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KEYNOTE PRESENTATIONS

Shaping our blue future: The EU Mission Restore our Ocean and Waters

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Dr John Bell is the European Commission's 'Healthy Planet" Director leading DG Research & Innovation policy transitions on Climate Change, Bioeconomy, Food Systems, Environment, Biodiversity, Water, Circular Economy, Oceans and the European Green Deal.

He leads the EU's €10 billion Horizon Europe Research & Innovation programme across these planetary transitions. As vice-Chair of the EU Governing Board of €2 billion Circular Bio-based Europe institutionalised partnership with industry, he leads the deployment of the EU Bioeconomy Strategy.

He is co-leading one of the EC's moonshot Green Deal "Missions": "Restore our Ocean and Waters by 2030". His commitment to international research and innovation cooperation ranges from the All-Atlantic Ocean Research and Innovation Alliance, International Bioeconomy Forum, Partnerships for Research and Innovation in the Mediterranean Area (PRIMA) and AU-EU Partnership on Food and Nutrition Security and Sustainable Agriculture.

A native of Dublin, Ireland, he was educated at University College Dublin, as the first Anglo Irish Banks scholar specialising in Irish studies (MA). As a Foreign Commonwealth Office Scholar at St John's College, Oxford University, he completed his Doctorate (D. Phil.) on Irish Nationalism and Seamus Heaney. He was awarded Doctor Honoris Causa by the Agriculture University of Plovdiv in 2022.

A man on the front line of exploration

Rose Paul

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A man at the front line of exploration and one of the world's most experienced divers, field science and polar experts, Paul Rose helps scientists unlock and communicate global mysteries in the most remote and challenging regions of the planet. He is an experienced television presenter and radio broadcaster.

Former Vice President of the Royal Geographical Society and Chair of the Expeditions and Fieldwork Division, Paul is currently Expedition Leader for the National Geographic Pristine Seas Expeditions.

He was the Base Commander of Rothera Research Station, Antarctica, for the British Antarctic Survey for 10 years and was awarded HM The Queen's Polar Medal. For his work with NASA and the Mars Lander project on Mt Erebus, Antarctica, he received the US Polar Medal.

Paul is a mountain and polar guide leading Greenland Icecap crossing and mountaineering expeditions and polar science support logistics. He worked for four years as a Mountain Safety consultant to the oil industry in the Middle East.

On his 2012 Greenland expedition, Paul led the first expedition to successfully traverse a new 275km icecap route of Knud Rasmussen Land and repeated his first ascent of the north face of Gunnsbjørnfjeld, the highest mountain in the Arctic.

His professional diving work includes science support diving in Antarctica as the British Antarctic Survey's Institute Diving Officer. He ran the US Navy diver training programme at Great Lakes Naval Training Centre and trained many emergency response dive teams including the Police, Fire Department and Underwater Recovery Teams. He remains a current and active PADI Dive Instructor.

Paul co-authored the BBC book, Oceans and wrote the Humboldt and Magellan chapters for the book Great Explorers published by Thames and Hudson in 2010. His commissioned magazine articles include the Sunday Times Eureka magazine and a monthly column for Sport Diver magazine.

He is an Honorary Fellow of the University of Cumbria and was a member of the 2010 Rolex Awards jury.

The Royal Geographical Society has awarded Paul the Founder's Medal and the Ness Award.

A mountain has been named after him in Antarctica.

AWARD PRESENTATIONS

Understanding and tackling jellification: from polyp to bloom

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This thesis is about the phenomenon of jellyfish blooms, which are sudden and massive increases in jellyfish abundance that can have negative impacts on various aspects of human society and the marine ecosystem. Jellyfish can potentially have a significant impact on economy, tourism and environment, especially when they form blooms. They can reduce the fishery production and the fish stocks by competing with or preying on fish, affecting the livelihoods of fishermen and the food security of many people. They can also sting humans and other animals, causing pain, irritation, allergic reactions or even death in some cases, which can deter people from swimming or visiting beaches where jellyfish are present. Moreover, they can clog the cooling systems of power plants, desalination plants, and other industrial facilities that use seawater, causing damage, disruption, or shutdown of the operations, resulting in economic losses and environmental risks. Furthermore, they can alter the biogeochemical cycles of the ocean, such as the carbon, nitrogen, and phosphorus cycles, affecting the primary production, the oxygen levels, and the nutrient availability of the water, influencing the marine biodiversity and ecosystem functioning. Finally, they can transport non-indigenous species (NIS) or pathogens across different regions, as they can act as hosts, vectors, or carriers, introducing new diseases, parasites, or invasive species to the native communities, threatening their health and diversity.

The thesis focuses on the occurrence and causes of jellyfish blooms in the Belgian Part of the North Sea (BPNS), which is a region that has been reported to experience frequent jellyfish blooms in the last decades. The aim was to answer two main research questions: (1) Can jellyfish blooms in the BPNS be predicted on the basis of environmental DNA (eDNA) metabarcoding? and (2) What are the possible factors that contribute to jellyfish blooms in the BPNS?

To answer the first question, the thesis uses both traditional morphology and eDNA metabarcoding to identify and quantify the gelatinous zooplankton in the BPNS over the course of six months. Traditional morphology involves counting and measuring the jellyfish specimens collected by nets, while eDNA metabarcoding involves extracting and sequencing the DNA fragments from the seawater samples and comparing them with a reference database. In this research project, we applied nanopore sequencing, which is a novel and portable technique that can generate long DNA reads in real time. We targeted a 500 – 1000 bp fragment of the 18S rDNA gene, which is a universal marker for eukaryotes. We focused on two phyla of gelatinous zooplankton: Cnidaria and Ctenophora, which include the most common and problematic jellyfish and ctenophore species.

The thesis compared the spatial and temporal patterns of jellyfish abundance obtained by both methods and evaluated the advantages and limitations of each method. We also identified the species and life stages of the gelatinous zooplankton detected by eDNA metabarcoding and discussed the implications for jellyfish monitoring and management. eDNA metabarcoding detected seven different species of Cnidaria and Ctenophora in the BPNS, but it could not predict jellyfish blooms, as there was no significant correlation between the eDNA reads and the morphological counts. We also found that eDNA metabarcoding can detect the presence of jellyfish larvae and polyps, which are the asexual and sessile stages of the jellyfish life cycle, but it could not distinguish them from the medusae, which are the sexual and free-swimming stages. We concluded that eDNA metabarcoding is a useful tool for jellyfish detection, but it needs to be complemented by other methods for jellyfish quantification and identification.

To answer the second question, the thesis reviewed the literature and discussed the possible factors that contribute to jellyfish blooms in the BPNS and other regions of the world. We considered both abiotic and biotic factors, such as water temperature, salinity, pH, turbidity, nutrient availability, predation, competition, symbiosis, and parasitism. The role of human activities, such as overfishing, eutrophication, aquaculture, global warming, and the introduction of non-indigenous species (NIS) was also considered, as these factors can alter the benthopelagic food web and create favorable conditions for jellyfish blooms. Our findings suggest that jellyfish blooms are the result of complex and multifactorial interactions between environmental and anthropogenic drivers, and that they may vary depending on the region, the season, and the species. It is concluded that jellyfish blooms are likely to become more frequent and severe in the future due to the ongoing changes in the marine ecosystem and the human society.

The thesis ends with a discussion of the implications and recommendations for the management and mitigation of jellyfish blooms. We argue that jellyfish blooms are not only a nuisance, but also a symptom of a larger problem: the degradation and imbalance of the marine ecosystem. To reduce the frequency and intensity of jellyfish blooms, changes have to be made that act directly on the causes of these blooms, such as reducing nutrient pollution, overfishing, transport of NIS, the amount of artificial substrate and global warming. It is acknowledged that these changes are not easy to implement, as they require a significant economic cost in the short-medium term and a global cooperation in the long term. The thesis also suggests that besides preventing jellyfish blooms, it is also important to adapt to them and to find ways to use them as a resource, such as for food, fertilizer, medicine, or biofuel. It is concluded that jellyfish blooms are a challenge and an opportunity for the human society and the marine ecosystem, and that they require a holistic and interdisciplinary approach to understand and manage them.

Local stakeholders' conservation perceptions in Cu Lao Cham Marine Protected Area (Vietnam) and Kep Archipelago Marine Fisheries Management Area (Cambodia): common challenges and country specificities

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With the diminishing ocean health over the last century, the protection of the ocean has been central to global effort to safeguard stable environmental conditions against the effects of climate change. One of the solutions that have been proposed and accepted worldwide is to increase the coverage of marine extents under official national or international legislative protections, which are known under the overarching term of *marine protected areas* (MPAs). However, setting up new MPAs is hardly the finish line of ocean protection. Mismatches in MPA management often occur as inadequate attention is directed to the social dimensions that are associated with the area concerned. Consequently, conflicts may arise between local communities who rely on the daily harvest of natural resources and management authorities whose responsibilities are to preserve those resources. This, in turn, results in the overall failure of MPAs in achieving an effective management system, leading to the continuing deterioration of marine resources.

One suggested approach for reconciling the conflicts within MPAs entails the study of local communities' perceptions and level of support for conservation. According to Bennett (2016), local support is driven by their perceptions of: (i) *ecological effectiveness*, the biological changes as the result of conservation efforts; (ii) *social impact*, the changes that conservation initiatives produce regarding socio-economic aspects; (iii) *governance,* the legitimacy of the management systems that shape the decision-making process; and (iv) *management,* the overall acceptability of local communities regarding management actions and conservation initiatives. Applying this model, the aim of this study was to examine the perceptions of local communities in Cu Lao Cham MPA (CLC–MPA, Vietnam) and Kep Archipelago Marine Fisheries Management Area (KA–MFMA, Cambodia) and their overall levels of support for conservation and management in these MPAs. Using semi-structured interviews supported by semi-quantitative questionnaires, the study also identified the determining factors that may influence the local level of support.

A total of 153 interviews were conducted during the survey campaign at CLC–MPA (n = 127) and KA–MFMA (n = 26), with a high response rate of 78% and 100%, respectively. In general, local stakeholders were mostly supportive of conservation and management in MPAs. Statistical tests indicated that respondents from KA–MFMA were significantly more supportive than those at CLC–MPA, with 92.3% of the respondents voicing their support for the MPA in comparison with only 78.7% at CLC–MPA. Local perceptions of different indicators related to the three perception categories were positive at CLC–MPA and more neutral at KA–MFMA. As with ecological effectiveness, more than half of the respondents at KA–MFMA perceived a negative change in the abundance, size, and richness of fisheries products in the region. Meanwhile, the majority of the respondents at CLC–MPA perceived no change in the size and richness of fisheries products, and about 50.3% of them reported an increase in fish abundance. Regarding social impacts, in both MPAs, many respondents, mostly fishers, found it difficult to find opportunity for livelihood alternatives or to gain benefits from them. Especially, respondents at KA–MFMA were pessimistic about their income and quality of life, where they perceived a critical reduction in their earnings and thus, could not make enough for a living. With regard to local perceptions of good governance, some fishers from KA–MFMA had trouble accessing administrative information in the MPA, while respondents from Koh Tonsay were not involved

in any participatory management process. The perceptions from local stakeholders at CLC–MPA were generally more positive. Altogether, the composite scores for ecological effectiveness and good governance were significantly higher at CLC–MPA than at KA–MFMA, while no significant difference was detected for social impacts.
Significant relationships between local perceptions and their support for conservation were essentially detected for indicators related to social impacts and good governance at both MPAs. Higher composite scores for social impacts and good governance were also correlated to higher levels of support for conservation in MPAs, while the pattern was not as clear for ecological effectiveness, suggesting that local perceptions of social impacts and good governance may be the stronger determining factors for their opinions of conservation and management in MPAs.

An important result from the study indicated that while local stakeholders at KA–MFMA had a higher level of support for conservation than those at CLC–MPA, their opinions on the impacts of conservation were more negative for all

perception categories. This may come from the different societal settings between the two MPAs, and the common challenges that hinder conservation in both areas. CLC–MPA has more favourable conditions for long-term settlement of human on an offshore island; as a result, the social dimension here was more complex with dynamic interactions between different stakeholder groups and between local communities and MPA authorities. The approach to management is, therefore, based on local participation to co-create management solutions that are centered around the regulating of the use of natural resources from local communities. This results in the fact that local communities here are more aware and understanding of the impacts that the MPA has on the ecological and socio-economic situations in the area. In contrast, the various conservation projects at KA–MFMA do not involve local communities and as the result, the objectives and impacts of the MFMA, together with its ecological and social benefits, may not be fully communicated to and understood by local communities. This rationale serves as a possible explanation for the lower composite score for social impact and good governance perceptions at KA–MFMA when compared to CLC–MPA.

