BOOK OF ABSTRACTS

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Assessment of metals and perfluorinated compounds (PFASs) in water, sediment, and edible fish species and the risk of human consumption in Lake Hawassa, Ethiopia

BY Bealemlay Abebe Melake

PROMOTER: Lieven Bervoets (Universiteit Antwerpen)
CO-PROMOTER: Bossissi Nkuba, Thimo Groffen

This study was aimed to determine the concentration of metals and perfluorinated compounds (PFASs) in water, sediment, fish tissue and to perform a risk assessment of humans' health due to fish consumption in Lake Hawassa, Ethiopia. The presence of 10 selected metals (i.e. arsenic (As), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), Lead (Pb), mercury (Hg), nickel (Ni), selenium (Se) & zinc (Zn)) and 15 perfluorinated compounds (PFASs; including 4 perfluorosulfonic acids (PFSAs) and 11 perfluorocarboxylic acids (PFCAs)) were investigated in Lake water, sediment and fish tissue. In total 118 (12 water, 12 sediments, and 94 fish tissue) samples were collected from four sampling sites. The concentration of all detected metals in water were lower than the recommended values by WHO. The concentration of As, Cr, Cu, Hg, Ni and Zn in sediment were above the threshold effect concentrations (TEC) values which implies that these metals could be toxic to aquatic benthic life, while elemental concentrations of Cd, Hg and Pb in the lake sediment were below the Sediment Quality Guidelines (SQGs; TEC values). The concentration of Cd, Pb, Ni, Cu, Zn and Hg were lower whereas the concentration of Cr, Cu and Se in fish muscle were higher than the permissible limits given by WHO. The mean concentration of all metals in the liver was always higher than in fish muscle. Strong significant positive correlations (r≥0.90, p<0.05) were observed between Pb and Zn, Cr and As, Co and Se, Zn and Pb, As and Cr, As and Hg and Se and Co, TOC and Cd, Co and Se and clay content and Pb, As and Hg. Among the detected PFASs, PFOA was the most abundant with a mean concentration of 6.93ng/L and 0.23ng/g dw in lake water and sediment, respectively. PFOA (0.17ng/g ww) and PFDA (0.21ng/g ww) were the most abundant in fish muscle. PFDA (1.43ng/g ww), PFUnDA (0.93ng/g ww), PFOA (0.27 ng/g ww), PFNA (0.17 ng/g ww), PFDoDA (0.08 ng/g ww) and PFOS (0.63 ng/g ww) were detected in fish liver. The mean concentrations of PFASs were higher in fish liver than in muscle. This study showed that, except cobalt (Co) and arsenic (As), no potential health risk due to consumption of contaminated fish by other investigated metals and PFAS (PFOA and PFOS). There was a strong correlation between PFOA in sediment and clay content (p=0.05, r=0.95), PFDoDA and PFOS in the liver (p=0.02, r=0.98), PFOA and As (p= 0.002, r=1.00), PFOA and Cr (p= 0.01, r=0.99), PFOA and Hg (p= 0.02, r=0.98).

Keywords: Ethiopia, Fish, Human health risk, Metals, Perfluorinated compounds (PFASs), Pollution.

Habitat Use and Movement Behaviour of the European Seabass in the Belgian Part of the North Sea

BY Camille Boileau-Locas

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The spatiotemporal variation in habitat use and movement behaviour of the European seabass in the Belgian part of the North Sea was studied using acoustic and archival data. 78 fish were tagged using the acoustic data storage tags between June 2018 and October 2019. 177,162 acoustic data and three archival data were available for analysis. Horizontal movement behaviour and habitat use was analysed through residency and site fidelity indices. The periodicity in the presence of individuals in the study site was performed and linked to environmental factors. The European seabass were highly present and resident in coastal areas during spring up to autumn and the majority of the individuals were absent from the study site during the winter months. Out of the absent individuals in winter, 63% returned to the study site after winter and, among those, 75% returned to the area where they were mainly detected before the absence. The sea surface temperature and habitat type influence the presence of the individuals in the study site. Overall, the seasonal movement pattern and habitat use matched the previously described seasonality in habitat use of the European seabass. Diel, tidal and roaming behaviour described the vertical movement of the species. Furthermore, they were mainly in midwater depth throughout the year. The extent of activity extended to demersal depth during spring and surface depth during summer and autumn. The characterisation in habitat use and movement behaviour could be significant to the management of the European seabass in Belgium.

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Multibeam backscatter response from stratified shallow marine soft substrates

BY Nikolaos-Kimon Chtouris

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High-frequency depth and backscatter from multibeam echosounders are nowadays used to describe the nature of the seabed, based on physical relationships of acoustic energy with seabed composition. Backscatter is influenced by multitude of seabed characteristics, mainly related to grain-size distribution, surface roughness and inhomogeneities within sediments. Two survey areas, one close to the Belgian coastline (Nearshore Survey) and the other further from the entrance channel to Zeebrugge harbour (Pas van het Zand) (Offshore Survey) were ensonified, and 22 box core samples and 23 SPIs (Sediment Profiler Imaging) were collected and analyzed for grain-size analysis and visual inspection, respectively. Furthermore, backscatter angular curves were extracted from each ground-truth station, with the aim of describing backscatter variation with incidence angle. Visual inspection of each core produced descriptive values of presence/absence of bioturbation, shell inclusions, shell hash and stratification. These parameters were used in statistical analysis, in conjunction with sediment properties from grain-size analysis, in order to quantify the effect of seabed composition on acoustic backscatter. Simple linear regression, polynomial linear regression and multiple linear regression were performed on the datasets of both surveys, as well as on a combined dataset derived from merging the data of the two surveys.
For the Nearshore Survey, mean backscatter intensities showed considerable variation, ranging in sound levels between -54 dB to -36 dB. This was also observed in the backscatter angular curve profiles. Visual inspection of core images, along with grain-size analysis from this area, showed high mud contents, but also the presence of fine and medium sands. Conversely, the Offshore Survey dataset displayed less variation in terms of mean backscatter intensity (-44 dB to -37 dB) and corresponded to a sedimentary environment of fine and medium sands, with surficial sediments being well sorted, exhibiting a unimodal distribution. Angular backscatter curves also showed that backscatter variation was similar between samples. SPI images from the Offshore Survey showed presence of mud in the subsurface and shell hash at the surface. The effect of these parameters on the acoustic response could not be determined due to the limitations of the instruments used. Still, simple linear regression models were able to establish statistical significance between Mean/Median backscatter intensity and Mean/Median grain size and D90, but only for the combined dataset. However, multiple-linear regression showed no effect of these variables with backscatter, a probable effect of merging data of two different sedimentary environments, as well as from the limited sample size. For the same variables, polynomial linear regression showed slightly increased statistical significance and better fit of the data with the regression model. Overall, interpretation of backscatter based on surficial grain-size analysis, backscatter angular profiles and sediment description was more applicable for the sandy sedimentary environment (Offshore Survey), compared to the area with a more variable sedimentological character (Nearshore Survey).

