2006: 32-34) kunnen we dit merkteken classificeren als beeldmerk 70, type A of in het geval van de kopjes als beeldmerk 71, type A. Deze twee beeldmerken worden door Polling onderscheiden door de aanwezigheid van een decornaam. Bij de kopjes was er, mijns inziens, echter geen plaats genoeg voor een decornaam. De decornamen die voorkomen bij deze artefacten zijn "Border", "Banka", "Pekin", "Lasso" en "Indian Traf" (vermoedelijk een afkorting van Indian Traffic). Om het exacte jaartal van fabricatie te geven, kunnen we gebruik maken van de turfdatering op de artefacten (Polling 2006: 12). In dit geval is de datering 1887.

Artefacten van de Leerdam
Porselein
Van de Leerdam hebben we twee stukken porselein, een diep en een plat bord. Er staat een stempel op de achterzijden en een glazuurversiering in de vorm van een vlaggetje op de vlag. Op het groen-wit-groene vlaggetje staan de letters "N.A.S.M.", die wijzen op het eigendom van de *Nederland-Amerika Stoomvaart Maatschappij*. Op de stempel aan de onderzijde vinden we de informatie "ALBERT . PILLIVUYT & CIE FOËCY (CHER)". Hierdoor weten we dat de twee borden gemaakt zijn in de fabriek van Albert Pillivuyt in Foëcy in Cher. (Danckert 1973: 84-85).

Artefacten van de Kilmore
Keramiek
Van de Kilmore zijn er negenenzeventig artefacten opgedoken. Vier artefacten hebben een Grieks opschrift in de glazuurtekening. Op één artefact zien we "ΥΓΕΙ" met daarachter nog de aanzet van wat op het eerste been van een A lijkt. Op een volgend artefact is enkel "ΓΕ" duidelijk te zien. Op nog een artefact zien we de eindletter "Σ", waarschijnlijk voorafgegaan door een A. Op het laatste artefact zien we eerst hetzelfde bloempje en vervolgens de letter "M". In het geheel zouden we het woord "ΜΥΓΕΙΑΣ" kunnen krijgen, helaas zonder betekenis. Wel betekenisvol is het spreekwoord

[1] Niet te verwarren met de Queen of the Channel (2) van na de Tweede Wereldoorlog.

[2] Dankzij deze verwijzing kwamen we op het spoor van de plaats van fabricatie. De fabriek van P(etrus) Regout is de voorloper van de aardewerkfabriek Sphinx, die nog steeds bestaat (Polling 2006).

"ΕΙΣ ΥΓΕΙΑΝ ΜΑΣ". Dit betekent "op onze gezondheid". Tenzij er tussen elk woord een bloempje staat kunnen we deze tekst niet voor zeker houden. De eerste twee scherven weerhouden me ervan om dit te aanvaarden, omdat er voor de Y telkens geen spoor is van een bloempje, maar zoals te zien is, kan dat ook met de breuk te maken hebben.

Artefacten van de Prangenhof

Keramiek

Het enige keramische voorwerp uit de Prangenhof is een zalfpotje uit faience fine (Termote, 2003: 137). Het is een merkwaardig object omdat de inhoud zich nog deels in het potje bevindt.

Hout

Bij de houten artefacten identificeren we onder meer een Mauser 71. Het bestudeerde type is waarschijnlijk een marine versie. De 71 in de naam wijst op het jaartal van de officiële aanvaarding van het ontwerp. De productie liep waarschijnlijk van 1872 tot 1882[3].

Artefacten van de Queen of the Channel

Zilver en het slot

Vervolgens hebben we drie zilveren vorken en één zilveren lepel. Op de eerste vork staan de blokletters "G.S.N.Co". Aan de achterkant staat er de stempel van de maker met "M & W UNPLATED". De M & W wijst waarschijnlijk op de makers Mappin en Webb, die voluit vermeld staan op artefact nummer 68. Op de tweede vork staan de letters "GSNC" maar dan in klassieke hoofdletters. Op de derde vork staat er op de steel "NMSC" gegraveerd in klassieke hoofdletters. Aan de onderkant staat er de stempel "*1A MAPPIN & WEBB U". Op de lepel staat onderaan de stempel "*1A MAPPIN & WEBB U" en staan de letters "NMSC" bovenaan de steel in klassieke hoofdletters. De U van het derde en het vierde artefact is een jaarkenmerk van zilver uit Londen dat gebruikt werd in het jaar 1912 (Giorgio, 2007).

Zoals vermeld behoort de Queen tot een maatschappij die heel wat overnames meemaakte. Het derde en het vierde artefact zijn gemaakt in 1912. Dit is dus wanneer er enkel sprake is van de MSC. De N lijkt echter pas later toegevoegd op de twee artefacten. We denken dus dat de twee artefacten oorspronkelijk voor de MSC zijn aangekocht en dat aan de inscriptie bovenaan toen pas een N is toegevoegd. Van de eerste twee artefacten kennen we geen exact jaar van fabricatie. Ze horen meest waarschijnlijk tot de periode na 1936, wanneer de GSNC de NMSC overgenomen heeft. Als we het lettertype bekijken, kunnen we daarbij ook nog vermoeden dat het eerste artefact jonger is dan het tweede, omdat het lettertype van het tweede artefact meer lijkt op de laatste twee.

Interpretatie van de ensembles

Voor de interpretatie werden de artefacten gekoppeld aan werkwoorden die beschrijven hoe ze gebruikt werden, zodat de verschillende werkwoorden visualiserend werken en een beeld vormen van het actieve leven aan boord. In ieder geval hoort bij elk schip het leven en werken van de bemanning. Voor Leerdam en Scholten komt daar het leven van de passagiers bij en het vervoerd worden van de vracht. Voor wat betreft de Prangenhof is er een relatie met oorlogvoeren, maar ook het vissen staat in verband met de oorspronkelijke bestemming van de boot. De Kilmore wordt gelinkt met vracht die vervoerd wordt en het leven en werken van bemanning. Met de Queen linken we nog de werkwoorden het leven van de passagiers en de vracht die vervoerd wordt.