Despite notable differences in geographical and societal settings, the management of CLC–MPA and KA–MFMA is confronted by similar challenges. *Firstly*, illegal fishing poses serious threats to the integrity of natural environment in both MPAs. At CLC–MPA, certain mechanisms exist to cope with the problem; however, a lot of resources are necessitated to handle a single incident, suggesting that the executive procedure at CLC–MPA is ineffective. At KA–MFMA, the autonomy of Marine Conservation Cambodia (MCC) in managing the area rid them of the bureaucracy that is associated with governmental organisations in natural resources management. MCC focuses on the prevention of illegal fishers which have been devastating the area for a long time prior to the establishment of the MFMA. It may be for this reason that although having poor opinions of the impacts of conservation on all perception categories, local communities here still showed a relatively higher overall level of support than those at CLC–MPA. *Secondly*, to achieve long-term conservation objectives, pressure is put on MPA managers to make sure of a sustainable continuation of conservation initiatives and local participation in the management of the MPAs. At CLC–MPA, the integrity of local participation in MPA management has been criticised by the communities for the shortage of financial resources to support livelihood alternative projects and the inappropriate restrictions of access to traditional fishing grounds. This suggests that there exists a possible mismatch between the management approaches and the needs of local stakeholders at CLC–MPA, which may explain the comparatively lower level of support for the MPA here.

Understanding dimensions of ocean literacy in the European maritime industry for a sustainable blue economy

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The ocean plays a crucial role in sustaining life on Earth, offering a wide range of benefits and services. Through its diverse ecosystems, the ocean offers essential resources like food, energy, and minerals, while also regulating the climate and supporting human health and well-being. It significantly contributes to the global economy through industries like offshore renewables, fisheries, tourism and maritime transport, namely blue economy, creating millions of jobs worldwide. However, the rapid expansion of these economic activities poses an increasing risk for the marine environment, that is already facing a growing array of threats, including acidification, overfishing, pollution, habitat degradation and biodiversity loss. As interest in the ocean's economic potential grows, it becomes imperative to adopt sustainable practices and raise awareness among all members of society, particularly those whose livelihoods come directly from the sea, that is the maritime workforce. A thriving blue economy needs a workforce that understands the importance of the ocean, makes informed decisions to manage marine resources and ecosystems, and advocates for sustainable policies. Ocean literacy emerges as a tool to achieve this target, as a way not only to increase awareness, but as an approach to encourage maritime workers to have a more responsible behaviour towards the ocean and its resources. This research aims to expand the understanding on the status of ocean literacy with a focus on the European blue economy and to assess the levels of ocean literacy across maritime workers.

Drawing upon an extensive literature review, the first part of this study presents a comprehensive analysis of key concepts to introduce the reader to the field of ocean literacy. Chapter 1 provides an overview of the European blue economy sectors describing the features of the maritime workforce. This chapter brings forward the need of integrating ocean literacy research within the maritime sector.

Given the emergence of numerous ocean literacy initiatives, it became essential to obtain a comprehensive understanding of this topic to effectively involve the wider community. In chapter 2, we assessed the development of global research on ocean literacy applying bibliometric analysis and science mapping of the available scientific publications on ocean literacy (2005-2019). These techniques enabled us to represent the development of the ocean literacy field, to analyze the level of collaborations and to uncover its thematic areas. Our approach further identified the gaps in research related to the blue economy. Bibliometric analyses were used to describe the field's main features, including indicators of growth and research collaboration. We then used science mapping techniques to build collaboration networks among countries and institutions, and to identify research communities. The findings of this study suggest that ocean literacy is an emerging field of research with promising trends in research collaboration. Our results also suggest disparities in the scientific production and collaborations between the Global North and South. This study allowed us to verify the presence of a gap in the existing research, given that only a small proportion of the global ocean literacy research was focused on the blue economy (7.2%).

Having set the scene for the need of studies on the coupling of ocean literacy and the blue economy, we needed a tool to measure ocean literacy targeted to professionally active people. In chapter 3, we developed and tested the Blue Survey, an online instrument meant to measure ocean literacy in adult populations. Factor analysis was used to explore the validity and internal consistency of the Blue Survey in a purposive online sample of 251 adults. We found ocean literacy to consist of six dimensions captured by 34 survey items, viz. knowledge, personal interest, ocean stewardship, ocean as an economic resource, ocean-friendly behaviour, and willingness to act responsibly towards the ocean. The Blue Survey is proposed as a new instrument to measure ocean literacy in an adult population. This multilingual validated tool combines aspects such as knowledge, attitudes, and behaviours, in the same construct and provides a more integrated perspective on ocean literacy as a means of producing change, which has not been done before for this stakeholder group.

Based on the results from chapter 3, and in order to assess the validity of the Blue Survey across populations closely related to the sea, particularly maritime professionals, we designed the Blue Survey 2.0. In chapter 4, we conducted the Blue Survey 2.0 to assess the levels of ocean literacy of 536 maritime workers across Europe, using exploratory factor analysis, univariate and cluster analyses. Our findings suggest that the way maritime workers connect to the ocean is

complex, but it can be simplified by considering the integration of five pillars including knowledge, attitudes towards ocean sustainability, attitudes towards the use of the ocean, behaviour and personal interest. In addition, we found that factors related to the industry such as the blue economy sector, region and occupation; as well as sociodemographics like age and gender, influenced the levels of ocean literacy in European maritime workers. In the second part of chapter 4, we showcased the application of the Blue Survey 2.0 among maritime workers in Peru. These results constitute a benchmark for measuring ocean literacy in the blue economy sector.

Finally, a comprehensive discussion of the main findings presented in the previous chapters is showcased in chapter 5. This chapter highlights the implications of our findings for marine science and broaden goals of sustainability, such as the UN Sustainable Development Goals, the Ocean Decade and the European Strategy for a sustainable blue economy.

In conclusion, this study has deepened our understanding in the topic of ocean literacy in the context of the blue economy and has highlighted the importance of ocean literacy to ensure a sustainable future. Through an in- depth assessment of the current state of ocean literacy research, our findings support the inclusion of ocean literacy as one of the priority areas of research of the Ocean Decade. By conducting empirical research on the dimensions and levels of ocean literacy using the Blue Survey, this study provides two validated multilingual tools to measure the various dimensions of ocean literacy. The findings of this study underscore the need to integrate ocean literacy content into the trainings of maritime workers, especially for young workers, which seem to be the least engaged. Our results might help companies to understand that for certain groups of maritime workers enhancing knowledge on the ocean alone is not enough to achieve ocean- friendly behaviour and that other approaches for engagement with ocean sustainability seem appropriate. Moving forward, further research in this field should continue building on the foundations laid here to obtain an ocean literacy baseline in maritime communities over time and to assess the mechanisms through which ocean literacy initiatives effectively lead to an increase of knowledge, positive attitudes and behaviours towards the ocean.

Living nearer to the coast and visiting it more often are associated with better self-reported health across 15 countries

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Societies value the marine environment for its health-promoting potential. In this preregistered study, we used cross-sectional, secondary data from the Seas, Oceans, and Public Health In Europe and Australia surveys to investigate: (a) relationships of self-reported home coastal proximity and coastal visits with self-reported general health; (b) the potential of both to buffer income-related health inequalities; and (c) the generalizability of these propositions across 15 countries (n = 11,916–14,702). We find broad cross-country generalizability that living nearer to the coast and visiting it more often are associated with better self-reported general health. These results suggest that coastal access may be a viable and generalized route to promote public health across Europe and Australia. However, the relationships are not strongest among individuals with low household incomes, thereby challenging widespread assumptions of equigenesis that access to coastal environments can buffer income-related health inequalities.

Evidence for the health benefits of the Belgian coast: Psycho-physiological mechanisms and environment- and person-specific influential factors

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Health is defined as a dynamic state of physical, mental and social wellbeing that is constantly responding to environmental, social, biological, emotional and cognitive conditions or states, and thus not merely the absence of disease or infirmity (Lovell *et al.*, 2018). Recent studies have highlighted that visiting or residing near **coastal environments can improve diverse mental, physical, and social aspects of health** (White *et al.*, 2020). This is highly promising for the many people who currently have a poor mental health or are socio-economically deprived and in need of **free health resources**. However, there is a major knowledge void when it comes to the effects of coastal environments on the restorative and instorative processes related to mental health (Gascon *et al.*, 2015, 2017). A recent high-level report of the Seas, Oceans, and Public Health in Europe (SOPHIE) project has identified several key target priorities for researchers on blue spaces, tourism, and wellbeing, referring to the '**what', 'why', 'where', 'who', and 'how much'** (H2020 SOPHIE Consortium, 2020). I have been contributing to addressing those knowledge gaps since I have begun to investigate the effects of the ocean on human health over four years ago.

The research that I conduct tries to acquire the knowledge needed to thoroughly understand:
- the **psychological and physiological effects** of coastal exposure on mental health,
- the environment- and person-specific **influential factors** that are at play, and
- the **underlying sociological structuring** behind these effects.

Conceptually, it must provide society with relevant knowledge **for making optimal use of these health-benefits** while maintaining sustainable interactions between the health of the ocean and the health of the people.

My first study tested whether coastal residents in Belgium have a better general health compared to inland residents (**Hooyberg *et al.*, 2020**). It also assessed whether the hypothesized mechanisms often described in the literature to explain the health benefits from natural environments (i.e. less stress, increased physical activity, better social interactions, and less environmental harm) might mediate the relationship between living near the coast and general health. By using national health survey data (N = 60,939), I provided **the first evidence that living at 0-5 km from the coast in Belgium associates with a better general self-reported health**. None of the four hypothesized mechanisms mediated these effects, which led me to believe that the spatial heterogeneity of the Belgian coast should be further investigated.

My second study quantified how restorative ten typical coastal environments and five beach-specific environments are rated by a sample of inland students, and which of these environments' natural and urban components are responsible for the observed differences (**Hooyberg *et al.*, 2022**). Using a lab-experiment showing pictures to inland students (N = 102), I show that **the perceived restoration of the ten coastal environments differed up to 30 %, was neutral to positive, and seemed to associate with the environments' 'naturalness'**. I was also able to differentiate between locations at the beach: being at a breakwater, in the water, or at an open beach scored up to 20% better than being between beach cabins or in a beach bar. The **vegetation, sand, and sky visibility** in coastal areas contributed positively to the perceived restoratives, while **buildings, vehicles, and hard undergrounds** contributed negatively.

My third study compared both psychological and physiological responses to beaches with those to inland green and urban environments (**under review**). Therefore, I did a comprehensive virtual reality experiment with adult participants from all ages and socio-demographic and health backgrounds (N = 164). As such, I was able to provide **the first evidence that exposure to beaches caused a lower sympathetic nervous system activity and slower breathing rates** compared to green and urban environments. The results of cardiovascular and muscular indices were inconclusive. I also show that the sympathetic effects of the beach
apply for any level of precedent stress, while those of green spaces only apply for those with a low stress level in the past week.

In my most recent study, I am disclosing the social structuring of coastal leisure activities and the experiences people gain from them (analysis stage). Although this seems as a very abstract target, it can actually reveal **what kind of people in terms of socio-demographic and health characteristics perform what kinds of activities, visit which types of coastal environments, and gain different kinds of mental and physical experiences**. As such, it will both widen and deepen the knowledge gained from the second and third studies by taking a person-centred approach on a societal level. Currently, a survey has gathered information from a representative sample of 1862 individuals from the Flanders population.

I always try to make sure that the knowledge that I generate **reaches the public, health-professionals, policy-makers, and other envisioned stakeholder**s. Therefore, I have published in high-impact-factor A1 journals, have exchanged knowledge on many top scientific events, am in the process of writing a policy-informing document about Ocean and Human Health relationships, have released local press-releases and social media posts (with explanatory video's), and have built a website (www.uitzicht.org).

I have a **deep motivation** for doing excellent research that contributes to understanding the relationships between the ocean and human health and is relevant for societal applications. The knowledge that I gather is relevant for using the coast on medical prescription, for the blue tourism sector, and for optimizing the spatial design of (coastal) cities.

BMRI PRESENTATIONS

Continuous monitoring of groundwater dynamics in coastal dunes

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Freshwater lenses beneath Belgian dunes have historically safeguarded hinterlands against saltwater intrusion (SI). Unfortunately, urbanization and anthropogenic activities have diminished these lenses, necessitating new research into understanding the hydrogeological feedback mechanisms during the developmental phases of dunes. This understanding is critical for predicting the evolution of freshwater lenses, especially with rising sea levels and climate change impacting water resources. Engineered dunes, integrated with traditional dikes, are emerging as vital components of coastal defenses, contributing to nature-based solutions, notably providing a critical ecosystem service through their potential induced barrier against seawater intrusion.

Our research, centred in the artificial dune area of Raversijde, Belgium, focuses on comprehending, monitoring, and modelling freshwater lens development during the early stages of dune growth. To support this initiative, we have received the Brilliant Marine Research Idea (BMRI) grant, which has been instrumental in advancing our efforts.

The BMRI grant enabled the implementation of a continuous surveying system, enhancing our capacity for comprehensive and uninterrupted data collection. This includes the deployment of a continuous Electrical Resistivity Tomography (ERT) system and a new measuring pole equipped with different sensors to monitor the overall freshwater recharge. This instrumentation enables detailed and extended monitoring of environmental parameters critical for a more comprehensive hydrogeological model.

The IRIS Syscal Pro ERT device, facilitated by ILVO, constitutes the cornerstone of our methodology. The BMRI grant enabled us to rent, insure, and buy new accessories for the ERT Device, enabling its use for continuous and more flexible measurements in general. We incorporated the use of longer electrodes to address challenges related to higher surface resistances. Newly acquired multicore cables, spanning 72m with 1m electrode spacing, enhance flexibility, ease of use, and underground installation. The possibility to semi-permanently or switch flexibly between installations of the ERT device across diverse zones within the artificial dune area ensures a multifaceted dataset, capturing subsurface dynamics under varying conditions. The surveying system's capacity to measure up to 15 meters deep, with weekly GNSS surveys of buried electrodes, ensures a comprehensive understanding of subsurface conditions. Time-lapse inversion techniques, dependent on accurate topography, enhance the accuracy and reliability of our continuous monitoring system.