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Macrozoobenthic biodiversity of the Bransfield Strait

BY Jolien Claes

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CO-PROMOTER: Isabelle Schön

Spatial distribution of biodiversity and community composition was determined for the macro-zoobenthos in the Bransfield Strait, based on a higher taxonomic level for the whole community (Class) and on a species level for the Asterozoa. All samples were collected using a Van Veen grab and the findings were then related to five environmental variables that were collected using a CTD. Significant differences were found between class level communities within the Bransfield Strait which were mostly driven by water depth and the interaction of depth with O2. The western side of the Bransfield strait was found to have a higher level of biodiversity and species richness and to be dominated mostly by the presence of bivalves. In contrast the eastern side was found to be poor in biodiversity and dominated by only Ophiuroidea or Amphipoda. The stations sampled at the Admiralty Bay were more similar to these poor areas than to species rich western side of the Bransfield Strait.

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ESTABLISHMENT OF BASELINE VALUES FOR THE ASSESSMENT OF TRACE ELEMENT CONCENTRATIONS IN THE SEDIMENTS OF THE BRANSFIELD STRAIT, ANTARCTICA

BY Louise Delhaye

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Increased human activities in Antarctica as well as long-range pollution pose a potential risk to this fragile ecosystem. In this context, the establishment of reference values for the concentration of trace elements in the sediments is encouraged by several authors. This is particularly true in the South Shetland Islands, which is the most visited area of the continent. During the 27th expedition of Peru to Antarctica, 32 sediment samples were collected at 28 stations around King George Island, in the Bransfield Strait and at Hope Bay (Antarctic Peninsula). Our results show a clear distinction between these three regions but also demonstrate the existence of local heterogeneity. The majority of the stations in the Bransfield Strait and around King George Island show moderate to significant enrichment in copper, arsenic and cadmium. All three are believed to be from natural origin. Two stations show moderate to heavy arsenic contamination, one of which presents a moderate ecological risk. Finally, chromium values that are three times higher than those measured by several authors between 1994 and 2007 were recorded at all sampled locations around King George Island.

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Current and future policy arrangements regarding mangrove management in Malaysia – What can be the role of Impact Assessment?

BY Morgane Dierkens

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For years benefits provided by nature have been well known and have been used to justify and frame biodiversity conservation. These conservation framings are based on the different ways to look at nature. Framings are a form of discourse (shared representations of what matters in a particular context), called "discourse as frames" and defined as shared frames of meanings. In other words, these discourses are based on people experiences and history which are reflected in and influence the way they speak or act (Arts and Buizer, 2009; Hugé et al., 2017). Therefore, the plurality of ways to see nature and its interaction with human induce different focus for nature protection and different types of actions (Hugé et al., 2017). These relationships between nature and people have changed and evolved over time, resulting in different viewpoints on "why nature matters" (Mace, 2014; Rice et al., 2018). Mace (2014) summarized four conservation framings in use today based on these discourses and hence involving a different focus and underpinning sciences (Table 1). The first framing to emerge was the "nature for itself" focusing on species conservation and protected area management through habitats and wildlife ecology. This framing prioritizes the intrinsic value of nature (Farley, 2012; Mace, 2014). The second framing "nature despite people" focuses on the impacts and threats of human activities on species and habitats. With the increasing and persistent pressures on habitats and their biodiversity, and the realization that nature provides irreplaceable goods and services, conservation started to focus on ecosystem services. Indeed highlighting the loss of ecosystem services (ES) due to the rapid depletion of natural capital and the increasing understanding of the ecosystem as a whole caused a change in perception of nature (Costanza et al., 1997; Mace, 2014; Costanza et al., 2017; IPBES, 2019). By incorporating the sustainability of goods and services from ecosystems to people, the third framing emerged as "nature for people" (Mace, 2014). The emergence of the concept of ES has been important in the recognition of a two-way relationship between nature and people. This shift allowed moving from a utilitarian idea of nature toward a more nuanced idea of conservation. The fourth and last framing "nature and people" includes dynamic relationships between nature and people and prioritizes interdisciplinary conservation by combining social and ecological sciences (Mace, 2014; IPBES, 2019).

ES are defined as "the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997), and are essential to human life and well-being. The valuation of ES, launched by Costanza et al. (1997) played an important role in linking these two streams of work through the emergence of the new field of ecological economics, further popularized by initiatives such as the Millennium Ecosystem Assessment (MEA) and 5

The Economics of Ecosystems and Biodiversity (TEEB). They valued services provided by nature by determining the impacts of changes in these services on human well-being and considered costs and benefits associated with the market and non-market components of human activities. Hence by valuing ES, their importance strongly increased in policy and research which would lead to a stronger focus on natural capital providing ES in policy and decision-making processes (Costanza et al., 1997; Mace, 2014; Costanza et al., 2017).

People, focusing on different framings of nature and conservation, tend to have different expectations regarding ecosystems management, which can create tensions and conflicts (Hugé et al., 2013; Mace, 2014; Friess et al., 2016). However, these different framings are not necessarily incompatible (Hugé et al., 2013) and highlight the need for multidisciinary tools in management that allow to incorporate the

perceptions and goals of various stakeholders to conserve and protect these ecosystems (Mace, 2014; Mukherjee et al., 2018). Also, within the 'ecosystem services'-framing, different stakeholders may prioritize and value different types of ES more than others.