Het is echter opvallend hoe bij de Scholten vooral de vracht in het ensemble vertegenwoordigd is. De Prangenhof heeft een lacune in zijn ensemble aangezien zijn functie als vissersschip niet aanwezig is. Op de Kilmore zijn leven en werken van de bemanning echter amper vertegenwoordigd in het ensemble. Voor wat betreft de Queen krijgen we het minst duidelijke beeld. Gelukkig zijn er reeds in een ander onderzoek van Termote (2000: 42) artefacten verschenen van de Queen. Het is echter treffend dat geen van de artefacten die deel uitmaken van het ensemble te maken hebben met oorlogvoeren.

Problematieken

Het initiële doel van dit artikel bestond erin een aantal wrakvondsten te bekijken binnen de ruimtes van het schip om zo een beter beeld te krijgen van het leven aan boord van een negentiende- of twintigste-eeuws schip. Er werd getracht de artefacten toe te wijzen aan hun oorspronkelijke ruimte in het schip. De nodige informatie hiervoor staat echter niet tot onze beschikking. Toch zouden dergelijke exacte gegevens een enorme bijdrage kunnen leveren aan de interpretatie van de artefacten, zoals te weten dat iets in een vrachtruim gevonden is.

De representativiteit van het aantal voorwerpen heeft een invloed op de lacunes die bij de interpretatie van dit onderzoek naar boven zijn gekomen. Het zou louter toeval kunnen zijn dat er bijvoorbeeld onder het kleine aantal artefacten van de Queen geen enkel het oorlogvoeren vertolkte. Hoe dan ook is het duidelijk dat er een verwachtingspatroon werd gecreëerd voor wat betreft de

[3] Het advies over het specifieke Mausertype is afkomstig van Willem Jonckheere.

functies van de artefacten aan de hand van de historische achtergrond van de schepen en dat de verwachting niet ingelost werd.
Om voorgaande problemen beter te kunnen behandelen, moet in de toekomst een grotere basis gevormd worden voor dergelijke negentiende- en twintigste-eeuwse wrakvondsten. Het aanbod aan vergelijkingsmateriaal dient vergroot te worden om te komen tot een betere identificatie voor wat betreft scheepsmateriaal. Veel informatie wordt nu enkel teruggevonden in het aanbod van antiquairs in plaats van in wetenschappelijke bronnen. Nog belangrijker is uiteraard de publicatie van dat soort onderzoeken, zodat de resultaten toegankelijk zijn.

Besluit

Het voorbije onderzoek heeft aangetoond dat het onderzoek van losse vondsten uit scheepswrakken potentieel waardevolle informatie kan opleveren. Zeker in België is er nog een tekort aan wetenschappelijke publicaties met betrekking tot onderwaterarcheologie. Dit onderzoek was een poging om voor een deel de basis voor toekomstig onderzoek te vergroten. Door meer onderzoek uit te voeren op losse scheepsvondsten en de publicatie hiervan, wordt een noodzakelijke basis gecreëerd voor later vergelijkend en interpretatief onderzoek.

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APPLICANTS
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SPECIES STRUCTURE AND BIOGEOGRAPHY OF *PSEUDO-NITZSCHIA PUNGENS*

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It is a long-held belief that marine microbial plankton communities consist of a limited number of ubiquitously distributed species that lack biogeographic structuring (Palumbi, 1994, Finlay, 2002, Carr *et al.*, 2003). This is not only attributed to the fact that oceans are fluid environments, lacking obvious barriers to gene flow, but also to the enormous population sizes and (supposedly) high passive dispersal potential of planktonic micro-organisms, which would effectively dampen diversification and speciation through allopatric mechanisms. This belief however, which is largely based on morphology-based taxon delineations, has recently been challenged by molecular-genetic investigations which are transforming our understanding of marine biodiversity, particularly regarding micro-organisms. Many taxa, which were considered single species on the basis of morphological criteria, have been shown to contain high levels of genetic diversity. As a result, several taxa that were believed to be cosmopolitan are now recognized as complexes of (semi)cryptic species, some of which have restricted geographic distributions (e.g. Kooistra *et al.*, 2008). A variety of evolutionary processes, both allopatric and sympatric, has been proposed to explain the presence of such genetic diversity in the marine environment (de Vargas *et al.*, 1999, 2002, Darling *et al.*, 2004; Goetze, 2005; Darling & Wade, 2008).
Diatoms are one of the most abundant and diverse groups of eukaryotic planktonic micro-organisms. Among them, the pennate diatom genus *Pseudo-nitzschia* has recently received much attention as some of its representatives are able to produce domoic acid, a neurotoxin responsible for amnesic shellfish poisoning (Bates and Trainer, 2006). *Pseudo-nitzschia* species occur in coastal and open-ocean waters worldwide and, based on morphological criteria, most appear to have a cosmopolitan distribution (Hasle, 2002). Recent studies however suggest that intraspecific genetic variation may be considerable in *Pseudo-nitzschia* species. For example, molecular probes designed for identification of certain species (Scholin *et al.*, 2003) appeared to be successful only in certain regions and not in others (e.g. Orsini *et al.*, 2002; Parsons *et al.*, 1999). In addition, differences in toxicity have been observed between strains belonging to the same morphospecies and conflicting data on the toxicity of species have been reported (Bates *et al.*, 1998). The occurrence of (pseudo)cryptic variation within *Pseudo-nitzschia* species would not only have important implications for harmful algal bloom monitoring, but may also affect our perception of geographical or temporal variation patterns within established species (Parsons *et al.*, 1999).
Pseudo-nitzschia pungens (Grunow ex Cleve) Hasle is one of the most commonly reported, potentially toxic representatives of the genus worldwide, and is also one of the most common species in the North Sea (Vrieling *et al.*, 1996; Hasle 2002). Interestingly, *P. pungens* isolates from various geographic areas have been shown to exhibit different abilities to produce domoic acid (until now toxic clones have only been reported from New Zealand and the Pacific coast of the USA), but the underlying causes of this variation remained unclear.
The present study was designed to obtain a better understanding of the species structure and biogeography of *Pseudo-nitzschia pungens*. More specifically, we wanted to find out (1) whether *P. pungens* is a single species or comprises multiple (semi)cryptic species, by analyzing variation patterns in selected molecular markers, sexual compatibility and morphological characteristics on local, regional and global scales; (2) whether the distribution of *P. pungens* is truly cosmopolitan or whether potential (semi)cryptic entities show different, possible restricted, geographic distributions; and (3) whether intraspecific, geographical genetic structuring could be detected by investigating population genetic diversity and differentiation both regional and global scales.