A new survey pole stands as a vital component for monitoring recharge dynamics. Equipped with a Pluviometer, pyranometer, soil moisture, EC sensor, and temperature logger, this instrumentation aims to provide a nuanced understanding of environmental parameters over an extended period. The Pluviometer records precipitation, the pyranometer offers insights into evaporation dynamics, while the soil moisture and EC sensors monitor the inflow of water into the dune. The temperature logger tracks temperature variations. Cross-referencing these parameters with data from a local weather station located a few kilometres away provides an additional layer of validation and precision.

The BMRI grant played a pivotal role in acquiring and deploying these advanced monitoring tools, ushering in a shift from sporadic field surveys to semi-continuous, high-resolution data collection. This methodological framework not only enhances our understanding of hydrogeological dynamics during early-stage dune growth but also establishes a robust foundation for predictive modelling and informed coastal management.

Keywords
Early-stage dune development; Nature-based solution; Saltwater intrusion; Hydrogeological feedback mechanism; Coastal protection; Artificial dunes; Geophysical surveys

What can whale songs tell us about population connectivity?

De Weerdt Joëlle

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Humpback whales (*Megaptera novaeangliae*) are a migratory species composed of 14 distinct populations distributed in both the northern and southern hemisphere. Traditional migratory route patterns of humpback whales involve movements between feeding and breeding areas. Populations are assigned according to their breeding areas which determines their genetical and acoustical identity.

Humpback whale males display strong acoustic behaviours, producing songs that are culturally transmitted and shared by individuals of the same population. Every population is characterized by their own song. The song can evolve through time within and between seasons, which implies that a learning process is involved between males. Humpback whale songs are traditionally classified into themes, phrases, and units, allowing comparisons of song elements across geographical regions. In Central America, two humpback whale populations from both hemispheres breed in the same area at different times of the year. Potential temporal overlap exists between both populations based on field observations and raises the question on potential acoustical exchange and therefore population connectivity.

The objective of this research is to understand population connectivity by analysing the song structure and assess correspondences and differences between song elements (including units, phrases and themes). Data were collected during boat-based surveys between January and April in San Juan del Sur, Nicaragua between 2021 and 2023. Signal-to-Noise Ration (SNR) was estimated by measuring NIST Quick Signal-to-Noise ratio for each labelled unit in every recording using RAVEN 1.5 program. Songs were visually inspected in RAVEN by generating spectrograms with a Fast Fourier Transform of 1024 points resolution.

Preliminary results showed the presence of a similar theme in 2021, song analysis of 2022 and 2023 are still in progress. This investigation holds significant implications to assess migratory routes and for the conservation of humpback whales in identifying key reproductive areas based on song connectivity.

Copepod guts, a new world in marine sediments?

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Copepods are abundant in the marine ecosystem and are considered microbial hotspots in the ocean, with bacteria residing both on their chitin exoskeleton and in their body cavities and intestinal tract. Especially in the gut canal, bacteria can perform important roles. Copepods have a simple digestive tract with fast egestion, causing a major fraction of the food to pass through the gut incompletely digested. Therefore copepods also show coprophagy, the breaking apart and reingestion of formed fecal pellets. This reingestion accounts for further metabolization of food particles, with microbial assisted degradation of fecal pellets potentially playing an important nutritional role. Copepods are even suggested to maintain a 'microbial garden' with the egestion and reingestion of their fecal matter. The guts of pelagic copepods have been studied and are considered a selective microhabitat in the open ocean. Bacteria of benthic copepods and their gut community were undescribed and studied for the first time here.

The benthic copepod *Platychelipus littoralis* (Harpacticoida, Family Laophontidae), a key species in intertidal mudflats of North-West Europe, was characterized throughout a one year period (Aug 2022 - Sept 2023), during which it experienced strong temporal fluctuations. After a 24h starvation period, the gut was microdissected to obtain the residential gut community without presence of fecal pellets. Cell counts in the gut and community composition fluctuated strongly over the seasons. The gut community was significantly different from the sediment, indicating that the lower pH and lower oxygen availability in the gut formed a selective microhabitat. Water temperature and the copepod physiological state changed as well over the course of the year, with individuals being able to grow larger in summer, and contain more lipid reserves in winter. This indicated a change in the diet of the copepods but the variables could not be easily linked one-to-one with changes in the microbial community.

Next to the residential or fecal pellet free community, an additional 24h starvation period was included to study the reingestion of fecal matter. Core taxa were defined both for the residential microbiome and starved microbiome. Bacterial taxa, including the genus Colwellia, were increased in the gut or water surrounding the copepods with starvation. This indicated a microbial flux from the surrounding water or so-called ‘microbial garden’ towards the gut with a potential nutritional implication.

While it was already known for pelagic copepods that their guts were selective, the same seems to hold true for copepods living in sediments. This new microhabitat of copepod guts should be taken into account for ecological modelling of marine sediments and their microbial food web. Bacterial taxa were identified which have a potential role in microbial gardening but future studies are require to quantify the ecological relevance of this microbial flux in the bacteria rich sediment environment.

Keywords
Microbial food web; Copepods; Microbiome

From bloom to foam: tracing the role of *phaeocystis* in marine gel formation

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Marine ecosystems harbor complex biochemical processes that are vital to the global carbon cycle[1,2]. A key component in this cycle is the generation of particulate organic carbon (POC), particularly through marine gels formed during algal blooms[3]. Our study focuses on *Phaeocystis*, a cosmopolitan, bloom-forming alga known for its foam production[4]. Under optimal conditions, *Phaeocystis* exudes excess energy as glucans and mucopolysaccharides. These molecules help form a gel matrix that facilitates colony formation and attracts specific bacterial communities. Post-bloom, the lysis of *Phaeocystis* colonies releases large quantities of carbohydrate-rich dissolved organic matter (DOM) into the water. This DOM serves as a precursor for transparent exopolymer particles (TEP), leading to marine gel and foam formation[5–7].

Our objective was to delineate and quantify the relationship between late-stage *Phaeocystis* blooms and TEP concentrations. We wanted to assess the metabolic contribution of *Phaeocystis* to the overall expression of genes involved in carbohydrate synthesis. We utilized a multidisciplinary approach, combining metatranscriptomics with measurements of ecosystem properties and abiotic factors. We organised a sampling campaign with the R/V Simon Stevin targeting two distinct ecosystem states during diel cycles: a *Phaeocystis globosa* bloom and a post-bloom ecosystem state. We measured primary production, phyto- and zooplankton community abundance and taxonomy via high-throughput automated microscopy, alongside microeukaryotic species' metabolic activity through metatranscriptomic analysis.

We captured a late-stage *Phaeocystis* bloom near Ostend harbour, and a post-bloom ecosystem 46.60 km northeast. Preliminary findings indicate significantly higher TEP concentrations during the late-stage *Phaeocystis* bloom compared to the non-*Phaeocystis* dominated ecosystem. Notable differences were also observed in the composition and abundance of phyto- and zooplankton communities. The *Phaeocystis* dominated ecosystem exhibited elevated nutrient loadings, dissolved oxygen, dissolved carbon, and turbidity. Successful RNA extraction and short-read sequencing have set the stage for the ongoing metatranscriptomic data analysis.

Thoroughly understanding these processes is vital for better grasping the global carbon cycle and the ecological impacts of algal blooms. This research provides detailed insights in the intricate connections between microbial processes and global biogeochemical dynamics.

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Keywords
Marine gels, *Phaeocystis*, Carbon cycle, Diel cycles, Metatranscriptomics, Ecosystem dynamics, Algal blooms

Towards unravelling the potential of red macroalgae for human health: a molecular approach

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As food requirements are shifting towards promoting human health and avoiding disease, seaweed has attracted much interest as a natural source of bioactive compounds, which, due to their supposed health benefits, attract attention for economic exploitation. Currently there are few to none studies available that have investigated the molecular mechanisms behind the production of these metabolites. Omics tools, including transcriptomics, can potentially bridge this knowledge gap and can help in understanding the interactions between complex metabolic pathways and environmental conditions, as they sample entire transcriptomes rather than focusing on a limited set of genes.

Therefore, in this project we aim to unravel the underlying molecular pathways involved in the production of three of those identified bioactive metabolites, i.e., floridoside, phycoerythrin and phycocyanin, in the Atlantic red seaweed species Palmaria palmata, one of the most common red macroalgae on rocky shores in the Northern Hemisphere.

In this project, we have subjected the macroalgae to two different constant temperatures: 12 and 14 °C at neutral days (12 h:12 h light:dark) for two different exposure durations (i.e. two and ten days of exposure, representing an acute and sustained exposure period, respectively), with 4 replicate tanks for each exposure scenario. In addition to quantifying the concentration of the bioactive compounds of interest, we sequenced the transcriptome and studied differences in the seaweed's gene expression as the molecular processes underpinning the studied phenotypic effects. We mainly focused on the carbohydrate metabolic pathways, underpinning the production of the studied bioactive compounds, in addition to typical stress responses of the seaweed. The results obtained from this study set a base line for future studies, as we are beginning to gain crucial insights into how environmental factors influence the seaweed metabolism in addition to developing quantitative relationships linking molecular endpoints (omics) to the nutritional value of seaweed.

Keywords
Seaweed; Nutraceuticals; Bioactive compounds; Transcriptomics; Gene expression

Unraveling the molecular mechanisms of diversification: Comparative genomics of the monogeneans infecting the gills of the marine barramundi, at both micro and macro evolutionary levels

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Biological diversity varies significantly across the tree of life: some clades are highly species-rich, and others remarkably species-poor[1]. Despite our growing understanding of the conditions and processes that lead to the formation of new species, we still struggle to identify what hinders diversification[2]. Lates perches (Latidae) are fishes with a unique dichotomous distribution pattern. The euryhaline species of lates perches can be found in the Indo-Pacific region, with barramundi (*Lates calcarifer*) being the most widespread representative with significant relevance to the aquaculture and fisheries sector. On the other hand, freshwater representatives are found solely in African river basins and lakes. Interestingly, while marine barramundi hosts a variety of monogenean gill parasites, the monogenean fauna of African lates perches is species poor with a single species being reported, *Dolicirroplectanum lacustre*[3, 4]. This contrast in parasite species richness is counterintuitive, because typically parasites diverge faster than their hosts because of their shorter generation time and faster mutation rate[5].

In this study, we want to understand the constraints on species diversification by delving into the genomic diversity of the monogenean parasites infecting lates perches. We integrate a comparative genomic study encompassing both micro-evolutionary (intraspecific) and macro-evolutionary (interspecific) levels (between Indo-Pacific monogeneans and *D. lacustre*). This approach aims to identify genomic signatures associated with diversification at both evolutionary levels, shedding light on the intricate interplay of host-parasite-environment interactions in shaping evolutionary outcomes.

Specimens of barramundi were obtained from the coast of China (n=22) and Sri Lanka (n=16). Their gills were collected and preserved in absolute ethanol. Gills were screened for monogenean gill parasites under a dissecting microscope using entomological needles. A total number of 125 parasites were retrieved from 11 screened hosts. The average infection intensity was 10.9 parasite individuals per infected host with the overall prevalence of 81.8%. The DNA of the parasites was extracted using an in-house protocol for low-input samples[6]. Species composition of monogenean communities was determined via barcoding approach using the part of 28S rDNA fragment. Genomic libraries were sequenced on the Illumina NovaSeq platform at 50x sequencing depth.

The resulting genomic data were adapter-trimmed and quality-filtered, and will consecutively be analyzed to identify outlier loci, evaluate genetic diversity indices, and estimate fixation indices (F_{ST}) for intra- and interspecific comparisons. This study aims to contribute novel insights into the mechanisms driving diversification in soft-bodied organisms, addressing a critical gap in our understanding of micro- and macro-evolutionary processes.

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Keywords
Comparative genomics; Monogenea; Diversification; Speciation; Biodiversity

PRE-DOC PRESENTATIONS

Quantification of panarctic benthic-pelagic carbon and nutrients fluxes

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With climate change, the Arctic Ocean is experiencing unprecedented changes. While much attention is directed to apparent impacts such as sea ice melt, permafrost thaw, and coastal erosion, our quantitative understanding of the substantive contribution of the Arctic seafloor in regulating nutrients and sequestering carbon and how it might change under climate change is very limited. The Arctic Ocean is unique regarding carbon and nutrients cycling because (i) the ice-free fraction is often highly productive, with significant atmospheric CO2 uptake, and (ii) the world's largest shelf sea surrounds it. Hence, the seafloor experiences large organic carbon (OC) settling and burial fluxes. However, a comprehensive quantitative analysis of carbon and nutrients fluxes across the Arctic seafloor is unavailable. In this study, we quantify carbon and nutrients fluxes across the entire Arctic seafloor using a novel analytical diagenetic model. Two case studies, in the Barents Sea and in the East Siberian and Laptev Seas, are realised to evaluate the model's performance in resolving Arctic diagenetic dynamics. To simulate budgets for the entire Arctic seafloor, we force the model with sediment organic carbon contents and reactivities, sedimentation rates, and bottom water boundary conditions (i.e., depths, temperatures, oxygen, and nitrate concentrations) from previous published relations and databases.