The Common International Classification of Ecosystem Services (CICES) categorized the ES into three categories which are provisioning, regulating (regulation and maintenance), and cultural services (CICES, 2019). The numerous services provided by coastal and marine ecosystems such as mangrove forests provide opportunities for many development projects such as aquaculture and shrimp farming, industrial and urban constructions, and recreational and tourism-based activities (Adeel and Pomeroy, 2002). Mangrove forests, because of the multiple services and goods they provide, merit further attention (Mukherjee et al., 2014). Moreover these ecosystems are among the most threatened due to their land-use development, overexploitation as well as pollution and climate change (Adeel and Pomeroy, 2002; MEA, 2005; Duke et al., 2007; Hugé et al., 2016). The analysis of the effects of these management regimes on mangrove ES allows the assessment of the different outcomes of management decisions providing information to develop more sustainable coastal management plans (van Oudenhoven et al., 2015). In that coastal development context, the sustainability of such projects is essential and requires effective management of such important ecosystems.

There are obviously various ways to manage mangrove ecosystems. As mangroves are typically subject to the –unintended- impacts of a wide range of development projects (e.g. harbor and dyke building, aquaculture, logging, urban development etc.), mangrove management may, in theory at least, benefit from impact assessments (IA). IA is defined as "the process of identifying the future consequences of a current or proposed action" by the International Association for Impact Assessment (IAIA, 2019).

IA has been introduced as decision-making support in order to promote sustainable development (Chanchitpricha and Bond, 2013). IA is an umbrella term covering different types including environmental assessments such as Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA) that are both discussed in this paper. While EIA can be defined as an assessment of the impacts of a project on the environment as well as the consideration of project alternatives and mitigations measures, SEA seeks to determine the environmental effects of implementing policies, plans, or programs (Komınková, 2009). Both are discussed later in more details. However, benefits from IA can already be pointed out as they allow considering the environment in planning processes (Kumar et al., 2013; Mareddy, 2017). Here, IA effectiveness can be understood as "their influence on decision-making processes in selecting the most appropriate option for the development, based on sustainability measures" (Chanchitpricha and Bond, 2013).

Moreover, IA could be a vehicle for better stakeholder engagement in planning and decision-making and, as seen previously, perspectives and knowledge of multiple stakeholders are important to provide various and more complete information for decision-making (Hugé et al., 2016). In that context, an impact assessment approach could be, in theory, helpful for mangrove forests management.

This paper focuses on mangrove forests in Malaysia in which EIA legislation has been introduced in 1987 with the purpose to integrate the environment into development decision-making, and came into effect in 1988 (Briffett et al., 2004; Hezri and Nordin Hasan, 2006; Memon, 2000).

Recognizing the importance of the consequences and the role of the plurality of views of management decisions, this study aims to (1) analyze the different stakeholder viewpoints on mangrove management in Malaysia, (2) map mangrove management stakeholders and their relationships in the Setiu mangroves area in Malaysia and (3) explore the potential role of impact assessments (Environmental Impact Assessment and Strategic Environmental Assessment) in support of mangrove management in Malaysia.

EFFECTS OF BINARY MIXTURES OF ZINC AND CADMIUM ON THE BIO-ACCUMULATION, ONHOMEOSTASIS AND OXIDATIVE STRESS OF THE COMMON CARP *CYPRINUS CARPIO*

BY Dinh Thanh Nguyen

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x In natural environments, aquatic organisms are often exposed to a wide variety of metal mixtures, which frequently interact and influence each other's toxicity. The objective of this study is to investigate the effects of cadmium (Cd) and zinc (Zn) mixtures on the bioaccumulation, ion-regulation and oxidative stress of common carp (*Cyprinus carpio*). Juvenile common carp were exposed to several mixtures of Zn and Cd for one week using sublethal concentrations associated with the 10%, 25% and 50% of the 96h LC50 values (concentrations resulting in death of 50% of the population during 96h) previously determined for each metal. The accumulation of both metals along with the electrolyte contents, including sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg) were determined in fish gills, liver, brain, muscle and carcass. At the same time, the gene expression of the metallothionein (MT), antioxidant systems including superoxide dismutase (SOD), catalase (CAT), glutathione reductase (GR), glutathione S-transferase (GST) and glutathione peroxidase (GPx) as well as an indicator of apoptosis - caspase 9 (CASP) were assessed in the gills and liver of the common carp. In both exposure series, Zn accumulation only occurred in the gills and carcasses at the highest exposure level (corresponding to the 50% 96h LC50 values of Cd and Zn), indicating the essential properties and strict regulation of the essential metal in fish. The Cd was accumulated in the order gills > liver > carcass but remained below the minimum quantification limit in the muscle and brain. In addition, an antagonistic-like effect of Zn on Cd accumulation was observed in the liver of the common carp after one week of exposure. Metal mixture exposure also induced the MT mRNA expression in the gills and liver of the common carp during one week of exposure. However, there was a lack of hepatic expression of antioxidantrelated genes, suggesting the minor effect of oxidative stress induced by metal mixture. Last but not least, metal mixture exposure had no significant effects on the ion homeostasis of essential electrolyte, particularly on Ca homeostasis despite the antagonistic properties of Cd and Zn to Ca2+. All in all, the absence of mortality and response of fish to metal stress indicate that the common carp can tolerate these levels of metal concentration, at least for a short period of one week.

Key words: Cadmium, zinc, metal mixtures, bioaccumulation, ion-homeostasis, gene expression, metallothionein, antioxidant systems, *Cyprinus carpio*

DESCRIPTION AND FUNCTIONAL TESTING OF FOUR SPECIES OF THE NOVEL PHOTOTROPHIC GENUS *FLAVAURANTIMONAS* GEN. NOV., ISOLATED FROM DIFFERENT EAST ANTARCTIC ENVIRONMENTS

BY Dugyu Gök

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SUPERVISORS: Guillaume Tahon, Liesbeth Lebbe

Seven Gram-negative, aerobic, non-sporulating, motile strains were isolated from terrestrial (R-67883, R-67880T, R-36501 and R-36677T) and aquatic (R-39604, R-39161T and R-39594T) East Antarctic environments (i.e. soil and microbial mats), between 2007 and 2014. Analysis of near-complete 16S rRNA gene sequences revealed that the strains potentially form a novel genus in the family Sphingomonadaceae. DNA-DNA reassociation and average nucleotide identity values indicated distinction from close neighbors in the family Sphingomonadaceae and showed that the seven isolates form four different species. The main central pathways present in the strains are the glycolysis, tricarboxylic acid cycle and pentose phosphate pathway. The strains can use only a limited number of carbon sources and mainly depend on ammonia and sulfate as a nitrogen and sulfur source, respectively. The novel strains showed the potential of phototrophy, based on the presence of bacteriochlorophyll a pigments, which was corroborated by the presence of all building blocks for a type 2 photosynthetic reaction center in the annotated genomes. Based on the results of phenotypic, genomic, phylogenetic and chemotaxonomic analyses, the strains could be divided into four new species in the novel genus *Flavaurantimonas* gen. nov. in the family Sphingomonadaceae, for which the names *F. soli* sp. nov. (R-67883, R-67880T and R-36501), *F. crassa* sp. nov. (R-36677T), *F. aquatica* sp. nov. (R-39604 and R-39161T) and *F. rubra* sp. nov. (R-39594T) are proposed.