The ***first part*** of the thesis (chapters 2 and 3) deals with a detailed analysis of morphological, reproductive and molecular-genetic characteristics and variation patterns of regional (North Sea) and global isolates of *P. pungens*.

Chapter 2 reports on the basic cell and life cycle features, and more specifically sexual reproduction, auxosporulation and mating system of a series of monoclonal *P. pungens* isolates from various localities in the southern part of the North Sea. During the mitotic cell cycle, the two plate-shaped chloroplasts were girdle-appressed during interphase and mitosis. After cytokinesis, the chloroplasts moved onto the parental valve and remained there during the formation of the new hypovalve and until separation and re-arrangement of the sibling cells within the cell chain. Clones were shown to be heterothallic and sexual reproduction involved physiological anisogamy. Meiosis I was cytokinetic and accompanied by chloroplast division. Meiosis II involved karyokinesis but not

cytokinesis and preceded the rearrangement and contraction of the two gametes. Auxospore development was accompanied by deposition of a transverse and then a longitudinal perizonium. The four chloroplasts of diploid auxospores did not divide, and behaved synchronously during the two acytokinetic mitotic cycles accompanying the deposition of the initial thecae. Just before the first division of the initial cell, the chloroplasts shifted onto the valves (two per valve). The division of the initial cell was not accompanied by chloroplast division and so the two daughter cells received two chloroplasts each. Two modes of abrupt cell size reduction were detected and described.

In **chapter 3**, genetic, reproductive and morphological variation patterns were studied in 193 global strains (six geographically distant areas in the North Sea, Atlantic and Pacific Oceans) of *P. pungens* to assess potential intraspecific variation and biogeographic distribution patterns. Genetic differentiation between allo- and sympatric strains was investigated using the ITS1 – 5.8S – ITS2 rDNA region. Phylogenetic analyses revealed three strongly supported ITS clades (I-III). All available clones were involved in crossing experiments to assess mating barriers. Clones of opposite mating type were sexually compatible within clades I and II, and viable F1 hybrid offspring were produced in crosses between them. The three ITS clades showed slight but consistent morphological differences. Strains of clade I were found to morphologically correspond to the nominate *P. pungens* variety while strains of clade II fit the circumscription of *P. pungens* var. *cingulata*, described by Villac and Fryxell in 1998. Members of the third clade have been described as a new variety, *P. pungens* var. *aveirensis*, based on morphological features and evidence for reproductive isolation (Churro et al., in press, appendix). The three ITS clades showed different geographic distributions. Clade II was restricted to the NE Pacific, whereas clones belonging to clade III originated from geographically widely separated but predominantly (sub)tropical-warm temperate areas (Vietnam, China, Mexico and Portugal). ITS clade I was recovered in all locations studied: the North Sea (Belgium, the Netherlands, France), the eastern and western N Atlantic (Spain, Canada), the NW and S Pacific (Japan, New Zealand) and the NE Pacific (Washington State). Clade I thus appears to be globally distributed in temperate coastal areas and provided the first strong evidence for the global distribution of a biologically, genetically and morphologically defined diatom species.
Hybridization between genetically distinguishable taxa provides opportunities for investigating speciation. While hybridization is a common phenomenon in various macro-organisms, natural hybridization among micro-eukaryotes has only rarely been documented.

In **chapter 4** we used a nuclear and a chloroplast molecular marker to demonstrate the presence of natural hybrids of two genetically and morphologically distinct varieties of the marine planktonic diatom *Pseudo-nitzschia pungens* (clades I and II, corresponding to the vars. *pungens* and *cingulata*) in a contact zone in the northeast Pacific. Cloning and sequencing of the rDNA internal transcribed spacer region revealed strains containing ribotypes from both varieties, indicating hybridization. Both varieties were found to also have different chloroplast encoded rbcL sequences. Hybrid strains were either hetero- or homoplastidial, as demonstrated by Denaturing Gradient Gel Electrophoresis, which is in accordance with expectations based on the mode of chloroplast inheritance in *Pseudo-nitzschia*. While most hybrids are probably first generation, there are also indications for further hybridization. Morphologically, the hybrids resembled var. *pungens* for most characters rather than having an intermediate morphology. Despite the occurrence of occasional hybridization between clades I and II, both clades appear to persist, even in sympatry, and can therefore be regarded as two independently evolving lineages.

In the ***second part*** of this thesis we studied genetic structure at the population level to increase our understanding of the underlying mechanisms that may have caused geographically structured variation patterns in the biodiversity of marine holoplanktonic organisms in general, and in *P. pungens* in particular. We focused on *P. pungens* var. *pungens*, which was found to have a widespread distribution in southern and northern temperate areas in both the Atlantic and the Pacific Oceans.