Our results show that 24.22 Tg of OC is buried each year in Arctic sediments and that 3.76 Tg of Nitrogen (N) is released each year from the sediments to the water column. We find that this benthic nitrogen return flux is more than 10 times the riverine dissolved inorganic nitrogen flux, thus highlighting the importance of understanding nutrients regeneration from Arctic sediments. The vast majority of Arctic OC is preserved in shelf sediments (i.e., 95%), where sulfate reduction and aerobic respiration dominate organic matter degradation (52 and 35%, respectively). Considering the significant uncertainties in Arctic biogeochemical cycling and the region's high climate sensitivity, our results provide a crucial starting point for future Arctic carbon burial and nutrients projections.

Keywords
Arctic Ocean; Sediments; Biogeochemistry; Benthic-pelagic Fluxes; Carbon Cycle; Nutrients Cycle; Organic Matter; Nutrients; Modelling

How Ulva blooms: Unravelling the genetic architecture of green tides

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Every year, more and more 'green tides' occur. A green tide happens when a green seaweed, most often sea lettuce, *Ulva spp.*, blooms incredibly fast, and is beached afterwards. These tides can stretch areas bigger than Flanders, >20.000 km^2 (1) along the coast, and can last 3-4 months (1). *Ulva* blooms cause a big disruption to the local ecosystems, but also impact human activities like tourism and represent a big cost to clean up. And because *Ulva* occurs around the world, so do these tides. However, the mechanisms surrounding them are still somewhat a mystery. What causes these blooms? Is it genetics, is it due to the environment? Or, more likely, is it due to a combination of both? In short, my project aims to find out what the genetic component is of these blooms (2). *Ulva compressa*, a macroscopic green seaweed that occurs around the world, is the focus of this study. The first step is to understand the genetic diversity. This is where the pangenome of *Ulva compressa* comes in. Now, what is a pangenome exactly? And how do we use it?

A pangenome is, ideally, a complete collection of all genes within that species. More realistically, it is a big collection of several genomes from different populations, with different phenotypes (3). Why do we want, or need, a pangenome? We hypothesize that the intraspecific genetic variation (meaning, the variation within our species), is very high in *Ulva compressa*. In the few available genomes, there are large observable differences: In size alone, some individuals can have a genome that's almost double the size of other individuals (4, 5). We need a pangenome to encapsulate all of this variation. Starting with a reference genome, other genetic material is carefully added, matched and compared to this reference. Here, we'll be able to see which genes are universal in our species, and which genes are unique to some individuals. Unique genes and other genetic variation (insertions, deletions, single-nucleotide polymorphisms) in common genes will be studied to understand the phenotypic differences between strains.

The reference genome in our case will be two lab strains. We are currently improving the reference genomes using longer reads, which will give us a better resolution than the one currently published. When this genome is assembled, we will start adding our other strains. For this, we will sequence individuals from across the world: The Netherlands, France, Germany, Denmark, Ireland, China, Japan, Chile, and are still collecting more. This will give a clear overview of the genetic diversity found within *Ulva compressa*. Additionally, we are documenting different phenotypic traits such as growth rate, morphology and rhizoid formation to perform genome-wide association studies. This pangenome will be the basis for other, more detailed genetic analysis that will follow in the coming years of this project.

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Keywords

Ulva Compressa; Green Tides; Pangenome; Algal Blooms; Population Genomics

What can be discovered from the most elaborate aquatic citizen science project inventory in Europe?

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PREP4BLUE is a Horizon Europe initiative supporting the EU Mission: Restore our Ocean and Waters by 2030. Under the wings of this project, VLIZ has taken the lead in two critical tasks— (1) establishing a comprehensive public online database encompassing as many marine and freshwater citizen science projects as possible in Europe for the very first time, and (2) creating a roadmap with recommendations and good practices on aquatic citizen science.

To create the database, a web and social media search strategy was devised, covering a wide array of search terms in every European language, to uncover as many projects as possible. At the end, approximately 1,000 citizen science projects were identified, spanning a diverse spectrum of subjects and levels of engagement in aquatic citizen science. At the end of 2023, the database will be available on the P4B website to promote synergies and spark inspiration for future aquatic citizen science projects.

Next to the creation of the database, we set up an online survey and a series of in-depth interviews with a select group of the projects in our database. These interviews served as a platform for open conversations and knowledge sharing, aimed at identifying best practices within marine and freshwater citizen science. With the gained insights, a roadmap for marine and freshwater citizen science was constructed to help starting or running projects on their journey towards restoring our ocean and waters, with active engagement of citizens at its core.

This roadmap emphasizes social inclusivity within citizen science, shedding light on the nuances and considerations inherent in working with citizen scientists in aquatic environments. Moreover, it also serves as a critical tool in unveiling the areas where aquatic citizen science still awaits its full potential, uncovering the missing links that will further enrich our understanding and stewardship of these vital aquatic ecosystems.

Keywords
PREP4BLUE; Aquatic Citizen Science; European Database; Good Practices and Recommendations

AI in marine sciences: detection and classification of marine vessels with underwater acoustic data

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The development of coastal regions has constantly been threatened by increasing human activities. This has led to the establishment of Marine Protected Areas (MPAs), where human activities are regulated or banned. However, when these areas are not efficiently monitored, they attract illegal activities. The monitoring of these MPAs poses a significant challenge, as they are often impossible to monitor visually. This project proposes to establish an underwater acoustic monitoring system to detect vessels by their sound signature. This is achieved by using machine learning techniques proficient in object detection and classification, laying the groundwork for robust underwater acoustic monitoring systems.

Human activity at sea is mainly tracked through the AIS. AIS data is an anti-collision system used for real time identification and tracking of vessels at sea. It contains information about the position (e.g., longitude, latitude, and speed) at a certain time and voyage information (e.g., MMSI and Vessel type) of a vessel. While the primary purpose of this data is to prevent collisions, including historical coordinate information and vessel types provides an opportunity to create a ground truth dataset to detect and classify marine vessels by their sound signature.

Through the integration of AIS data and passive acoustic hydrophone recordings, obtained from two North Sea stations over a total duration surpassing 100 days (with approximately equal distribution across the two stations), a comprehensive database has been established. This database includes acoustic recordings and relevant information such as the distance to the nearest boat and its type. By using state-of-the-art machine learning methods, two convolutional neural networks (CNNs) are being created. Both networks are based on a pretrained audio model, notably from Yu *et al.* (2018), and apply the framework introduced by Á. López García *et al.* (2020). The first CNN predicts the absence or presence (i.e., binary) of a vessel within a certain range (e.g., presence within a range of 7km). The second CNN aims to predict the actual distance of present vessels and information about the vessel (vessel type).

Under the iMagine project (https://www.imagine-ai.eu), we aim to publish this database and classifiers within a user-friendly module. This tool allows domain scientists to process acoustic underwater recordings, identifying the presence, distance, and type of vessel. In this learning process, the final goal is that classifiers could be used as a reliable autonomous monitoring system in maritime environments.

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Keywords
AI; ML; CNN; AIS; Underwater Acoustics; Hydrophones

Quaternary sediments of the southern North Sea – core analyses in aid of paleo-reconstructions. A case study of the Brown Bank, The Netherlands

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The Brown Bank (BB), a sand ridge located midway between the Dutch and British coastlines of the southern North Sea, is a site of interest thanks to the recovery of archeological and paleontological material, including tools, human remains, etc., of Mesolithic age (10–7.5 ka BP) (Peeters & Amkreutz, 2020; Missiaen *et al.*, 2021). They were found *ex situ* by e.g. dredging a large area, which emphasizes the need to advance paleo-landscape research to pinpoint areas of archeological potential, where these artifacts could be retrieved *in situ* (Missiaen *et al.*, 2021).

This master thesis research combines ultra-high-resolution parametric echosounder sub-bottom profiler (PES) and core data obtained during several surveys (2018–2022). Core data include lithological descriptions, multi-sensor core logging (MSCL) data (density and magnetic susceptibility), micropaleontological analyses of pollen, ostracods, foraminifers and diatoms, as well as optically stimulated luminescence (OSL) and radiocarbon dates. Interpretation of this dataset yields four acoustic units (AU), which represent eleven lithological units (LU). Paleoenvironmental analysis of the fossil content and correlation between cores further aid in determining the environmental evolution of the BB area.

During past glacial periods (e.g. the last glacial MIS4-2), sea levels were globally more than 100 m lower than today, with the southern North Sea subaerially exposed and consisting of a low-lying area in which large rivers coalesced and drained the European continent. Around 11–9.5 ka, based on ^{14}C-dates, rising groundwater levels, caused by rising sea level, led to freshwater peat development in vegetated slow- flowing and stagnant water bodies, along with deposition of organic-rich sands. Previously analyzed pollen data indicate pine trees prevailing in a marsh environment, with increasing amounts of deciduous trees. Around c. 9.5 ka, two small sandy, dominantly freshwater deposits with a small brackish signal in the diatom composition, hint to a first phase of tidal influence in these rivers. Shortly after, fine laminae of clay and fine sand and brackish microfossils indicate widespread estuarine tidal flats, creeks and shallow rivers until c. 8.5 ka. The approaching coastline is marked by an increase in salinity and depositional energy. For this period, the pollen data indicate the presence of marsh conditions at the edge of a pine, elm, oak and hazel forest. After a period of erosion, from c. 8 ka onwards, shelly sands indicate high-energy marine conditions.

Some important conclusions and hypotheses result from this reconstruction. (1) The presence of dominantly freshwater deposits above the peat layer has hitherto not been described in the literature. Their origin requires more research. A possible explanation is an estuarine system comparable to that of the river Scheldt (Belgium) today, where the tidal influence reaches far inland, but with predominantly fresh environmental conditions. (2) The freshwater peat can be used as a limiting point for sea-level reconstructions. (3) Preliminary mapping of the tidal sediments suggests a complex channel network. Its orientation allows to hypothesize that the first marine influence entered the area from estuaries north of the BB area. (4) From our acoustic data, there appears to be no indication that the BB was already a topographic upstanding feature during the Mesolithic, as suggested by Missiaen *et al.* (2021).

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Keywords
Econstruction; Paleoenvironment; North Sea, Netherlands; Brown Bank; Multi-proxy, Micropaleontology, Sedimentology; Parametric Echosounder Sub-bottom Profiler; Dating; Sea-level Rise; Holocene; Mesolithic; Peat

Ammothea hilgendorfi: a New Invasive Species on the Belgian coast

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Pycnogonids, or sea spiders, constitute a peculiar group of marine arthropods that historically has been considered negligible in marine ecosystems due to their low abundance. However, this perception has been challenged by the recent emergence of *Ammothea hilgendorfi* in Europe. Originating from the North Pacific Ocean (*i.e.*, Japan and the USA), it has settled in many countries since the late '70s, including Italy, France, the Netherlands and Belgium.

This comprehensive study consisted of a 24-month monitoring of *A. hilgendorfi* in the wave breakers of Knokke, Belgium. The findings revealed unprecedented population densities, characterized by a rapid life cycle and a year-round reproductive activity. In contrast, native pycnogonids seemed to have almost totally disappeared.

Only punctual observations of *A. hilgendorfi* have been made in other countries. Hence, this research signifies a milestone, providing the first evidence that it can develop important and self-sustainable populations in its non-native range. This prompts the classification of the species as invasive. Among the 1,400 extent pycnogonids, *A. hilgendorfi* is thus the first ever to be called an invasive species. Considering the general oversight of pycnogonids by zoologists, further investigations are imperative to assess the intrinsic and extrinsic factors that facilitated its invasion in Europe, as well as its potential ecological impact on the Belgian coast.

Keywords
Pycnogonid; Invasive; Population Monitoring; Belgian Coast

Sand, sand, sand, where does it all end?

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Our society is hungry for sand, and its steady supply is needed increasingly to secure coastal safety in the low-lying countries. Sparked by nature's solutions on coping with water, more and more alternative ways to shoreline protection are on the rise, relying typically on huge volumes of marine sands. To what extent we can keep on increasing such marine sand usage without affecting adversely the environment remains an open question.

The offshore extraction of marine sands causes sediment reworking at accelerated rates. But sand extraction is not the only actor disturbing the seafloor. We dredge and relocate, we fish, we plough, we build and cultivate. Meanwhile, we assess impacts, though hitherto mostly for single cases and considering one period of interest. The combined disturbance we exert on the seafloor remains mostly in the cumulative impact hypotheses sphere.

Hitherto unprecedented, we attempted a cumulative dispersal modelling of sediment particles released by the main seafloor disturbing activities (e.g., fisheries, extraction, dredging and disposal) over the entire Belgian part of the North Sea and for a full year. An integrated database was set-up comprising spatial data from electronic monitoring systems (location and time), technical information from vessels (size and gear), but also estimated particle amounts in kg. Three-dimensional hydrodynamic models (https://odnature.naturalsciences.be/coherens) were used to force the Lagrangian dispersion model OSERIT (Dulière *et al.*, 2013) that has been further developed to simulate the transport and fate of sediment particles. Processes that are accounted for are: (1) advection of particles under the complex influence of the met-ocean conditions (3D currents, waves and tides); (2) turbulent mixing; (3) sedimentation; and (4) resuspension. Running more than hundred thousand of numerical simulations, the release of silt and fine sand particles per disturbing event in the year 2019 was tracked for 14 days.