A Time-Series Analysis on Interannual Variability of Meteorological Factors Influencing Sea Level in the Southern Bight of the North Sea

BY Symine Henkens

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Temperature and sea level are primary indicators of global climate change (GCOSa,2019). Sea level variability on short time scales such as waves and tides can easily be averaged out as opposed to atmospherically induced interannual and decadal variability which is found to be irregular. The latter conceals the climatic trend and the fact that interannual variability usually is in the order of decimeters while climatic sea level rise is typically only estimated to be a few millimeters per year, complicates the analysis even further (Gerkema and Duran-Matute, 2017).

This dissertation uses intelligible machine learning methods to gain insight into the monthly and annual mean sea level data that was obtained via the Permanent Service for Mean Sea Level (PSMSL) for the stations Ostend and Nieuwpoort. These stations lie in the southern bight of the North Sea. By utilising generalised additive models, the goal is to combine the advantage of decomposability of a simple linear model, with the added bene_t of enhanced performance due to the estimation of more complex relationships between the independent and dependent variables. This 1) permits the formulation of formal relationships between factors in the Belgian Part of the North Sea (BPNS) that inuence sea level variability and 2) increases the understanding of the mechanistic relationships of the physical forces that drive sea level variability at the Belgian coast. They also serve as the basis for the formation of new hypotheses for future research.

What follows is a selection of the conclusions drawn from the results obtained in the present study:

- Moderately positive linear relations were found for westerly winds and sea level in Ostend. Easterly winds correlate moderately negative with sea level.
- Generalised additive models have shown promising potential to model annual and monthly mean sea level and to analyse time series of physical variables.
- According to the models derived in the present study, sea level has risen approxiamtely 2.8 mm/year during the time period 1979-2017.
- The models for seawater temperature have not yielded a linear yearly trend. The results presented here show a seawater temperature change of -2 _C/century between 1903-1913, +0.8 _C/century between 1949-1965, +0.53 _C between 1950-1959, +4.6 _C between 1979-2017 and +3.4 _C between 2001-2019.
- On average the wind energy has decreased between 1979-2017 with -0.53 J/s. However this could not be proven with a statistical signi_cance of *p< 0:05.

Genetic Diversity and Connectivity of Giant Mangrove Crabs (*Scylla* spp.) in The Indo-West Pacific

BY Muhammad Iqram

PROMOTER: Marc Kochzius (Vrije Universiteit Brussel)

The giant mangrove crab Scylla spp. is one of main fishery commodities in many developing countries, providing livelihood and source of food. However, overexploitation and habitat degradation are likely to reduce the wild population. A study on the population genetic structure is necessary to provide baseline information for the conservationists and policymakers to understand the ecological and evolutionary processes shaping the genetic diversity and connectivity. This study focuses on the phylogeography and genetic diversity of the four congeneric species of *Scylla* spp. in the Indo-West Pacific. A cytochrome oxidase (COI) marker was sequenced in four different species, and the rest of sequences were retrieved from GenBank. The results revealed different level of genetic differentiation in different species. A significant pairwise differentiation was observed in three species, including *Scylla serrata* (ϕst = 0.71), *S. olivacea* (ϕst = 0.13) and *S. tranquebarica* (ϕst = 0.32), (P < 0.001). Based a hierarchical AMOVA, geographical grouping could be divided into four haplogroups in *S. serrata*: (1) the Western Indian Ocean (WIO); (2) The Red Sea, India and the Indo-Malay Archipelago (IMA); (3) the Northwest Australia (NWA); and (4) the West Pacific Ocean. Other species, however, showed a smaller geographic region. Test for differentiation between different geographic grouping exhibited various level of genetic structure. A strong genetic structure was observed among the groupings in *S. serrata* and *S. olivacea*, while high gene flow was revealed within the geographical distribution of S. *tranquebarica* and *S. paramamosain*. These various genetic structure were assumed to be formed by palaeo-oceanographic events and contemporary ocean dynamics, as well as habitat selection and migration model. The patchy genetic distribution among different species could suggest the policymakers to create regional fishery management and conservation.

Quantification and identification of microplastics in the Zenne river upstream and downstream from Brussels, Belgium

BY Laura Knops

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SUPERVISOR: Natacha Brion

The Zenne is a relatively small river which flows from south to north through the city of Brussels, which is the most densely populated area of Belgium with 1.2 million residents (Statbel 2019). The Zenne watershed is characterized by a very high population density, especially in the metropolitan area of Brussels (7057 inh.km-2) (Brion et al. 2015). Because of the rather low discharge and high anthropogenic pressure, the Zenne receives a large amount of pollutants (Brion et al. 2015), but there is no report of microplastic pollution in the Zenne river so far. In this study, the presence of microplastic pollution in the water surface and the sediment of the Zenne river was investigated. Between November 2018 and June 2019 a total of 32 water samples and 14 sediment samples were collected in a station upstream and a station downstream from the Brussels capital Region. Microplastic particles (0.3 - 4 mm) were extracted using wet peroxide oxidation to digest the organic material and density separation to separate the particles. They were visually identified, counted, weighed and classified by shape and colour. Based on the results, a mass balance for microplastics in the Zenne in Brussels was calculated. Afterwards, some specific associated elements were identified In two water- and two sediment samples using micro-XRF spectrometry. Microplastics were found in all samples and the abundances vary from 1.63 to 75.6 items.m-3 in water samples and from 0.03 to 0.49 items.g-1 in sediment samples. Downstream Brussels the concentrations of floating microplastic particles are significantly higher than upstream, but for particles in the river sediment this trend is not observed. The microplastics are dominated by white and black particles and fibres and "other shaped" particles were the most abundant particle shape. The highest concentration of floating particles in the Zenne downstream Brussels (75.6 items.m-3) is more than 5 times the highest concentration found upstream (13.7 items.m-3) and therefore it can be concluded that the metropolitan area of Brussels is a source of floating microplastics for the urban river. Between up- and downstream the Zenne receives between 9.48 and 41.5 million microplastic items per day. The microplastic particles from the water samples contained the elements Ca, Cu, Fe, Pb, Ti and Zn. In the sediment samples, Ca, Cl, Cu, Fe, Pb, Ti, and Zn were identified. After iron, titanium was the most frequently encountered element, especially in the plastic particles from the two analysed water samples, where 50 % and 42% of all particles contained Ti.