In **chapter 5** the spatial and temporal variation patterns in population genetic structure of *P. pungens* var. *pungens* populations in heterogeneous water masses of the Southern Bight of the North Sea was investigated using six microsatellite markers. We isolated 310 cells from contrasting coastal environments (sea, estuary and non-tidal saline lagoon) and with different degrees of connectivity (from complete isolation to supposedly free exchange between environments) on a scale of ca. 100 km. No evidence for genetic differentiation was found, indicating that different environmental conditions or partial isolation does not restrict gene flow between populations at a local to regional scale. Furthermore, broadening of our sampling area by the inclusion of isolates from the German, French and the Dutch parts of the North Sea (ca. 650 km), suggest the presence of homogenous population structure for this species in large parts of the North Sea.

In **chapter 6** global patterns of population structure and gene flow were investigated in *P. pungens* var. *pungens* to find out whether *P. pungens* var. *pungens* consists of a single homogenous global population or if genetic structure could be detected, providing clues for barriers to gene flow in global marine species. 242 isolates from different localities in the Atlantic and the Pacific were genotyped using six polymorphic microsatellite loci. Population genetic analyses indicate that even within a globally distributed lineage, significant population differentiation exists, suggesting restricted gene-flow on a global scale. Our results provide indications that allopatric processes may play an important role in the diversification of potentially high-dispersal marine plankton, such as diatoms. Our study is the first to investigate population genetic structure of a marine planktonic diatom on a global scale using microsatellite markers, and is a first step in understanding genetic structure at the species level and in determining the biogeographic extent of planktonic micro-organisms.

SEA (IN)SIGHT – FROM PHYLOGEOGRAPHICAL INSIGHTS TO VISUAL LOCAL ADAPTATION IN MARINE GOBIES

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Rationale for the study

Exactly 150 years ago, Charles Darwin described natural selection as the motor of the evolution of life. Natural selection is the process by which favorable heritable traits become more common in successive generations of reproducing organisms in comparison with unfavorable traits. Under natural selection, individuals tend to adapt to local environmental conditions, resulting in a pattern of **local adaptation**. Understanding the genetic basis of local adaptation is of prime interest in biology as it involves the role of natural selection in promoting evolutionary change. Since gene flow is thought to hamper adaptive population divergence, the established idea was that local adaptation might be rare or even absent in marine organisms. Today, indications for local adaptation have become increasingly documented, suggesting that natural selection is a potent evolutionary force in the 'open' ocean. Knowledge on adaptive evolution in marine organisms remains limited, yet crucial to improve our understanding of how evolution functions in the ocean. The aim of the doctoral thesis was to contribute to the knowledge on the importance of natural selection as evolutionary force in marine organisms and on the spatio-temporal scale of adaptive genetic variation in marine systems.

The reason for the lack of knowledge on adaptive evolution in the ocean is the shortage of suitable genetic systems to evaluate natural selection. One of the few promising models to elucidate the mechanism and importance of selection as evolutionary force is the spectral tuning mechanism of the **visual pigments** (VP) in marine vertebrates. This model identifies amino acid changes that are responsible for adaptation to specific environments. Moreover, visual pigments have a well-defined role in nature as they detect differences in the spectral composition of the environment. Therefore they have a strong effect on the evolution of organisms, providing an excellent system to study adaptive evolution at the molecular level. A candidate gene approach was followed to demonstrate local adaptation on the rhodopsin (*RH1*) gene, the VP located in the rods which determines the spectral sensitivity of dim-light vision. The sand goby *Pomatoschistus minutus* (Gobiidae, Teleostei; Dutch name: dikkopje), a common marine demersal fish along the European coasts, was selected as study model to realize the objectives of the doctoral thesis.

Outline of the thesis

The specific research question of the thesis was: '**Is visual local adaptation detectable on the rhodopsin gene of the sand goby?**' The possibility for visual local adaptation was studied on a geographic macro-scale (the European coasts) as well as on a micro-scale (the coastal and estuarine areas of the Southern Bight of the North Sea). An approach was adopted with five steps to demonstrate local adaptation in the wild:
Step 1. Revealing the neutral population structure of the species.
Step 2. Demonstrating that the populations differ for a heritable trait.
Step 3. Demonstrating that the population differences on the functional variation are due to selection as opposed to neutral processes (revealed in step 1).
Step 4. Establishing a link between functional variation and selection regimes.
Step 5. Demonstrating selection on a higher taxonomic level (on genus level) for the same trait.

Demonstrating of visual local adaptation

First, a **phylogeographic and population genetic analysis** derived from neutral markers was realized for the sand goby based on high quality mitochondrial and microsatellite genotypes (**Step 1**). An evolutionary scenario with temporally stable genetic structuring among populations was observed. It indicated that strong local selection would be able to override the effects of drift and gene flow, resulting in adaptive population divergence. Moreover, the robust phylogeographic and population genetic structure of the sand goby served as an appropriate neutral background to detect the effect of natural selection on the rhodopsin gene.
Second, the genetic basis for measured phenotypic differences in the maximum absorbance (λmax) of the retinal rods between sand goby populations was confirmed based on sequence analysis of the *RH1* gene (**Step 2**). Five amino acid sites were polymorphic at *RH1*, with some known to be

spectral tuning sites, sites with a significant effect on the λmax values of vertebrate rods. Moreover, sand goby sites were differentiated from each other based on the functional variation at *RH1*, including on the **spectral tuning** sites.

Third, based on two independent approaches it was demonstrated that the differences between sand goby populations on the functional variation at *RH1* are due to natural selection and not due to neutral processes (**Step 3**). Sequence-based neutrality tests detected unambiguously significant **signals of positive Darwinian selection** at the *RH1* gene. Moreover the comparison of the geographical distributions of the rhodopsin variation with the neutral marker-derived phylogeographic and population genetic structure revealed also a clear signature of local selection on the rhodopsin gene.