For comparative analyses, the mass of sediment released by the various activities was accounted for. For all activities, spatially-explicit deposition maps were created at a resolution of 1 x 1 km with a minimum time resolution of 1 day of activity. These can be further aggregated into other time intervals such as monthly, seasonally, or yearly. In a next step, these are then evaluated against the presence of sensitive receptors (e.g., gravel beds) of which distribution maps were recently renewed (Van Lancker *et al.*, 2023). Per region of interest the main influencing human activities can be backtraced.

Future applications relate to identification of potential environmental effects of seafloor disturbing projects. It is meant to support environmental risk assessment and decision making, e.g., evaluating technical choices, proposing appropriate mitigation, choosing best restoration sites, guiding and optimizing management and monitoring measures.

Research is conducted in the framework of the projects VLAIO SUSANA (SUstainable use of Sand in NAture-based solutions) and ZAGRI, a federal Belgian program for the continuous monitoring of sand and gravel extraction, paid from private revenues. The developments align with RBINS' Research Strategy on Science for a Sustainable Marine Management and with the roadmap of RBINS Marine Forecasting Centre to deliver an operational service on impact forecasting of human activities, which is a shared 2030 vision within EuroGOOS.

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Data acknowledgement
Maritime Access (Flemish Department of Mobility and Public Works) and Continental Shelf Service (Federal Public Service Economy) are acknowledged for the spatial datasets of dredging-disposal and extraction, respectively. Fisheries data were obtained from the Global Fishing Watch as gridded data.

Keywords
Lagrangian Modelling; Particle Transport; Cumulative Dispersion Modelling; Far-field Impact; Seafloor Integrity; Decision Support

Mobilization and distribution of trace metals in the Scheldt sediments

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As a macrotidal estuary, Scheldt Estuary connects terrestrial industrial zones with the North Sea, and receives diverse pollutants and also massive organic matter from anthropogenic activities. The accumulation and mobilization of metal contaminants in the Scheldt sediments were impacted by several environmental parameters including pH, redox potential, and organic matter contents. The recent studies showed mercury (Hg) concentration levels in the sediment of Groot Buitenschoor (GB) were still comparable with those 40 years ago[1]. Therefore, in this study we investigate the mobilization of trace metals in the intertidal sediments of GB and also another nearby station S15, which is all the time covered by water. Two sampling methods were applied in these sediments including an active porewater extraction for a depth interval of 2 cm and a passive sampling technique of Diffusive Gradients in Thin-Films (DGT) for higher resolution (0.5 cm) analysis of Fe, Mn, Co, Cd, Pb, Cr, Ni, Cu, and Zn. In addition, dissolved sulfide was also measured by the DGT technique to investigate its impact on metal mobilization. Different from the dissolved concentrations of metals obtained by porewater extraction, the DGT technique provided the bio- available metal fraction in these sediments. The preliminary results showed that Mn, Co, Ni, Pb, and Cr concentrations in the porewater of sediments at GB were higher than those at S15. Nevertheless, DGT measured concentration showed an opposite trend, indicating that trace metals at GB were more bioavailable despite lower concentrations in porewater. The mobilization of bioavailable metal fractions was impacted by pH and redox potential. However, the DGT results showed that dissolved sulfides were below the detection limits at S15, suggesting the possible reason for substantial Fe mobilization in the sediments. The trace metal concentrations in the solid phase of GB are higher than those of S15. Metal precipitation and mobilization in these sediments were also simulated by using Visual MINTEQ software.

These results will help us better understand the pattern of metal mobilization and distribution in these typical estuarine sediments: one with intertidal impact and another one submerged by water, which can be used as a case study for colleagues working in this field.

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Keywords
Trace Metal Mobilization; The Scheldt Sediments; Porewater; DGT; Bioavailable Metal Fraction;

Immune receptor- and transcription factor- stimulatory effects of bacteria and endotoxin in sea spray aerosols on human cells

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Frequent, low-level exposure to marine microorganisms and bioactive compounds in sea spray aerosols (SSA) has been suggested to confer various health benefits (Moore 2015; Asselman *et al.*, 2019; Van Acker *et al.*, 2020). Few studies to date have, however, examined the potential immunostimulatory consequences of SSA exposure. In this study, we investigated the immunostimulatory activity of SSA by exposing human reporter cells to SSA samples with total bacterial counts ranging from 3.0×10^3 to 2.4×10^6 cells/m^3 air and endotoxin levels from 7 to 2,191 EU/m^3 air. The induction of immune receptors toll-like receptor 4 (TLR4) in HEK-Blue hTLR4 cells and TLR2/6 in HEK-Blue hTLR2/6 cells, as well as the induction of the transcription factor nuclear factor kappa B (NF-κB) and interferon regulatory factors (IRF) in THP1-Dual monocytes were measured. We observed that all tested SSA samples activated TLR4, TLR2/6, NF-κB, and IRF, which correlated dose-dependently with the total bacterial counts, endotoxin levels, or both.

Next, we examined immunostimulation by investigating how exposure to SSA modulate the activation of TLR4, TLR2/6, NF-κB and IRF to subsequent challenges with potent agonists. Human reporter cells were pre-exposed for 30 minutes to SSA samples or negative controls, followed by 24 hours exposure to *Escherichia coli* lipopolysaccharide (LPS) (for HEK-Blue hTLR4 cells and THP1-Dual monocytes) or the synthetic diacylated lipopeptide Pam2CSK4 (for HEK-Blue hTLR2/6 cells). We observed that SSA exhibited a dual modulation effect on both TLR4 activation and TLR2/6 activation. Specifically, SSA samples inhibited TLR4 activation induced by *E. coli* LPS at low bacterial and endotoxin levels, but enhanced it synergistically at high levels. In contrast, SSA samples inhibited TLR2/6 activation induced by Pam2CSK4 at high bacterial and endotoxin levels, while enhancing it synergistically at low levels. Regarding on the modulation on NF-κB and IRF activation induced by *E. coli* LPS, SSA showed a neutral effect at low bacterial and endotoxin levels, while exerted a synergistic effect at high levels.

To further elucidate the potential mechanisms underlying the immunostimulatory effects of SSA, we measured the bacterial communities in SSA samples. This was done using full-length Nanopore sequencing of the 16S rRNA gene. We are now using the Phylogenetic Investigation of Communities by Reconstruction of Unobserved states (PICRUSt2) algorithm, referencing the Kyoto Encyclopedia of Genes and Genomes (KEGG) and MetaCyc databases, to analyze which specific bacteria or their predicted metabolic functions contribute to the differential immunostimulatory effects observed.

This study sheds the first light on the immunostimulatory consequences of SSA and its underlying mechanisms. Our findings not only provide new insights into coastal health benefits, but also highlight the need for further research to deepen our understanding on the health implications of SSA exposure.

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Keywords
Sea Spray Aerosols; Bacteria; Endotoxin; Immunostimulatory Effects; Human Cells

Past and present carbon dynamics in the Scheldt estuary as traced by changes in the isotopic composition of dissolved inorganic and particulate organic carbon

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The freshwater Scheldt estuary, located in Belgium, is known as one of the most populated and most industrialized estuaries in Europe. The historical emission of a variety of pollutants by the agriculture, domestic and industrial activity in the watershed decreased its water quality. Wastewater treatment (WWTP) efforts since the nineties allowed the system to recover from hyper-eutrophication around 2006. Although the water quality of the Scheldt estuary has since impressively been improved, the situation needs continuous monitoring data to understand the complex interactions between the anthropogenic (WWTP, dredging, dumping and channel deepening) and natural influences. Since 1996, a systematic, long-term multidisciplinary monitoring program called OMES (Onderzoek Milieu-Effecten Sigmaplan, Van Damme *et al.* (2005)) monitors monthly the water quality of the Scheldt estuary by measuring variable parameters at representative sampling stations. Results presented are part of this OMES project.

Particulate organic carbon concentrations (POC) are monitored since the beginning of the project, and since 2006, the stable carbon isotopic composition ($d^{13}C$) of POC, but also of dissolved inorganic carbon (DIC), are analyzed. $d^{13}C$-POC and -DIC are influenced by the inputs and origin of organic carbon and by the balance between primary production and respiration.

In this study, the isotopic composition of POC and DIC were combined with an isotopic mixing model to estimate the fraction of allochthonous and autochthonous (phytoplankton) carbon in the POC pool. This composition of POC is a crucial factor in estuarine ecology as it defines the biodegradability of the POC, and so, its biological oxygen demand, but also its "quality" as a food source for higher trophic levels. Indeed, allochthonous carbon sources (POC_{ALL}) are general composed of old, already highly mineralized material with a low biodegradability and low nutritional value, while freshly produced phytoplankton biomass carbon (POC_{PHY}) is highly respirable and has a high nutritional value.

Our study focusses on the evolution over the last 17 years of the POC composition, combined with other variables, such as turbidity, biological oxygen demand, chlorophyll a and carbon to nitrogen ratio to highlight long-term changes in the estuary. Recent studies highlighted that this period is characterized by an increased turbidity in the freshwater part of the estuary combined with a reduced chlorophyll a. The contribution of allochthonous material and phytoplankton biomass to suspended particulate matter (SPM) was investigated. The evolution of these fractions over the last two decades will provide insights in the main sources that drive the food web and the quality of the ecosystem.

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Keywords

Scheldt Estuary; Dissolved Inorganic Carbon; Phytoplankton Biomass Carbon; Allochthonous Carbon; Suspended Particulate Matter

Protected yet unmanaged: insights into the ecological status of conservation priority stony reefs in Belgian waters based on the integrative use of remote sensing technologies

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Stony reefs are complex and heterogenous habitats that host a unique fauna and provide irreplaceable ecosystem services. These habitats are as ecologically valuable as they are fragile and susceptible to anthropogenic disturbances. Bottom-contacting fisheries are one of the principal sources of anthropogenic disturbance to the seafloor's physical and ecological integrity having immediate and destructive consequences on stony reefs and compromising ecological functions. In this study we aimed to assess the ecological status of two stony reef areas – the Northwest and Hinder Banks study sites – in Belgian waters in relation to their chronic exposure to bottom-contacting fishing pressure. We used three hierarchically nested data sources obtained from multiple minimally invasive remote sensing techniques at both study sites; i) publicly available commercial fishing activity data, ii) hydroacoustic surveys, and iii) images of benthic communities from underwater video transects. We used a trait-based approach linked to the organisms' resistance and recovery potential to trawling to compare community compositions in function of fishing pressure. At both study sites trends revealed a significant decline in species characterized by low resilience and recovery potential scores parallel with a significant increase in species displaying moderate scores when fishing pressure was higher. More than 85% of the stony reef area within both study sites appeared impacted by varying degrees of bottom-contacting fisheries.

While the overall richness and abundance of species remained similar at both study sites, our study revealed that chronic fishing disturbance has induced shifts in community composition with implications for ecosystem integrity and functionality. Stony reefs are recognized as conservation priorities by all relevant European policies. In Belgium, the Hinder Banks stony reef area is part of the Natura 2000 network, while the Northwest area has been designated as a search zone for biodiversity protection. Nevertheless, detrimental bottom-contacting fishing activities are still allowed within their range regardless of their management regime.

This study provides the scientific evidence needed to argue against the coexistence of such activities with marine protected areas comprising natural hard substrates, while it supports the enforcement of fisheries exclusion measures. With our research we hope to inspire environmental managers to strive for adequate implementation of environmental legislation in the face of rapid and widespread anthropogenic changes.

Keywords
Stony Reefs; Fishing Impact; Hydroacoustics; Underwater Video; Ecological Status; Conservation; Environmental Policy

Analyzing Belgian marine soundscapes using unknown sound events

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Soundscape studies haven been proven to be a reliable tool to provide information about marine ecosystems in a non-invasive and continuous way. The most common way of doing such analysis is to detect known sound events and analyze their spatio-temporal patterns of occurrence. This can provide insight on animal presence, migration patterns, seasonal changes, ecological composition, and the interaction with human activities. These sounds can be from biological sources (biophony), from physical sources (geophony) and from human activities (anthropophony).

To be able to detect these sound events, prior knowledge on the sound sources present in the environment is needed. This is not yet the case in the North Sea in terms of biological sources, meaning that the link between marine fauna and their sound production is very limited. One of the reasons is due to the high turbidity present in the Belgian Part of the North Sea (BPNS), which reduces visibility and therefore limits the possibility of ground-truthing sound sources with their producers. The other method to determine sound produced by the fauna is doing tank experiments and recordings, but these are expensive and labor-intensive tasks.