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FEEDING RATE IN CRUSTACEANS ALONG A METAL POLLUTION GRADIENT

BY Priscilla Kugonza

PROMOTER: Lieven Bervoets (Universiteit Antwerpen)

In this study we were to investigate the feeding rates of two crustacean species (the isopod *Asellus* sp. and the amphipod *Gammarus* sp.) and how they were affected by metal contamination along a pollution gradient. We particularly wanted to know if accumulated metals had a relationship with environmental and accumulated concentrations and also compare if feeding rate is affected in a similar way as respiration rates of mussels (Quagga) exposed along the same gradient. Five sites were used along the river Dommel with two upstream sites (1&2) as our refence sites, site 3 as a source of pollution as its near to a metallurgic factory and sites 4 & 5 as the diluted concentrations. Translocation of organisms from a clean site to in situ in the river was done during August and ex situ experiments in the lab were done during January. The organisms were all exposed for about a week and then their feeding rates were measured with those from the ex situ done under two temperatures of 15°C and 20°C. Unfortunately, due to the COVID19 crisis, we could not carryout respiration measurements for mussels and metal accumulation data for the different species.

Our results indicated that the Dommel river is still contaminated with metals like Zn, Ni, Co and As having concentrations above the recommended European Quality standards and Belgian standards. We also saw that although the concentrations of some metals are above the standards, most concentrations are lower than in previous studies. The feeding rates of both species show that *Gammarus* had higher feeding rates than *Asellus* with both organisms feeding more at 20°C than at 15°C. The survival rate was also higher for *Asellus* followed by *Gammarus* and then mussels with sites 1&2 having the overall highest survival and site 3 with the lowest survival rate. We also found out through the yearly metal concentration data that January had the highest overall concentration while August had the lowest.

THE FEEDING ECOLOGY OF THE HARBOUR PORPOISE *Phocoena phocoena* L. IN A CHANGING ENVIRONMENT

BY Elke Lambert

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CO-PROMOTER: Bob Rumes
SUPERVISOR: Jan Haelters

The stomach contents of 180 harbour porpoises (*Phocoena phocoena*) stranded or bycaught along the Belgian coastline between 1997 and 2018 were analysed to reconstruct the diet and study the factors shaping their feeding ecology. This was investigated combining two techniques used in diet studies: population averages (i.e. diet indices) and analysis of individual variation in the diet through multivariate analysing techniques (nMDS and PERMANOVA). More than 25 fish and invertebrate prey taxa were identified, highlighting the broad prey spectrum that these generalist predators can feed on. However, the majority of porpoises consumed between 1 and 4 prey groups. The diet was primarily dominated by four key prey guilds (i.e. "The big four"): gadoids (mostly whiting *Merlangius merlangus*), gobies (*Pomatoschistus* sp.), sandeels (*Ammodytes* sp.) and clupeids (both herring *Clupea harengus* and sprat *Sprattus sprattus*), whilst other taxa were of less importance. Harbour porpoises mainly consumed small prey species or the juveniles of larger sized gadoids (e.g. Atlantic cod). Even though the optimal foraging strategy expresses the need for porpoises to strive to feed on mainly prey with a high energetic return (i.e. high-quality prey), they do not solely feed on prey that are most profitable in Belgian and surrounding coastal waters (i.e. sandeels and clupeids) and tend to eat a considerable amount of relatively low-energy lean prey (i.e. gobies and gadoids). Our analysis recovered an ontogenetic development in prey choice, with juveniles eating mainly small lean gobies as opposed to larger gadoids, possibly complemented with energy rich sandeels in adult porpoises. Ample seasonal variation in the diet was also recovered, clearly linked to the changing availability of the different prey groups throughout the year in the Southern part of the North Sea. Our study could neither confirm nor reject an opportunistic or selective foraging strategy, though we present slightly more evidence for the former, with porpoises feeding on locally abundant and easy-to-access prey species. Though, more quantitative data on resource availability, especially for pelagic species, is needed in our waters to confirm or reject opportunistic feeding behaviour. A relatively low amount (15%) of empty stomachs was recovered during this study and preliminary analysis suggested that the highest chance of starving in harbour porpoises can be ascribed to juveniles during the summer months.

Key words: *Phocoena phocoena*; diet; individual variation; stomach content analysis; multivariate analysis; empty stomachs

Hydrogeology of the Aynalem wellfield, Tigray, Northern Ethiopia: Assessment & modelling

BY Daniel Lear

PROMOTER: David Van Rooij (Universiteit Gent)
CO-PROMOTER: Kristine Walraevens

The Tigray Regional State of northern Ethiopia lies in the Sahel region, the arid southern border zone of the Sahara Desert. A notoriously drought prone area with highly erratic rainfall, the Sahel has been growing in size over the last 50 years and has been the cause of water and food insecurity, malnutrition and conflict to inhabitants of the area. The Aynalem wellfield is the primary water supplier of Mekelle, a rapidly growing city of nearly half a million people and capital of the Tigray region.

Most precipitation is received during a short rainy season during the change of season in July/August and has become increasingly unpredictable in timing and amount in recent years. Exploitation of the aquifer system began around 35 years ago; since then a drastic decrease in the height of the water table has been seen, causing once flowing rivers to dry up and fertile land to become barren. At present the people of Mekelle, agriculture and industry all rely on the dwindling resources of the Aynalem wellfield, causing an estimated 40m decrease in water table height since exploitation began. The importance of the aquifer to Mekelle and the decline it has seen in recent years warrants its study and interpretation. The aim of this project was to firstly better understand the dynamics of the aquifer system, and secondly to simulate the aquifer using a numerical model. A field campaign during the rainy season between July and August of 2019 was made during which EC profiling of available boreholes, discrete piezometric measurements and long term piezometric measurements were carried out. Water samples were collected representing the 3D Aynalem hydrosphere and brought back to Belgium where they analysed for geochemistry and stable isotope composition ($\delta18O$ and δD).