Fourth, a link was established between the functional variation at the *RH1* gene and a **selection regime** that the sand goby populations experience as well on a macro-scale (European coasts) as well on a micro-scale (coastal and estuarine areas of the Southern Bight of the North Sea) (**Step 4**). The solid differences in maximum environmental light transmittance (WMTL) between the various marine systems correspond well with the differences in the absorbance spectra of the retinal rods and the temporally stable differentiation on the functional variation at the *RH1* gene. Based on *RH1* variation sand gobies clustered according to the photic conditions of their habitat instead of historical or geographic proximity. The WMTL values of all sample locations were measured based on remote sensing data (in cooperation with MUMM, Management Unit of the North Sea Mathematical Models, a department of the Royal Belgian Institute for Natural Sciences).

Finally, adaptive molecular evolution on the rhodopsin gene was demonstrated in a phylogenetic framework among related species of the sand goby (the 'sand goby' group) that inhabit different photic environments in regards to turbidity, salinity and depth (**Step 5**). With the observation that different species are evolutionary adapted to their photic habitat at the *RH1* gene and that species with a similar selective regime have also an analogous genetic pattern at the *RH1* gene, the arguments are reinforced that selection on the candidate gene influences the contemporary population level in *P. minutus*.

All five steps have been fulfilled to detect local adaptation at the rhodopsin gene in *P. minutus*. Consequently, **clear evidence was provided for visual local adaptation in the sand goby**. The rhodopsin gene showed that the molecular basis of adaptation of proteins may occur by amino-acid replacements at a small number of critical sites. However, no matter how strong the indications are for visual local adaptation in *P. minutus*, new approaches are required to validate these results. They include common-garden experiments to measure relative fitness of individuals from different populations in an identical environment. Nevertheless, the observed pattern for rhodopsin is one of the strongest genetic signatures of natural selection yet reported in marine organisms. The signals of natural selection are common in marine organisms but it is usually difficult to know what was being selected for. Therefore this rhodopsin study suggests that local adaptation is possible in the sea, and that selective forces may explain function and shape patterns in the ocean.

Visual local adaptation on the Southern Bight of the North Sea

Visual local adaptation on the sand goby was also examined on a geographic micro-scale, namely on the coastal and estuarine areas of the **Southern Bight of the North Sea**. Within this region, sand gobies showed a high level of polymorphism on *RH1*. This polymorphism can most likely be maintained by the high heterogeneity of the light regime along the coastline of the North Sea. On the other hand, the heterogeneity can also be the outcome of the individual inshore-offshore migration patterns of juvenile sand gobies. The trend that estuarine migrants in the Scheldt have much more rhodopsin variants which are associated with brackish water than sand gobies sampled in open sea, showed that the observed genetic heterogeneity in the North Sea may be stabilized by different migration strategies within the population. Recent ecological studies based on biochemical markers studying the migration pattern of *P. minutus* between the Scheldt Estuary and open sea supported this hypothesis. There seems to be no obligate estuarine stage but a highly individual movement pattern in estuarine habitat use. The results of this study showed that their spectral sensitivity in turbid water may be a crucial factor in the individual exploitation of the estuarine habitat use.

Consequences of visual local adaptation

The **main consequence** of the evolutionary adaptation to light environment is that rapid changes in spectral habitat by human interference may be negative for the sand goby and other marine organisms. If marine fishes do not have the possibility to adapt physiologically to the new conditions, it will affect their visual breeding system and search for food. Consequently, changes in water clarity must be considered in monitoring programs to evaluate marine ecosystem change.

Subsequently, the rhodopsin case shows that adaptive variation can also be a significant component of intraspecific biodiversity. Since neutral genetic data often fail to recognize locally adapted populations, this means that marine management by using only neutral genotypes, might misidentify management units, leading to erosion of genetic resources. Therefore it is essential that genetic information of locally adapted traits is taken into account to manage marine stocks. Finally, the rhodopsin study stimulates further research to find additional evidence for local adaptation to other marine environmental conditions such as temperature and salinity tolerance. It will contribute to more insights on the importance of natural selection as a common evolutionary force that shapes life in the ocean.

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RECONSTRUCTION OF COMPLETE SPACE-TIME SURFACE CHLOROPHYLL A (CHL), TOTAL SUSPENDED MATTER (TSM) AND SEA TEMPERATURE (SST) OVER THE NORTH SEA WITH MONOVARIATE AND MULTIVARIATE EXPLOITATIONS OF THE DATA INTERPOLATING EMPIRICAL ORTHOGONAL FUNCTIONS METHODOLOGY

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Optical remote sensing data is now being used systematically for marine ecosystem applications, such as the forcing of biological models and the operational detection of harmful algae blooms. However, applications are hampered by the incompleteness of imagery and by some quality problems. The Data Interpolating Empirical Orthogonal Functions methodology (DINEOF) allows calculation of missing data in geophysical datasets without requiring a priori knowledge about statistics of the full data set and has previously been applied to SST reconstructions.

The first part of this study demonstrates the reconstruction of complete space-time information for 4 years of surface chlorophyll a (CHL), total suspended matter (TSM) and sea surface temperature (SST) over the Southern North Sea (SNS) and English Channel (EC). Optimal reconstructions were obtained when synthesising the original signal into 8 modes for MERIS CHL and into 18 modes for MERIS TSM. Despite the very high proportion of missing data (70%), the variability of original signals explained by the EOF synthesis reached 93.5% for CHL and 97.2% for TSM. For the MODIS TSM dataset, 97.5% of the original variability of the signal was synthesised into 14 modes. The MODIS SST dataset could be synthesised into 13 modes explaining 98% of the input signal variability. Validation of the method is achieved for 3 dates below 2 artificial clouds, by comparing reconstructed data with excluded input information. Complete weekly and monthly averaged climatologies, suitable for use with ecosystem models, were derived from regular daily reconstructions. Error maps associated with every reconstruction were produced according to Beckers *et al.* (2006). Embedded in this error calculation scheme, a methodology was implemented to produce maps of outliers, allowing identification of unusual or suspicious data points compared to the global dynamics of the dataset. Various algorithms artefacts were associated with high values in the outlier maps (undetected cloud edges, haze areas, contrails, cloud shadows). With the production of outlier maps, the data reconstruction technique becomes also a very efficient tool for quality control of optical remote sensing data and for change detection within large databases.