In this study we propose to analyze Belgian underwater soundscapes with a novel approach based on detecting, clustering and analyzing unknown sound events. The method is applied to the data from the LifeWatch Broadband Acoustic Network (Parcerisas *et al.*, 2021), which comprises recordings from 6 different locations in the BPNS. First, a deep learning object detection algorithm from computer vision - Yolov8, (Jocher *et al.*, 2023) - is re-trained on a representative subset of the data to detect any acoustic event in the recording. As input to the model, the recordings are converted into spectrograms, which are a visual representation of the spectrum of frequencies of a signal as it varies with time. For this method, we define an acoustic event as anything which is acoustically and visually salient from the background, in the raw audio and the spectrogram, respectively. Next, the detected sound events are clustered in different classes in an unsupervised way. The obtained clusters represent the different sound classes present in the BPNS. These unidentified sound classes are then manually studied, providing insights into their source – if possible -, acoustic characteristics, and potential ecological significance. The soundscape of each location can then be described using these clusters to unravel daily patterns, seasonal variance and differences between stations.

The implications of this study have practical applications in environmental monitoring and marine conservation efforts. The knowledge of Belgian underwater soundscapes contributes to increasing the understanding of the region's marine acoustic biodiversity, enabling more informed conservation strategies. Furthermore, the ability to monitor marine soundscapes regardless of whether the sound sources are known or not allows for early detection of environmental changes, such as shifts in species composition or habitat disturbances**.**

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Keywords
Soundscape; Acoustic Event Detection; Clustering; Machine Learning; Unknown Sounds

Assessing plastics dynamics in a typical estuarine zone during full high tide cycles

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Estuaries, serving as essential transition zones between freshwater and marine environments, are considered as significant reservoirs for plastic pollution. Almost 80% of ocean-bound plastic originates from land-based sources, with estuaries being the main export route (Lima *et al.*, 2020). The remaining 20% of plastics come from overseas or derived from maritime transport activities (Morrit *et al.*, 2013, Scheinder *et al.* 2022). The Slack estuary, flowing into the English Channel at Ambleteuse (France), provides a remarkable case study.

Some plastics were collected in this estuary in order to define a set of 480 plastics, including microbeads (3-4 mm) and meso- and macroplastics (1 cm² to 25 cm²), and composed of three types of polymer: PP, PE and PET. They were strategically placed along the estuarine banks in three types of quadrats with distinct substrates: gravels, sand and vegetation. The remobilization of these plastics was analyzed during six different campaigns from June 2022 to July 2023, corresponding to dry and wet seasons, with high tidal coefficients and different environmental parameters (e.g. wind, precipitation). Observations were made during a complete tidal cycle. Plastics deposited by the tides were also observed.

Results showed that over 90% of the manually deposited plastics were remobilized in water, with macroplastics exhibiting the least remobilization. Seasonal variations were significant (Kruskal-Wallis, p-value<0.05), with wet months showing a slightly higher average remobilization (115±3.57 plastics/3m²) than dry months (113.08±4.92 plastics/3m²). Notably, autumn exhibited the highest remobilization, whereas the lowest was observed during summer. Seasonal dynamics were influenced by hydrological parameters, with a significant negative correlation (Spearman, p-value < 0.05) observed during the dry period, highlighting the complex interaction between environmental conditions and the distribution of plastics. Consequently, we can hypothesize that, during the wet season, the hydrological parameters of fresh water velocity and flow influenced the remobilization of plastics in this estuary. Polymer analysis showed PP as the predominant remobilized macroplastics (94.44%), whereas PET exhibited the lowest remobilization rate (75.69%) during dry period.

Plastic mass analysis entering the water during complete tidal cycle exhibited an remobilization average of 2.8 ± 0.17 g of plastics during dry periods primarily macroplastic (Mmacro = 4.97 ± 0.46 g), followed by beads (Mbead = 2.1 g), and mesoplastics (Mmeso = 1.55± 0.04 g). In wet periods, 3.54 ± 0.44 g of plastics were remobilized from a 3m² area, dominated by macroplastics (5.06 ± 0.24 g) and mesoplastics (3.45±1.09 g). Unremobilized plastics were retained by gravels and vegetation, with vegetation exhibiting the highest retention. Vegetation accumulated 0.49 g/m^2 during the dry season (490 g over 100 m^2), and 0.2 g/m^2, during the wet season, (200 g/100 m^2). After a complete tidal cycle, 2.6 ± 2.07 plastics/m^2 was deposited especially fibers and ropes, highlighting the role of maritime activities in plastic pollution. Finally, all the results showed the necessity of understanding the remobilization and deposition of plastics along estuarine riverbanks in order to develop effective mitigation and remediation strategies.

Keywords
Plastics; Estuary; Remobilization; Deposition

A long term standardized assessment of the influence of dredge disposal activities on different ecosystem components in the Belgian part of the North Sea

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Dredging and the associated dredge disposal activities are necessary to prevent harbours and navigational channels from silting up. Possible effects of dredge disposal are for instance smothering of benthic organisms, loss of habitat, contamination of the site and sediment changes. In the Belgian part of the North Sea (BPNS), five locations (Br&W Zeebrugge; Br&W S1; Br&W S2; Br&W Oostende; Nieuwpoort) are designated as disposal sites. These sites are situated in three different habitats (*Abra alba*, *Macoma balthica* and *Nephtys cirrosa* habitat). The Marine Strategy Framework Directive requires monitoring of these sites to assess whether the benthic habitats are adversely affected.

At the moment, data is available, covering a period of 15 years (2005-2019) to assess the impact of dredge disposal in the three habitats. Besides the time span, this study is also unique as it focuses on three ecosystem components (macrobenthos, epibenthos and demersal fish), whereas the majority of studies focuses on macrofauna (Dauvin *et al.*, 2022; Bolam *et al.*, 2016). To have a standardized evaluation methodology, the Benthic Ecosystem Quality Indicator (BEQI) (www.beqi.eu) was calculated according to a control-impact design. Within this analysis, four parameters (species richness and composition, density and biomass) were compared between the set of impact samples (disposal sites) and control samples. That way, BEQI scores between 0 and 1 for each parameter were calculated, where values below 0.6 implied that the system deviated from the control. For macrobenthos, the BEQI was calculated per year, while for epibenthos and fish, periods of 4-5 years were used for the calculation (2005-2009; 2010-2015; 2016-2019), since the confidence of the BEQI assessment increased with sampling size. As the disposal intensities (i.e. pressure) differed throughout the years and at the different disposal sites, linear mixed-effects models (LMM) were performed to define the relationship between the pressure and the BEQI scores for each parameter and ecosystem component. Pressure and habitat were defined as fixed effects, while disposal site and year or period were set as random factors.

According to the BEQI assessment, the highest impact was observed on the macrobenthic community at the disposal site Br&W S1 within the *Abra alba* habitat, where the highest amount of dredged material was disposed yearly. The BEQI scores were also low for epibenthos and fish, probably because of indirect sediment changes and shifts in the macrobenthic community. The impact was lowest at the disposal site with the lowest pressure (Nieuwpoort). At Br&W Zeebrugge and Br&W Oostende, a good similarity between impact and control was observed, although the dumping intensities were high throughout the years at Br&W Zeebrugge. This was probably because the disposed material was similar to the receiving habitat (muddy sediments within the *Macoma balthica* habitat), minimizing the impact, as the sediment has not changed. The impact was evaluated as low at the site Br&W S2 within the sandy *Nephtys cirrosa* habitat, probably because there was an attraction of new species associated with muddy sediments. The epibenthic and fish community was in most cases very similar between impact and control, probably because of the higher mobility of these organisms (except for Br&W S1).

The LMMs demonstrated that the impact on the (macro)benthic community significantly increased as function of an increasing pressure, which was not the case for the epibenthic and fish community. Unfortunately, it was statistically not possible to detect a significant different impact for the three habitats based on the current dataset, despite some pressure-response differences in the habitats. To show whether the pressure response differ statistically with habitat type, more data are required, especially in sites with intermediate disposal intensities. Also a more extensive dataset for epibenthos and fish is required in future studies.

The present study indicates that the influence of dredge disposal on the seafloor ecosystem varies with pressure intensity, ecosystem component and habitat type. These findings are relevant for a sound management of dredge disposal in the BPNS.

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Keywords
Dredge Disposal; Benthic Ecosystem; BEQI; Linear Mixed-Effects Models; BPNS

Exploring the diversity of DNA viruses in the North Sea using a metagenomic approach

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Infamous for causing diseases and wreaking havoc, viruses also play significant roles in keeping our planet functional. They are the most abundant biological entities in the ocean and represent the greatest reservoir of genetic diversity on Earth. Viruses play crucial roles in driving global biogeochemical cycles by (re-)shaping planktonic community structure and influencing microbial host metabolism and evolution through lysis and horizontal gene transfer. Some viruses (*i.e.* temperate viruses) may also enter a lysogenic cycle where, instead of killing their hosts, they incorporate themselves within the host genome and proliferate with the host cell. The choice between lytic and lysogenic cycle of temperate viruses is dependent on interactions with their hosts and environmental factors. Understanding the diversity of viruses and their interactions is imperative in understanding the functioning of an ecosystem.

The North Sea is a relatively shallow but highly productive sea that receives input from the Atlantic Ocean, and 5 major European rivers, causing considerable ecosystem heterogeneity. Despite its proximity to land, making it vulnerable to overexploitation, understanding is scarce on how viruses influence microbial diversity and ecosystem functioning in the North Sea. To date, only one study (4 stations) has attempted to delineate bacteriophage (viruses that infect bacteria) diversity in the North Sea. With our study, we aimed at increasing our understanding of the diversity of viruses in the North Sea and shining a light on the complexity of their role. We collected seawater samples at 7 sampling stations in the central North Sea. We then employed size filtration followed by iron chloride flocculation to enrich for viruses below 0.22 µm in size. As DNA virus genomes can be single (ssDNA) or double-stranded (dsDNA), we utilized a library preparation kit for Adaptase-Linker Amplification to reduce bias for or against ssDNA. Libraries were sequenced on Illumina NextSeq 500 and further analyzed using various bioinformatic tools to extract information on viral diversity, lifestyle, and putative hosts.

Overall, we identified more than 50,000 unique viral sequences, with 99 % sequences belonging to the viral realm *Duplodnaviria* (dsDNA viruses). We used PhaBOX to identify bacteriophage sequences, assign taxonomy, and predict viral lifestyle and host. Viruses representing 12 bacteriophage families were present in our samples, and over 30 % of our viruses exhibited a temperate lifestyle. We predicted 35 potential bacterial host species for these viruses. With this study, we have pushed the known diversity of viruses in the North Sea by employing state- of-the-art technologies, providing a baseline for future studies on marine viral ecology in the North Sea.

Keywords
North Sea; Marine Viruses; Bacteriophages; Metagenomics; Viromics; Ecogenomics; Lysogeny

Impact of weathered and virgin polyethylene terephthalate nanoplastics on growth dynamics and the production of Extracellular Polymeric Substance (EPS) by microalgae

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In context of the ever-increasing plastic waste accumulation in the marine environment, it is important to understand the interaction between primary producers, i.e. microalgae, and the smallest plastic particles, i.e. nanoplastics (NP). A key unknown factor in this process is the role of extracellular polymeric substances (EPS). EPS production is a known algal stress response, and its adhesive properties may induce aggregation of algae, both with themselves and with other particles, which in turn may affect ecological and hydrodynamic processes. The ensuing effects can include the trophic transfer and vertical transport of nanoplastics. In this study, the impact of fragmented, polydisperse virgin polyethylene terephthalate (PET, $D_{average}$ = 1400 nm) and weathered polyethylene terephthalate (wPET , $D_{average}$ = 680 nm) on algae growth and the production of EPS was studied. We exposed the brackish marine microalgae *Rhodomonas salina* to a range of NP concentrations (10, 100 and 1000 and 10000 NPs ml^{-1}) for 12 days. A positive control with kaolin ($D_{average}$ = 2900 nm) a natural sediment particle, was included to distinguish particle effects from plastic effects. Baranyi parametric growth-models were fit to the data to analyze growth-dynamics. Exposure to all particles (plastics and kaolin) resulted in an initial increased growth rate, followed by significant decreases in algae population density. At low concentrations, the effect was independent of the particles' nature (natural or anthropogenic) or age (virgin or weathered). At the highest exposure concentration, the plastic particles caused significantly higher decreases in population density compared to kaolin, and the effects were amplified as the nanoplastics were weathered. The effects of weathered PET (10000 NPs ml^{-1}) on growth were accompanied by significant increases in cellular EPS production. This suggests that algae exhibit an increase in EPS-production as a stress response that is absent when exposed to natural particles or virgin nanoplastics. This raises questions about the toxicity mechanisms of NPs at concentrations of 10000 NPs ml^{-1} or higher, and hints towards the role of EPS production as a defence mechanism, which changes the energy budgets, with less energy allocated to growth. This study underscored the intricate interactions between particle types, age and concentrations, and their distinct impacts on algae density, growth inhibition and EPS production.

Keywords
Nanoplastics; Microalgae; Natural Particles; Weathering

Predictive modelling of Atlantic herring distribution in the North Sea for informed decision-making

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Introduction
Due to the withdrawal of the United Kingdom from the European Union, the Belgian fishing fleet lost access to part of their fishing waters in the southern North Sea and the English Channel and experiences diminished catches (estimated at a loss of 3.7 million euro in 2023). The Belgian fishing fleet currently targets bottom dwelling fish. One of the initiatives to overcome the loss of fishing grounds is to provide information about alternative fishing grounds and niche fisheries, such as pelagic fishing, as financed through the Brexit Adjustment Reserve. Because the Belgian fishing fleet targeted bottom dwelling fish in past decades, the whereabouts of pelagic fish are often unknown, anecdotical, or expert based. Habitat suitability models have been widely used to derive species-environment relationships and predict the geographical distribution of species. This study developed habitat suitability models for an important commercial pelagic fish species, Atlantic herring (*Clupea harengus*). Both adults and larvae were modelled separately.