Lithology is the main controlling factor of groundwater geochemistry in the study area through primary dissolution of calcite and secondary dissolution of gypsum, calcite precipitation is also prevalent. High sulphate concentrations are noted in areas associated with shale and gypsum intercalations. A large difference in isotopic composition is seen between surface and groundwater samples from the study area. Recharge of the lower aquifer from higher elevation parts of the catchment to the east of the study area is theorised to be responsible for the more depleted values seen at depth.

Transient flow modelling simulated similar levels of drawdown (up to 40m) to what has been recorded in the field by numerous authors (e.g., Van Den Broeck (2019). Calibrated hydraulic conductivity of assimilated dolerite units were between 1 and 2 orders of magnitude higher than limestone units, however the larger size of the limestone units (in particular the lower unit found below the pervasive dolerite sill) results in higher transmissivity than that of the assimilated dolerite units, contrary to recent postulation (e.g., Girmay et al., 2015) suggesting their role as primary aquifer units.

The rapidly growing population of Mekelle and unchecked water extraction by industry, coupled with the limited and erratic rainfall the area receives are the primary problems facing water supply in Mekelle. Limited borehole maintenance, a lack of historical data and uncertainty regarding the hydrodynamics of the aquifer have exacerbated the already dwindling water supply Mekelle has. Future water security relies on diversification of water resources and an improvement in management technique and implementation.

Evaluation of elasmobranch bycatch in artisanal gillnet fisheries off the coast of Rio de Janeiro, Brazil

BY Benoit Moreaux

PROMOTER: Steven Degraer (Universiteit Gent)

Elasmobranchii are a subclass of cartilaginous fishes (Chondrichthyes) that includes sharks, rays and skates. Elasmobranchs are often top-level predators and exercise important control over food webs. In the past 30 years, populations have shown strong declines, both globally and in Brazil. This is mostly due to the exploitation by commercial fishing operations, and amplified by biological characteristics, such as slow growth, a late age at maturity, relatively long lifespans, a low fecundity and often a small number of offspring. In Brazil, small-scale fishers yield in average 50 % of all catches. Yet the impact of small-scale fisheries that operate gillnets on local elasmobranch populations is little researched and officially classified as incidental bycatch. This study aims to provide baseline data on the frequencies and species diversity of elasmobranch catches for several established small-scale fishing communities in the state of Rio de Janeiro. All of which exclusively or frequently use gillnets in coastal areas as the predominant fishing technique. Landing sites and associated fish markets were visited and landed elasmobranchs were sampled. Additionally, informal interviews with veteran fishers were conducted to better understand why and how gillnets are a major tool for the artisanal fishers. This study found that elasmobranchs are landed regularly and randomly in all locations. In total, 18 often endangered species of sharks, rays and skates were identified during 30 field trips between June-November 2019. Extrapolated rarefaction curves based on sampling effort and available literature suggest that greater sampling effort is needed to identify most local species subject to coastal gillnet fisheries. Most prevalent reasons for the use of gillnets are overall improved catch yield, relatively low costs to obtain and maintain and furthermore, gillnets are reported to often being used for traditional and cultural reasons. Based on these findings we suggest increased monitoring of artisanal landed catches in the future. Furthermore, fisheries management should make stronger efforts to regulate the use of gillnets, while at the same time the socioeconomic realities of associated fishing communities are being taken into account holistically sustainable conservation efforts.

Phylogenetic relationships and biogeographic diversification of shallow water octopuses
BY Cretusi Joseph Mtonga

PROMOTER: Marc Kochzius (Vrije Universiteit Brussel)
CO-PROMOTER: Cyrus Rumisha

With more than 200 species, octopus constitute an important fishery resource in the world. The close similarity in morphological features, life strategies and behaviour has hampered taxonomic and phylogenetic studies. In this study, mitochondrial COI and 16S gene sequences of 67 specimens belonging to 54 species from previous studies were analysed. The phylogenetic analyses suggest that the genus *Octopus* is polyphyletic and that the species *O. conispadiceus* and *O. hongkongensis* might belong to another genus. Biogeographical analyses proposed that the most recent common ancestor of octopus lived in the Pacific Ocean about 42 mya. This ancestor gave rise to lineages between 39 - 24 mya that underwent diversification due to various vicariance and dispersal events (up to 3 mya), resulting in the present-day distribution of octopuses. The most recent diversification between *O. tetricus* and *O. vulgaris* took place between 6 – 3 mya. This study indicated that there is a need for a taxonomic revision to resolve the classification in the genus *Octopus*.

Phylogeography of the giant clam Tridacna maxima across the Indo-Pacific: implications for connectivity and conservation

BY Navisa Nurbandika

PROMOTER: Marc Kochzius (Vrije Universiteit Brussel)

Marine ecoregions represent the areas of relatively homogenous species composition, which are driven by combined biogeographic, geomorphologic, and oceanographic assessments. The Indo-Pacific region harbours the world's highest diversity, and yet subject to high vulnerability due to climatic and anthropogenic stressors. Information on genetic diversity and gene flow are necessary to be included, especially in making conservation prioritization at the most biodiverse marine area. The present study demonstrates the utility of molecular marker to define phylogeography of giant clams *Tridacna maxima* and its implication to connectivity and conservation in a broader context. Mitochondrial COI sequences of a 352-bp fragment from 59 localities across Indo-Pacific show seven distinct lineages, dividing the populations into following groups: (1) Red Sea, (2) Coastal East Africa, (3) Madagascar, (4) Eastern Indian Ocean, (5) Indo-Malay Archipelago and South China Sea, (6) Western Pacific, and (7) Central Pacific. All populations indicate a moderate to a high level of haplotype diversity (h) and low level of nucleotide diversity (π), with the overall value of 0.98 and 4.5%, respectively. Analysis of molecular variances suggests significant genetic differentiation (ϕCT = 0.762, p < 0.01) among eleven groups: (1) Red Sea, (2) East African Coast, (3) Juan de Nova, (4) Madagascar, (5) Eastern Indian Ocean and Java Sea, (6) Indo-Malay Archipelago and the South China Sea, (7) Biak-Yapen, (8) Western Pacific, (9) Kiribati, (10) Palmyra, and (11) Society Islands. These eleven genetic partitions of T. maxima support five ecoregion barriers which situated between (a) northern and central of the Red Sea; (b) areas in the Java Sea and its eastern region (Makassar Strait and Lesser Sunda Islands); (c) Gilbert/Ellis Island; (d) Line Islands; and (e) Society Islands and its surroundings. This wide range phylogeographic information and its comparison with ecoregions are essential to support effective design marine protected area by ensuring both species and genetic diversity.