The second part of this study aimed at testing for potential improvement of satellite TSM reconstructions by exploiting an extended multivariate data-set for the DINEOF processing. For this, the MODIS TSM images of year 2005 (BELCOLOUR database) were used with various combinations of informations from the Channel and Southern North Sea (C&SNS) hydrodynamical model (wind fields, mean depth currents, surface elevations and bottom stresses). Results concerning TSM reconstruction quality are encouraging for univariate treatment. Comparisons with the multivariate reconstruction confirmed the interest of searching correlations with modelled fields. Monovariate treatment of MODIS TSM data for 2005 could be synthetized into 6 EOFs accounting 97,2% of the total variability of the input signal. In multivariate approach, the best improvement was obtained with mean depth current U and V components, (12 EOFs accounting for 99,1% of the total input signal variability), with less filtration of smaller structures (correlation length estimate reduced from 17,1 to 15,6km).

PACIFIC OYSTERS IN DUTCH ESTUARIES

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Since the 1960s, the Pacific oyster *Crassostrea gigas* has been introduced for mariculture at several locations within NW Europe. The oyster established itself everywhere and expanded rapidly throughout receiving ecosystems, forming extensive and dense reef structures. It became clear that the Pacific oyster induced major changes in NW European estuaries along the North Sea coast. This PhD thesis reviews causes of the Pacific oyster's remarkably successful establishment and spread in the Netherlands and neighbouring countries, and a comprehensive review of consequences for the receiving communities is given, including own experimental results on food competition with native bivalves (Chapter 2) and the predation of pelagic larvae of native bivalves by *C. gigas* (Chapters 3-6). The case of the Pacific oyster in NW European estuaries is only one example in an increasing series of biological invasions mediated by human activities. This case-study will contribute to further elucidate general mechanisms in marine invasions; invasions that sometimes appear a threat, but can also contribute to ecological complexity.

TIDAL FLAT MACROBENTHOS ECOLOGY, RECOLONIZATON AND SUCCESSION

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Estuaries and the adjacent intertidal habitats fulfill several important ecosystem functions (e.g. high productivity, nursery and feeding habitats for epibenthic fishes, crustaceans and birds) and services (e.g. pollution filter, counteracting coastline erosion) (McLusky and Elliott, 2004). However, along with the expanding human population, the diversity and intensity of anthropogenic stressors (e.g. dredging, eutrophication, fishing) has increasingly diminished the quality of these ecosystems (Worm *et al.*, 2006; Wolanski, 2007). Consequently, there is an increasing need for restoration of these habitats in order to regain the essential ecosystem function and service losses that we take for granted. It is now in many cases legally demanded that anthropogenic activities that damage ecosystems require mitigation measures [e.g. the Water Framework Directive (Anon, 2000)]. As an integral part of management practice, monitoring should occur in order to detect change and to determine whether management is having the desired effect (McLusky and Elliott, 2004). The macrobenthos (i.e. bottom fauna commonly defined as organisms retained on a 1 (0.5) mm mesh sized sieve) of estuarine tidal flats recycles nutrients (Lohrer *et al.*, 2004), alters sediment transport processes considerably (Solan *et al.*, 2008) and represents an important trophic linkage, being a food source for epibenthic crustaceans, fish and birds (Hampel *et al.*, 2005) and feeding on benthic algae and bacteria (Herman *et al.*, 2000; Van Oevelen *et al.*, 2006). Consequently, given its central role in the functioning of the tidal flat ecosystem, monitoring of the macrobenthos should take part in an integrated evaluation of the progress of marine and estuarine restoration projects. In order to enhance our understanding of restoration of tidal flat sediments, this thesis aimed to investigate the role of macrobenthos-environmental interactions in determining benthic settlement, community recovery dynamics (i.e. succession) and benthic community structure, in general.

The macrobenthos community structure along the cross-shore gradient of the Paulinapolder tidal flat was investigated in Chapter 2 of this Ph.D. manuscript. This tidal flat, located in the polyhaline part of the Westerschelde Estuary (SW the Netherlands), has a semi-diurnal tidal regime with a mean tidal range of 3.9 and the bed material generally consists of mud (average median particle size = 65 µm, average mud content = 51 %). The established macrofauna community is rich, consisting of, on average, 20000 individuals of 10 different species which are characterized by a wide variety of biological traits. Diversity and assemblage-wide biological traits were explained by a large extent to hydrodynamic stress along the tidal flat gradient. Species richness and diversity peaked at low stress whereas evenness was lowest at intermediate stress indicating that species sorting in response the hydrodynamic stress rather than competitive exclusion at low stress drives the diversity stress response. The decrease in species richness and diversity towards the hydrodynamically harsher low intertidal was reflected in the assemblage-wide shifts towards a lower dietary dependency on microalgal carbon and a deeper living position. Intermediate stressed assemblages were associated with a shift towards a higher mobility and a more resistant development mode to superficial sediment disturbance which are suggested to result from species sorting in response to interference from *Cerastoderma edule* bioturbation which peaked at intermediate hydrodynamic stress where optimal hydrodynamic conditions for suspension feeders prevail. The sediment disturbance of *Cerastoderma edule* was assessed into detail in Chapter 8, using two size classes UV-fluorescent sediment fraction tracers (luminophores). Image analysis of the vertical distribution of the different luminophore size classes in the field and in an additional mesocosm experiment showed that cockles selectively remove fine material from the sediment, thereby rendering it less muddy.