Materials & methods
We retrieved occurrence data of both adult and larval Atlantic herring from DATRAS trawl surveys from 2000 to 2020 (21 023 records in total). To have sufficient data to create robust models, models spanned the spatial extent of the entire northwestern European Shelf, however model outcomes will focus on the southern North Sea. Occurrences were sampled to account for sampling bias and spatial autocorrelation to a final dataset of 800 occurrence records (400 for adults and larvae each).

Environmental variables were derived from the European Marine Observation and Data Network (EMODnet) and Copernicus Marine Service, including depth, sea surface temperature, sea surface salinity, zooplankton, phytoplankton, distance to windfarms and seabed characteristics. Preprocessing of the environmental variables involved aggregation to a 10 NM by 10 NM grid per month to match the spatiotemporal resolution of the occurrence data.

To create species-environment relationships, spatiotemporal maximum entropy (MaxEnt) models were developed in R. Eighteen unique combinations of model settings were tested using the corrected Akaike's Information Criterion (AICc). Model performance was evaluated using 5-fold cross-validation. Finally, spatial predictions were created for each month of the period January 2000 to December 2020.

Results & Discussion
Both models performed well with Area Under the Curve (AUC) values above 0.7. In 2020, habitat suitability indices for the southern North Sea ranged from 0.3 to 0.7 for adults and from 0 to 1 for larvae. Adult Atlantic herring are most likely to be present in the southern North Sea during January and February (average habitat suitability index, HSI, of 0.6 and 0.7 respectively). For larvae presence is most likely during December and January (average HSI 0.5 and 0.6 respectively). The model highlighted the generalistic character of adult herring, being tolerant to a wide range of environmental gradients. Depth explained 63% of the variability in the adult distribution, and SST explained 13%. Adult herring were present mostly along European continental shelf waters, at sea surface temperatures between 3 – 20 °C, with a preference for 7°C.

The larval model showed more specific needs and preferences, including specific seabed substrate and a dependency of spawning success on food sources (phyto- and zooplankton). In the spatiotemporal predictions a shift of spawning events can be seen from the north during summer to the south during winter.

In order to maintain a sustainable population of herring, it is important to preserve their spawning ground. Both larvae and adults are simulated to be present during winter months in the southern North Sea. Since trawling can alter the substrate of spawning grounds and destroy deposited eggs, fisheries need to be well managed during this period.

On top of this, due to Atlantic herring's preference towards colder water temperatures, global warming might disrupt their current migration patterns. A shift towards more northern spawning grounds might be hindered for autumn-spawning herring by shorter daylengths during winter in the north.

Keywords
Atlantic Herring; Species Distribution Modelling; Sustainable Blue Economy; Fishery; Northwest European Shelf

Plant establishment and plant-sand feedbacks as fundaments for dune-for-dike nature-based solutions

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Coastal foredunes serve as a natural defense against rising sea levels and storm floods, support important Natura2000 biodiversity and habitats, and offer areas for human recreational activities. Along urbanized coasts, a large proportion of dune systems have been replaced with hard infrastructures such as dikes and sea walls. Over the past decade, the limitations of these traditional grey infrastructures (their static character and high maintenance costs) were recognized. This caused scientists across many disciplines to **explore coastal dunes as nature- based solutions** for sustainable and cost-effective long-term coastal protection.

Coastal dunes develop from ecological interactions between sand fluxes and vegetation development. Plant-sand feedbacks are the basis for the unique dynamic and self-organizing properties of coastal dunes. These properties are anticipated to make them resilient and responsive to tidal and wave conditions, and hence future climate change impacts. The construction of **hybrid dune-dike systems**, where dunes are built in front of the dike, emerges as a promising solution to secure coastal regions against floods and storms.

To allow the design, the creation but also the natural development of such dune-dike hybrid nature-based solutions in the most optimal way, we have to understand the responses of plants to changes in environmental conditions, as well as their effects on the environment.

First, to be able to predict where natural dune development is possible, I constructed an **ecological niche model for embryo dune plants** on the Belgian coast. These embryo dune plants are the pioneer plants responsible for the natural initiation of dune development on the high beach. They consist of (rare) annual species that lay the foundation for further dune development and are subject to both human and environmental stressors. I built a spatio-temporal regression model, based on annual sand dynamics and flooding potential, to deduce and demonstrate that the establishment of embryo dunes is feasible along the entire Belgian coast, but is mainly constrained by mechanical beach cleaning and beach management.
Second, to be able to **optimize the construction of dune-for-dikes** through planting strategies of marram grass, I analyzed how the abundance and spatial configuration of marram grass impact the development of established pilot dune-dike hybrids along the Belgian coast. This mechanistic insight on sand burial-plant growth interactions allows for a better prediction of the outcome of different marram grass planting strategies, and the corresponding dune shape and characteristics related to storms and erosion.
In conclusion, my research emphasizes the importance of understanding the ecological dynamics of coastal dunes as essential components to gain a dynamic rather than static understanding of dune-dike hybrid nature-based solutions for effective coastal and biodiversity protection.

Keywords
Spatio-temporal Modeling; Plant Ecology; Dune Engineering; Nature-based Solutions; Climate Change

The history of Bruges is written in water

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Research Focus
To give water a chance to flow and infiltrate naturally in cities, landscape studies in urban archaeology have vital information to offer. This lecture focuses on the 2023 excavation of the Eekhout Abbey at the Brusk museum site in Bruges. Employing mechanical coring techniques, archaeologists uncovered the original position on a sandy ridge and a previously unknown waterway, challenging existing hydrological narratives.

Significance of Landscape Studies
Urban archaeology in Bruges, known for information-dense sites, encounters challenges in effectively managing time and resources. Landscape studies play a crucial role in adjusting research strategies and accurately interpreting findings, transcending the realm of archaeology. Understanding our historical relationship with water contributes to shaping a vision for the future.

The history of Bruges unfolds in layers, from hunter-gatherers in prehistory to a sea-port during Roman times. From the 9th century onwards the city features medieval settlement zones on the highest points of the sandy ridge. Due to low altitude and proximity to coastal plains, marshes are found next to and within this medieval metropolis. This makes for a dynamic landscape, especially when we also consider waterways.

The Reitjes, canalized waterways in Bruges, are both a tourist attraction and a crucial consideration in archaeological research. Originating from a river system flowing through the sandy ridge, the Reitjes contribute to a complex subsoil, influenced by human refuse, construction layers, tidal sediments, and peat. To fully grasp this complex environment, Raakvlak the Archaeological Service of Bruges and Ommeland , drew upon their experience from large scale investigations in the coastal wetlands to introduce new methods in urban archaeology.

Archaeological Implications
Mechanical corings at the Eekhout Abbey site uncovered a filled-up waterway, more than 20m wide and 7m deep. This discovery challenges existing hydrological histories and has broader archaeological implications. The site's dimensions hint at a part of the original, natural river system running through Bruges, the Reitjes.

The historical and cultural significance of water in Bruges, from Celts worshiping it as the place of Gods to its role in Christian liturgy, reflects changing human perceptions of environmental control. The enlightenment era saw waterways in cities as a danger or a nuisance. Historical waterways were vaulted over or filled up, but contemporary challenges highlight our integral role within the natural landscape.

Advocacy for Landscape Studies in Urban Archaeology
In advocating for landscape studies in urban archaeology, this presentation emphasizes the importance of understanding our historical relationship with water. By letting water flow and infiltrate naturally in cities, landscape studies provide vital information to address contemporary challenges. By telling the story written in water, we hope to inspire awareness about the current challenges facing us and hint at possible solutions, even in urban settings.

I propose a 5-minute oral presentation at #VMSD24 to share the compelling narrative of Bruges' hydrological history and its implications for the future. This project not only challenges archaeological norms but also prompts reflection on our dynamic relationship with water.

Keywords
Bruges; water infiltration; landscape studies; urban archaeology; mechanical coring techniques; hydrological narratives

Shallow bioturbation promotes benthic iron release more than deeper bioturbation

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Iron availability limits marine primary productivity in large parts of the ocean. Lithogenic iron is an important iron source for the ocean and can be delivered via dust deposition or transitional systems such as estuaries, rivers and fjords. As iron in oxic waters is highly insoluble, rapidly oxidized, and removed from the water column by settling to the seafloor, benthic iron recycling is a critical part of land-to-ocean iron transport. The activity of benthic fauna ("bioturbation") is known to promote benthic iron recycling in marine sediments and can be further divided into the up and downward transport of particles ("biomixing") and solutes ("bioirrigation"). The balance of these two processes controls the release of iron from the sediment and is ultimately determined by the faunal community present and their functional traits. How all these components are specifically linked to each other however remains largely unquantified and represents an important knowledge gap, preventing a reliable assessment of the role of benthic faunal communities in benthic iron cycling.[1-4]

To address this knowledge gap we investigated the benthic iron cycle and faunal activity in three fjord systems from southwest Sweden with different water-column oxygenation states (permanently oxic, seasonally hypoxic, permanently anoxic). Pore-water distributions of dissolved iron, dissolved iron efflux rates, and iron mineralogy were complemented by a quantification of faunal activity and qualitative assessment of the community composition. Our results confirm that faunal activity is crucial for benthic iron recycling and iron transport along the fjords. We found that benthic iron recycling and iron release are promoted by shallower biomixing activity rather than deeper biomixing, provided a sufficient upward transport through bio-irrigation is present in both cases. This suggests that the biomixing depth is critical for iron production and the benthic release of dissolved iron. Our results illustrate the need to differentiate different modes of bioturbation as ecosystem functions in relation to iron cycling and release from marine sediments.

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Keywords
Iron cycling; benthic macrofauna community; bioturbation; Swedish fjords

POSTER PRESENTATIONS

Exploring phylogeographic pattern in the giant clam *Tridacna maxima* across the Indo-Pacific: insight into connectivity

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The study of marine ecoregions, influenced by combined biogeographic, geomorphologic, and oceanographic factors, delineates regions with relatively uniform species compositions. The Indo- Pacific, renowned for its unparalleled biodiversity, faces increasing vulnerability due to diverse climatic and human-induced stressors. Giant clams provide food, shelter, and protection for various marine species, as well as economic benefits for local communities. Despite their importance, giant clam species are declining in abundance. Understanding the genetic population structure is important for their effective conservation and management. This study aims at investigating the genetic population structure of the giant clam *Tridacna maxima,* the most prevalent and widely distributed giant clam species.

Samples were collected from the Red Sea, Kenya, Tanzania, Madagascar, Mozambique, Sri Lanka, Indonesia, and French Polynesia. The DNA extracted from these samples will be analysed with genome-wide SNPs obtained by next-generation sequencing, aiming to investigate both genetic diversity and the genetic population structure. These results will be compared with previous studies based on COI sequences and microsatellites. Comparing this extensive phylogeographic data set with ecoregions aims at providing insights into connectivity, genetic diversity and biogeographic pattern in order to provide crucial information for marine protected areas networks, safeguarding the species and genetic diversity effectively.

Keywords
Connectivity; Giant Clam; SNP; COI; Microsatellite; Next-generation Sequencing

Clay Tectonics and deformations of the Kortrijk Formation in the Princess Elisabeth Zone, Belgian Continental Shelf

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A thorough investigation of the subsurface structure is required for planning and risk assessment of the future wind energy developments in the Princess Elisabeth Zone (PEZ) on the Belgian Continental Shelf. The PEZ is underlain by the Kortrijk Clay Formation, of Eocene age, which is characterized by the presence of a dense and complex intraformational (i.e. affecting the formation itself but not the over- and underlying deposits) system of faults and other deformations, often referred to as Clay Tectonic features. A detailed understanding of the fault behaviour and attributes (e.g., geometry, orientation, depth, damage zone, displacement, and density) is currently lacking although this is highly relevant for the project planning and would provide important clues on the origin and processes that have led to these clay tectonic features.

We utilise ultra-high-resolution seismic reflection surveys with dense spacing to investigate the subsurface structures and their attributes in three carefully selected study areas. In preliminary observations, distinct structural styles among the three blocks in the PEZ were observed: Fairy Bank, Noordhinder Zuid, and Noordhinder Noord. In the Fairy Bank block, the structural style is dominated by regularly spaced (ranging from 20 to 120 m) normal faults with relatively uniform fault geometry. Faults in this zone also feature layer bending towards the fault plane, marking the fault damage zone. In Noordhinder Zuid, fault spacing is larger (90 to 490 m) and its depth varies, as indicated by shallow fault tips terminating at different depths and layers, dividing the faults into two types: major and minor faults. In Noordhinder Noord, faults are narrowly spaced (10 to 40 m) with irregular geometry and depth and here also reverse faults are present.