Quantifying Changing Ecosystem Services in Relation to Coastal Defense Planning along the North Sea

BY Ronald Reagan Okoth

PROMOTER: Dries Bonte (Universiteit Gent)
SUPERVISORS: Martijn Vandegehuchte, Ruben Van De Walle

Coastal areas are considered among the most densely populated in the world; as they produce diverse ecosystem services. Because of their high temporal and spatial dynamics, coastlines are highly threatened by erosion, which is a result of increased flooding induced by both human and climate aided drivers. A significant number of coastlines are at present eroding at high rates especially in lower European countries. The erosion risks being elevated if the present trends in climate change and human activities persist. In the past, hard engineering structures have been implemented as a protection measure, however, these structures can only protect against erosion and not sea level rise. As it's expected that sea level rise will cause severe socio-economic damages, managers are shifting to resilient coastal protection approaches for example using dune-building vegetation like European marram grass (*Ammophila arenaria*) to build resilient and resistant dunes to protect the coast. Despite being extensively studied, knowledge gap on spatial vegetation configuration of marram and hence the dune's resilience to climate change still prevail. In this study, we investigate how hydrodynamics (tidal regimes) and urbanization impact dune properties (Vegetation proportion, patchiness, dune growth, sand volume and dune resilience) in different countries. Urbanization was linked to dune stabilization in British dunes hence less marram cover and activation in French, Belgian and Dutch dunes thus more cover. Areas with high tidal regime had less marram cover potentially explaining high cover in Belgian and Dutch dunes and low in French dunes. Urbanization, unexpectedly, did not fragment marram into small patches. Dune erosion was observed in all the countries in the past five years thereby increasing topographic changes. Erosion was more in high tide areas and areas with high urbanization where dune growth was slow and consequently low dune recovery after storm (resilience). This study shows that both hydrodynamics and increased coastal urbanization reduces dune resilience.

The effect of organic and conventional agriculture on the biodiversity of freshwater Ostracoda (Crustacea) in West Flanders (Belgium)

BY Dorien Oude Luttikhuis

PROMOTER: Bram Vanschoenwinkel (Vrije Universiteit Brussel)
SUPERVISOR: Koen Martens

Organic agriculture is promoted by the European Union and it is expected that this type of agriculture would have a smaller impact on the environment than conventional agricultural practices. 62.8 % of West Flanders (Belgium) land surface was covered by arable land of which 0.09 % was organically farmed in 2018. Ponds are sensitive to the land use in their catchment on a local scale, owing to their small size and catchment area. This makes them good sentinels for assessing the effect of agriculture on a local scale. Ostracods (Crustacea) are present in a large variety aquatic and (semi-)terrestrial environments and a sensitive to a wide range of environmental variables. They are common in ponds and as they are sensitive to environmental variables they can be good proxies for assessing the impact of agricultural practises on the diversity in farmland ponds. As part of the project on " A comparative analysis of ORganic and Conventional Agriculture's impact on Aquatic systems – ORCA", the present study investigates if the ostracod diversity in ponds is higher in organic agricultural land compared to ponds in conventional agricultural land. 28 ponds in conventional (n = 16) and organic (n = 12) were sampled on ostracods and water physical and chemical measurements were done. Also information about land use and vegetation cover were collected. By using QGIS the arable land was quantified and the statistical analysis were conducted to investigate if there were differences between ponds in conventional and organic agricultural land in the ostracod community structure and the environmental variables. The present study shows that there is no difference between the impact of conventional and organic agriculture on ponds neither in ostracod community structure nor in the environmental variables. The absence of a difference in environmental variables can explain the absence of a difference in ostracod community structure.

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Investigating Species Interactions in the Light of Ocean Acidification in Benthic Communities of the North Sea

BY Sidanth Kumbagowdana Satish

PROMOTER: Jan Vanaverbeke (Universiteit Gent)
CO-PROMOTER: Carl Van Colen

In recent years, ocean acidification has become a very pertinent field of study in recognition of the expected drop in pH by the end of the century and its implications on the oceanic environment and ecology. Benthic meiofauna, being highly sensitive to environmental changes, have been found to be suitable descriptors of changing ecological dynamics. It has also been documented that the effects of changes in the physical and chemical environment, on meiofauna, are more accurately described in the presence of keystone species. This study incorporates the presence of marine polychaete, Lanice conchilega, which is a known autogenic and allogenic ecosystem-engineer. The study investigates whether acidification, as projected for the end of the century, modifies the effects of Lanice sp. on benthic meiofauna communities. In a controlled laboratory experiment, the individual and combined effects of 3 factors, pH(ambient and acidified), Lanice(presence and absence) and sediment depth(2 layers) on total meiofauna abundance, nematode abundance and copepod abundance were studied. The results showed that sediment depth was the only factor that consistently had a significant effect on meiofauna abundance, exhibiting a negative relationship with it. Acidification was observed to have a significant effect on the copepod abundance in the topmost layer of sediment. Apart from this, neither pH nor Lanice, nor any combination of the 3 factors exhibited a significant relationship with any of the meiofaunal abundances. It is likely that the experimental parameters considered in this study were not adequate to conclusively test the hypothesis. Further studies are therefore required to improve the conclusiveness of this study.

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PREDICTIVE MODELING OF THE ABUNDANCE AND BIOMASS OF FUNCTIONALLY IMPORTANT SPECIES AT BELGIAN PART OF NORTH SEA

BY Vincent Sindikukwabo

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CO-PROMOTER: Gert Van Hoey
SUPERVISOR: Jolien Buyse

This study had the objective to model the density and biomass of functionally important macrobenthic species (*Abra alba*, *Nephytys cirrosa*, *Magelona* species, *Macoma balthica*, *Hesionura elongata* and *Ensis directus*) in the Belgian Part of North Sea. These species are known to be key species for five communities at Belgian Part of North Sea and have high contribution to the final score of the bioturbation potential and ecosystem functioning. In addition, the models for those species we get in this study can be applied in other EU countries, where those species occurs for facilitating the marine ecosystem management plans. We predict individual species responses, based on fifteen environmental variables. Hence, for density prediction, we tried general linear model (GLM), Poisson model, general additive model (GAM) and general additive model with negative binomial distribution (GAM (nb)). For biomass we tried GLM and transformed response general linear model (TGLM) using R software. To conclude if a model was appropriate, we checked different assumptions including normality of residuals, dispersion of predicted observation, homogeneity of variances in the models, zero inflated and nonlinear pattern of variables. We successfully predict density by using count distribution models by general additive model with negative binomial, but we didn't get a good model for biomass. The highest model predictions were achieved for *Macoma balthica*, *Ensis directus* and *Hesionura elongata* with respective percentages of 82%, 81.4% and 81%, while the least one is *Nephtys cirrosa* with 34%, (GAM (nb). But why most of the models we tried failed to predict marine benthic species ? Based on our results we listed some of disadvantages and advantages of the employed models in ecological data prediction analysis which are useful for other marine scientists.