Macrobenthos recolonisation patterns after complete mortality resulting from experimentally induced hypoxia were investigated in Chapter 3, 4 and 7. Hypoxic conditions were created by covering replicated 16 m² sediment patches at the Paulinapolder tidal flat with a waterproof polyethylene sheet during a 40-day incubation period. Subsequently, from spring 2005 onwards, the macrobenthos recolonisation was assessed and compared with control sediments during 3 years, focussing on how the temporal scale of macrobenthic recovery interacted with the temporal scale of biotic (e.g. microphytobenthos, meiobenthos) and sedimentological developments (e.g. grain size, bed level, erosion threshold).
Macrobenthic recovery was predominantly determined by juvenile recruitment and the time scales of changes in microphytobenthos and abiotic characteristics of the sediment were largely set by the

time scale of macrofauna recovery. During the first 2 years, a Pearson-Rosenberg type of community recovery took place along with the improving bottom water oxygen conditions. After 3 months, spionid polychaetes became highly abundant, followed rapidly by a steep decline. Subsequently, a steep increase in biomass, related to the growth of the long-lived species occurred. Transitions between different succession stages appeared to be related to recruitment of species and the congruous changes in sediment characteristics (oxygenation state of the sediment, bio(de)stabilization, food availability) inhibiting or facilitating early and late macrobenthic colonizers. Such biotic-environmental interactions may have far-reaching consequences for recovery of disturbed tidal flat sediments. For example, Chapter 7 shows that recovering communities may diverge from control conditions at the long term whenever the impact of species which are affected by biotic-environmental interactions occurring at early recovery stages becomes (more) important. Moreover, benthic-mediated changes in benthic primary production and susceptibility to physical stress were found to significantly affect the recovery of nematode communities from hypoxia (Chapter 6) and the growth and production of benthic recruits (Chapter 5). Additionally, Chapter 9 shows that benthic-mediated differences in benthic primary production may also directly affect macrobenthos recovery by affecting the settlement success of macrobenthos larvae.

In summary, this thesis highlights that the macrobenthos plays a critical role in the biotic and abiotic (recovery) dynamics of estuarine intertidal sediments and that macrobenthic recovery in a tidal mudflat habitat should be considered as a dynamic process, related to the natural temporal variation, the life history traits and the bio-engineering capacities of the colonizing species. Consequently, scientific information on these aspects, as discussed in Chapter 10, should be addressed to consider and to evaluate habitat degradation and restoration.

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CARBON FLOWS IN THE PLANKTONIC FOOD WEB OF TEMPERATE ESTUARIES: COMBINED APPROACH USING STABLE ISOTOPES, BIOMARKERS AND MODELING

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Introduction

European estuaries are characterized by high loads of nutrients and organic matter. They have therefore the potential to sustain high primary production rates as well as high bacterial activity, with the balance often tipping towards a net heterotrophic ecosystem (respiration exceeds primary production). Organic matter that is imported from upstream reaches and terrestrial origins is considered allochthonous, while organic matter derived from local, estuarine primary production is autochthonous. The ecological focus of this thesis is on the balance between autochthonous and allochthonous organic carbon sources for secondary production. Mesozooplankton, mostly comprising small crustaceans and larval stages of larger organisms between 0.2 and 2 mm length, are an important link in the aquatic food chain, grazing smaller size fractions and serving as food for larger animals, including fish. We studied the contribution of autochthonous versus allochthonous food sources for mesozooplankton biomass in the Scheldt Estuary, Belgium and the Netherlands (chapter 4). Bacteria use dissolved organic matter (DOM) as a source of energy and biomass. They have the choice between allochthonous DOM, which is present in high concentrations but is rather refractory, and autochthonous DOM, which has a higher turnover rate and includes many compounds that are readily available for bacterial consumption, but whose concentration is lower and more variable. We studied interactions between bacteria and algae, the producers of autochthonous DOM, in two European estuaries: the Scheldt Estuary, the Netherlands (chapter 6), and Randers Fjord, Denmark (chapter 5).

Besides the ecological aspect of the thesis, focusing on the microbial food web of estuaries, substantial effort has been put into the development of statistical and modelling techniques and their application in an ecological context. Bayesian statistics are fairly new to ecology, and have potential for parameter estimation, especially in non-linear models. They have been applied to simple food web models in the Scheldt Estuary (chapter 6), and formed the basis for two methodological chapters. Chapter 2 discusses a method to sample parameter distributions in underdetermined, linear systems, a type of models that is often encountered in food web ecology. Chapter 3 offers a Bayesian alternative to existing techniques that estimates taxonomic composition in ecological samples from molecular biomarkers, such as pigments or fatty acids.

Methods

Stable isotopes of C and N have a central role in the unraveling of the estuarine microbial food web. Stable isotope ratios in different food web components are strong indicators for the origin of organic matter, based on the fact that the isotopic signature of allochthonous and autochthonous organic matter is significantly different (chapter 4).

When this is not the case, or when one wants to study in detail short-term interactions between food web compartments, stable isotopes can be added deliberately to an experimental setup and food web fluxes can be derived from stable isotope incorporation into different food web components. We measured 13C concentration in polar lipidderived fatty acids (PLFA) using gas chromatography - combustion - isotope ratio mass spectrometry (GC-c-IRMS). The isotope composition of algae- or bacteria-specific PLFA can be used as a proxy for the isotopic composition of algae and bacteria, respectively, thus avoiding the need for physical separation of these groups.

Calculations and model fitting have been done partly in FEMME, a FORTRAN environment providing tools for ecological modeling (chapter 5), and partly in R, a free software environment for statistical computing and graphics. The methods developed in the framework of this thesis (chapters 2 and 3) have been published as contributed packages for R, and are available for download on the R website.