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Colonizing macrobenthos and sediment dynamics in a developing coastal lagoon, the Zwin nature reserve

BY Nathalie Van Caster

PROMOTER: Ann Vanreusel (Universiteit Gent)
CO-PROMOTER: Carl Van Colen

The Zwin nature reserve on the border of Belgium and the Netherlands is an important coastal lagoon with several important ecosystem services such as a feeding and breeding habitat for shorebirds. The last decades the area has been threatened by silting up. Since 2013 management actions were undertaken to counteract siltation and improving habitat quality of the tidal nature in the area, including the expansion of the tidal floodplain, and the widening and deepening of the main channel which was finished in February 2019. To evaluate these management actions an integrated monitoring program started in April 2019, including the monthly collection of sediment abiotic properties and macrobenthos communities. Sediment total organic matter, median grain size and mud content did not differ significantly over time in the old area whereas a clear temporal variability was observed in the new area. January was the most significantly different month in all three stations in the new area. Total organic matter, median grain size and mud content were all significantly different from other sample moments in the new area, and with the old area. The mud station however was not significantly different in median grainsize and mud content. Macrofauna communities present in the expanded area after 8 months of colonization differed significantly from the old area. Species with a highly mobile adult or pelagic larvae were more present in the new area, than species with a less mobile life form like *Tubificoides benedeni*. Colonization was most successful for opportunistic species, such as *spionid polychaetes*, that are known to be dominant early succession communities. *Hediste diversicolor*, a species found in all stations of both locations, showed a light preference for the pump and sand stations. The more stable sediments of these stations are more preferred by this burrowing species. A full modeling of the colonization of the area was not possible due to Covid-19, however a first glance in the macrobenthic community structure shows succession follows the storylines of most ecological models described in literature.

Keywords: Coastal lagoon – Zwin nature reserve – Intertidal habitat - Macrobenthos

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POPULATION GENOMICS OF THE ANTARCTIC BIVALVE AEQUIYOLDIA EIGHTSII BY MEANS OF REDUCED REPRESENTATION SEQUENCING AND GENOME-WIDE SNP CALLING

BY Lore Van Craenenbroeck

PROMOTER: Ann Vanreusel (Universiteit Gent)
CO-PROMOTER: Francesca Pasotti
SUPERVISOR: Isabelle Schön

The West Antarctic Peninsula (WAP) is currently facing rapidly increasing temperatures as a consequence of climate change. Changes in environmental conditions will likely impact marine organisms inhabiting the adjacent Southern Ocean (SO) and might cause their extinction if they are unable to adapt or migrate. However, organisms of the SO were able to survive major climate changes during past glacial-interglacial cycles. Reconstructions of these past responses could help predict how they will react to future climate change scenarios. The Refugia and Ecosystem Tolerance in the Southern Ocean (RECTO) project aims to understand these past responses by studying six marine taxa with different life histories and dispersal capacities. This study focusses on the Antarctic bivalve *Aequiyoldia eightsii*, a broadcast spawner with lecithotrophic larvae, and is part of the second work package of the project that deals with phylogeography and reconstructing population histories. *Aequiyoldia eightsii* individuals were sampled at ten different locations along the WAP and East Antarctica. These individuals were genotyped at more than 2000 Single Nucleotide Polymorphism (SNP) markers that were identified using Genotyping-by-Sequencing (GBS), a reduced representation sequencing approach. This SNP data was used to assess the genetic population structure and connectivity of *A. eightsii*. Results suggest the presence of two major genetic cluster, separating Terra Nova Bay (TB) populations in East Antarctica from sampling locations at the WAP. The TB population was highly genetically differentiated from the other sampling locations and might constitute a cryptic species. This might be driven by geographical distance, as the WAP and TB are separated by more than 5000 km. Several genetic subclusters along the WAP were also observed, possibly resulting from oceanographic features in the region, allowing or restricting gene flow between certain locations.

Early root development and establishment efficiency of mangrove propagules (Ceriops tagal)

BY Paulien Wyns

PROMOTER: Nico Koedam (Vrije Universiteit Brussel)

Mangrove forests are very well studied ecosystems when it comes to knowledge about their importance for biodiversity and the roles they play in providing different ecosystem services. Nevertheless, basic principles in the lifecycle of mangrove trees, such as root initiation of propagules and the influence of a previous dispersal phase on this process, surprisingly remain almost unknown. Propagules of the mangrove species *Ceriops tagal* were selected to study (1) early root development and (2) to study the possible link between mangrove propagule dispersal and its establishment efficiency, as reflected in rooting dynamics. Early root development of *Ceriops tagal* propagules is characterized by gradual transition over four different phases: 1) bumps, 2) initial roots, 3) short roots and 4) long roots. Significant differences in timing of rooting (days after planting) and treatment (freshly abscised or *in situ* exposure to tidal currents) were found among the different phases in early root development. Propagules which have been exposed to tidal currents for 6 or 18 days or for an unknown period of time, have a head start in root initiation and anchoring compared to freshly abscised propagules which have never been exposed to tidal currents before. The result of this study is an addition to the current knowledge about the environmental conditions and triggers for root initiation of mangrove propagules (emphasis on *Ceriops tagal*). Apart from contributing to a better understanding of establishment efficiency, results of this study indicate that propagules need a sufficiently long previous floating period to root faster, which may be of importance in mangrove forest restoration. It also confirms that the delayed dormancy of propagules can be rapidly reversed, which demands further research into underlying physiological processes.

Keywords: Root initiation, obligate dispersal period, establishment efficiency, *Ceriops tagal*, Gazi Bay

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