Results

Modeling tools

We developed a technique to obtain parameter distributions of linear systems, regardless of whether they are overdetermined of underdetermined. The technique can be applied to isotope mixing models to estimate which food sources contribute to a consumer's diet, or to food web models where fluxes are assumed constant. An R function is implemented that uses Markov Chain Monte Carlo (MCMC) algorithms to uniformly sample the feasible region of constrained linear problems. Two existing hit-and-run sampling algorithms are implemented, together with a new algorithm where an MCMC step reflects on the inequality constraints. The new algorithm is more robust compared to the hit-and-run methods, at a small cost of increased calculation time. The obtained results are also more correct than what can be obtained from existing methods to solve underdetermined isotope mixing models (Isosource). (chapter 2)

A second method, the Bayesian Compositional Estimator (BCE) determines the microbial taxonomy of a sample based on lipid or pigment spectra. We present a new approach based on Bayesian inference and that is implemented in the open software platform R. BCE aims not only to obtain a maximum likelihood solution, but also to provide a complete estimate of the taxonomic composition, including probability distributions and dependencies between estimated values. BCE results were compared with those obtained with CHEMTAX. The BCE has not only a similar accuracy, but also extracts more information from the data, the most obvious being variance and covariance estimates. (chapter 3)

The planktonic microbial food web of temperate estuaries

Carbon stable isotope signatures of algae, bacteria, particulate and dissolved organic carbon (POC and DOC) were followed during one year over a transect of the Scheldt Estuary. The carbon isotope signatures of DOC, POC, and bacterial biomass were similar and significantly enriched relative to those of diatoms and green algae, pointing to allochthonous subsidies as an important carbon source for bacteria. The contribution of algae to zooplankton diets as estimated from isotope ratios and fatty acid profiles averaged 41% and 75%, respectively and did not differ significantly among stations, taxa and life stages. Mesozooplankton primarily relied on grazing on phytoplankton and direct consumption of particulate organic matter. Mesozooplankton appeared to receive little of its carbon from DOC via bacteria. (chapter 4)

Besides stable isotope natural abundance studies, we performed two labelling experiments. We tracked flows of carbon and nitrogen during an experimental phytoplankton bloom of a natural estuarine assemblage from Randers Fjord, Denmark and from the Scheldt Estuary, Netherlands.

In Randers Fjord, we used 13C-labeled dissolved inorganic carbon to trace the transfer of carbon from phytoplankton to bacteria. Ecosystem development was followed over a period of 9 days through changes in the stocks of inorganic nutrients, pigments, particulate organic carbon and nitrogen, DOC, and algal and bacterial PLFA. We quantified incorporation of 13C in phytoplankton and bacterial biomass by carbon isotope analysis of specific PLFA. A dynamic model based on unbalanced algal growth and balanced growth of bacteria and zooplankton adequately reproduced the observations and provided an integral view of carbon and nitrogen dynamics. There were three phases with distinct carbon and nitrogen dynamics. During the first period nutrients were replete, an algal bloom was observed, and carbon and nitrogen uptake occurred in a constant, Redfieldian ratio. Because there was little algal exudation of DOC, transfer of 13C from phytoplankton to bacteria was delayed by one day compared to labeling of phytoplankton. In the second phase, exhaustion of dissolved inorganic nitrogen resulted in decoupling of carbon and nitrogen flows due to unbalanced algal growth and the exudation of carbon-rich dissolved organic matter by phytoplankton. During the final, nutrient-depleted phase, carbon and nitrogen cycling were dominated by the microbial loop and there was accumulation of DOC. The main source (60%) of DOC was exudation by phytoplankton growing under nitrogen limitation. Heterotrophic processes were the main source of dissolved organic nitrogen (94%). Most of the carbon exudated by algae was respired by the bacteria and did not pass to higher trophic levels. The dynamic model successfully reproduced the evolution of trophic pathways during the transition from nutrient replete to depleted conditions, indicating that this type of models provide a powerful tool to study the response of pelagic ecosystems to external forcings.

A slightly different approach was used for an experiment in the Scheldt Estuary. Carbon and nitrogen flows in a natural phytoplankton assemblage from the plume of the Scheldt Estuary were followed by measuring changes in concentrations and stable isotope ratios in a 10-day period after addition of 13C (bicarbonate and glucose) and 15N (ammonium and nitrate) to mesocosms. Again, decoupling of nutrient fluxes was observed during and after a diatom bloom. Only this time, P turned out to be the limiting nutrient. The heterotrophic phase following the diatom dominated

bloom, was marked by nutrient regeneration, and followed by a Phaeocystis bloom. While addition of 13C-bicarbonate showed a strong coupling between algal primary production and bacterial secondary production, addition of 13C-glucose provided complementary results for carbon cycling in the microbial loop. We could also trace the 13C into mesozooplankton and identify selective grazing on algae during the phytoplankton bloom, transfer of carbon from bacteria to mesozooplankton and opportunistic feeding strategies after the bloom.
Nitrogen labeling confirmed carbon labeling findings and identified bacteria rather than mesozooplankton as ammonium regenerators and also allowed quantification of nitrification in the water column with an estimated rate of 0.1 μ mol N L−1 d−1.

Conclusion

In conclusion, we unraveled in detail the interactions among primary producers, bacteria and mesozooplankton in the planktonic food web of temperate estuaries. Bacteria were shown to be important consumers of DOC both from autochthonous and from allochthonous sources. Allochthonous sources contribute significantly to mesozooplankton diet and should not be ignored, despite the fact that algae are still a preferred and more nutritious food source. On the methodological side, we proved the added value of ecosystem models of different scales of complexity, and successfully applied Bayesian techniques to ecological case studies, an area of research which is still in its infancy.