This distinct variation in structural style in a relatively limited area put into question which processes and parameters control the deformation within the Kortrijk Clay Formation and to which degree. The detailed mapping based on the seismic survey is currently on-going to build a robust structural model of the region and to provide a better understanding in the genesis and development of the faults within the Kortrijk Clay Formation. In turn, these novel insights will prove highly valuable for the development of the PEZ, as well as for other offshore construction projects in fine-grained sediments characterized by similar deformations.

Keywords
Clay Tectonics; Princess Elisabeth Zone; Belgian Continental Plate; Renewable Energy

Determining the effects of operational offshore wind farms on harbour porpoise distribution and foraging behaviour in the North Sea

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The North Sea is an important region for anthropogenic activities ranging from maritime traffic, gas and oil mining, gravel and sand extraction, fishing, and aquaculture to renewable energy (Moullec *et al.*, 2021). The North Sea is expected to host 300 GW of wind energy by 2050, making wind farms the most important anthropogenic activity next to fisheries. Therefore, it is crucial to investigate how these operational wind farms will affect the marine environment.

Around 340.000 harbour porpoises of the estimated global population size (700.000) are present in the North Sea, proving it to be a vital habitat for these cetaceans (Hammond *et al.*, 2002). Harbour porpoises generate echolocation clicks to navigate, forage and communicate, making them sensitive to noise pollution from offshore wind farms, maritime traffic and offshore construction work amongst others (Wisniewska *et al.*, 2016). Most studies on offshore wind farms have focused on the effects of construction noise on harbour porpoises with only a few recent studies characterizing the operational wind farm noise and its potential effects. Hence, the importance for species conservation and mitigation measures to assess how these anthropogenic noise sources influence their behaviour and distribution in a growing wind energy industry.

We use passive acoustic monitoring to investigate how operational offshore wind farms influence the foraging behaviour and small-scale distribution of harbour porpoises. We will determine how harbour porpoises respond to the operational noise generated by the moving mechanical parts in the nacelle and whether they are attracted by the foraging opportunities offered by the artificial reefs created around the turbines.

The study site is located in the Belgian Part of the North Sea and makes use of tripod-mounted cetacean loggers stationed within 1) the operational offshore wind farms and 2) around marine traffic lanes. Acoustic data at the offshore wind farms will be collected continuously for approximately a year along a gradient of increasing distance from the closest turbine. Hydrophone data and windspeed will be collected to characterise the environment.

The acoustic data retrieved from the cetacean loggers provide information on species presence and behaviour through the recorded click characteristics and frequencies. Such response variables will be analysed in timeseries and general additive models to assess the hypothesis that harbour porpoise distribution and foraging behaviour changes as a function of the presence of artificial reefs and levels of operational offshore wind farm noise. This research will provide crucial information on operational noise effects with implications to improve cetacean management and conservation in heavily used areas like the North Sea.

This research is part of PURE WIND, an UN Ocean Decade endorsed project that aims to study the effects of operational offshore wind farms on several parts of the food web, ranging from top predators like seals and harbour porpoises to zooplankton.

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Keywords
Harbour Porpoise; Foraging Behaviour; Operational Offshore Wind Farm Noise; Artificial Reefs; Passive Acoustic Monitoring

Changes in benthic community structure of coral reefs at the Kenyan coast

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As fisheries pressure maintains to build up, it is necessary to monitor the impact this has on biodiversity, especially in key environments like coral reefs. Coral reefs, crucial for sustaining fishermen and the vulnerable coastal communities they are part of face threats from overfishing and climate change. This project assesses benthic biodiversity changes due to artisanal fisheries pressure focussing on sites along the East African coast, like Watamu and Mombasa in Kenya. Utilising video transects, current benthic biodiversity is analysed so that it can be compared with historic data previously collected. The changes in biodiversity through time can be mapped and then used to implement into policies to conduct more efficient management plans for small-scale fisheries. By implementing scientific data, the aim of this project is to empower governmental bodies to foster the development of laws for sustainable fisheries management.

The research objective is to contribute to reduce the effect of overfishing and enhancing small-scale fisheries sustainability along the East African coast, helping to achieve both local and global goals for a secure future.

Keywords
Kenya; Coral reefs; Small-scale fisheries; Benthic community

The optical fiber like-structure of the bioluminescent brittle star *Amphiura filiformis*: a path to light

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Bioluminescence is a phenomenon that has emerged in numerous phyla, from bacteria to certain bony fish (Lau & Oakley, 2021). Marine living beings with this ability to emit visible light are commonly associated with abyssal species. But luminous organisms can be found even in shallower waters of European seas. This is the case of certain brittle stars such as *Amphiura filiformis*. In this species, a blue light is emitted when stimulated mechanically as a hypothetical defense against predators (Delroisse *et al.*, 2017a). More precisely, this light emission is observed at the level of the spines which traverse the brittle star's arms (Delroisse *et al.*, 2017b). This brittle star has become a well-studied species in terms of echinoderm bioluminescence, but it hasn't yet revealed all its secrets ... especially about the biochemical and mechanical players involved in its bioluminescence control.

The luciferase enzyme is the central biochemical player in the photogenic reaction. Through *in silico* analysis, at least 9 genes coding for luciferase-like proteins have been found in a new *A. filiformis* reference genome (Parey *et al.*, 2023). *In situ* hybridization revealed that several of these genes are expressed at the level of the brittle star's spines, and therefore have a potential involvement in bioluminescence.

Morpho-functional analyses revealed that different morphotypes of ciliated structures (called *stäbchens*) are observed on the spines surface of *A. filiformis*. These structures are typical of brittle stars tegument and are generally considered to be mechanoreceptors or chimioreceptors (Delroisse *et al.*, 2017a). For *A. filiformis*, further evidence in this study points to a potential connection between these structures and the light-producing cells found in the spine inner tissues. So these *stäbchens* could be at the origin of the light response after a mechanical stimulation. Once produced, this light would be channeled along the spine thanks to the presence of a calcareous skeleton and a pigment sheath, in a manner comparable to an optical fiber.

By seeking to clarify some gray areas surrounding *Amphiura filiformis* bioluminescence, these findings may also provide clues to the process of bioluminescence in the marine world.

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Keywords
Echinoderm; Bioluminescence; Luciferase; Receptors; Pigments

Freshwater lens monitoring in an artificial dune

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Introduction

Historically, freshwater lenses beneath Belgian dunes have served as a natural barrier against saltwater intrusion (SI), safeguarding the hinterland's freshwater storage and economy. Urbanization and anthropogenic activities have led to a decline in freshwater lenses, heightening the threat of saltwater intrusion. Understanding hydrogeological feedback mechanisms driving freshwater lens development is crucial for predicting growth and implementing effective coastal protection strategies. This is especially pertinent as more coastal managers turn to nature-based solutions, such as engineered or artificial dunes, like the dune-in-front-of-a-dike approach, to counter seawater intrusion. However, there is still a gap in knowledge regarding freshwater lens growth in dynamic environments, particularly in juvenile (artificial) dunes.

Method

Over four years, our study aims to conduct a thorough investigation, monitoring, and modelling of freshwater lens development during the early stages of dune growth at a newly established artificial dune area measuring 750 x 20 m² in Raversijde, Belgium. The study area incorporates a split-plot design for vegetation with diverse spatial distributions and planting densities. Additionally, a portion of the vegetation is enclosed by brushwood fences featuring varying densities. To capture and comprehend these hydrogeological mechanisms comprehensively, we employ a multifaceted approach combining field measurements, advanced data analysis, and numerical modelling. Our methodology has evolved to incorporate the latest advancements and insights into the study. Our initial focus involves regular time-lapse inversion of Electrical Resistivity Tomography (ERT) data, conducted on a weekly or bi-weekly basis. This process facilitates the visualization of subsurface resistivity (salinity) and provides a detailed examination of the evolving freshwater lens. In addition to ERT measurements, continuous monitoring of the water table, tidal response, and salt levels along several transects is carried out using strategically placed well-monitoring points perpendicular and parallel to the dune area. Detailed monthly drone surveys document topographical changes, while Real-Time Kinematic (RTK) measurements, both pre-and post-storm conditions, evaluate the impact of storm surges on groundwater variations and salinity. An enhancement to our methodology includes the installation of a dedicated monitoring station that tracks solar radiation, soil moisture, and precipitation. This addition provides valuable insights into the overall recharge dynamics of the study site.

The initial ERT measurements have validated the existence of a growing freshwater lens beneath the dune. As part of our ongoing optimization efforts, we are refining the data acquisition process. This includes adjusting the measurement regime for ERT, evaluating the influence of electrode placement, and optimizing the installation of monitoring wells. Additionally, soil samples are being collected to provide a comprehensive understanding of the subsurface conditions.

Conclusion

The collected data forms the basis for a combined dataset of forcing factors, topographical changes, and geohydrological responses. This dataset identifies factors influencing dune lens development, serving as boundary conditions for our MODFLOW 6 groundwater model, developed using Model Muse and FLOPY. The model aims to simulate freshwater lens development, saline-freshwater recharge mixing, and maximum storage of fresh groundwater. This comprehensive approach provides valuable insights into freshwater lens dynamics, enhancing our understanding of interactions during the early stages of dune growth. The project's outcomes will be instrumental in addressing scenarios like sea-level rise and coastal management. By combining field measurements, data analysis, and numerical modelling, we unravel feedback mechanisms shaping freshwater lens development.

Keywords

Early-stage Dune Development; Nature-based Solution; Saltwater Intrusion; Hydrogeological Feedback Mechanism; Coastal Protection; Artificial Dunes; Geophysical Surveys

Phylogeography of the semi-pelagic spotted eagle ray (*Aetobatus ocellatus*)

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Spotted eagle rays are large free-swimming batoids that trophically depend on the benthos. Although commonly occurring on coral reefs and associated habitats, they can undertake long pelagic migrations and are subsequently considered as semipelagic organisms (*i.e.* organisms that penetrate oceanic waters but concentrate close to continental landmasses). These life history traits, associated with the lack of clear biogeographical barriers to dispersal in marine environments, led to the long-held assumption that spotted eagle rays were comprised of well- connected population that formed a single circumtropically distributed species. However, molecular data has revealed high levels of genetic structure, possible due to their apparent dependency on coastal ecosystems. These genetic patterns have resulted in the sundering of spotted eagle rays into several allopatric species.

We herein attempt to link phylogenetic patterns with underlying ecological processes in a phylogeographic study of the Indo-Pacific spotted eagle ray (*Aetobatus ocellatus*). We firstly apply molecular species delimitation methods to sample data that we collected throughout the

Indo-Pacific therein revealing the presence of several hypothetical species units, suggesting that *A. ocellatus* is a complex that is comprised of several cryptic species. These data were then clubbed with public sequence data with high geographic coverage to recreate a time-calibrated phylogeny of the species complex. Our findings suggest that that the evolutionary history of Aetobatids is linked to shifts in biodiversity hotspots. We conclude that the migratory propensity of these semipelagic organisms is diminished by their dependency on coastal ecosystems.

Keywords
Biogeography; Phylogenetics; Species Delimitation; Conservation Genetics

The impact of microbial life (exopolymer gels production) on the formation of Sea Spray Aerosols

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In recent years, the pivotal role of sea spray aerosols (SSA) in cloud formation and their impact on human health have gathered significant attention. Research conducted by VLIZ and Ghent University has unveiled new features of SSA, containing marine biomolecules with intriguing bioactivity potential (Van Acker *et al.* 2020, 2021), while other research revealed the presence of harmful marine phycotoxins posing health risks (Cheng *et al.* 2005). However, all these studies highlight the considerable variability in the enrichment of biomolecules in SSA.

This project aims to elucidate the factors influencing the production of SSA alongside their enrichment in biomolecules under controlled conditions. Our hypothesis postulates a correlation between SSA production and the presence of microbial exudates, specifically Transparent Exopolymeric Particles (TEP) and Coomassie Stainable Particles (CSP) in seawater. The influence of the physicochemical properties of the water column and the water-air interface, such as salinity, temperature, surface tension, and viscosity, on SSA production and composition is well-established in literature (Cravigan *et al.* 2020; Modini *et al.* 2013; Saliba *et al.* 2019). Concurrently, microbial gels like TEP and CSP have been identified as influential elements affecting surface tension and the overall composition of the sea surface microlayer (Santschi *et al.* 2020; Schwehr *et al.* 2018; Thornton, Brooks, and Chen 2016). Preliminary findings from our ongoing research, conducted within a controlled environment using a Marine Aerosol Reference Tank (MART), suggest a mild positive relationship between the concentration of exopolymer gels in the water column and the amount of SSA produced.

To comprehensively understand the impacts of TEP and CSP on the production of SSA, further investigation is imperative. This involves refining experimental conditions and employing specific analytical methodologies. The outcomes of this research hold promise for advancing our understanding of SSA dynamics, contributing to both atmospheric science and considerations for human health.

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Keywords
Sea Spray Aerosols; Marine Gels; Transparent Exopolymeric Particles; Coomassie Stainable Particles; Surface Microlayer; MART

Navigating the spectrum of sea cucumber pigmented cells: from hemocytes to carotenocytes!

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Sea cucumbers are marine invertebrates belonging to the phylum Echinodermata. Their immune system is based on circulating cells called coelomocytes. These cells circulate in the fluids of the perivisceral cavity and the hydrovascular system of these organisms. For some species of sea cucumber, hemocytes are the predominant type of coelomocytes in the fluid of their hydrovascular system. These cells are also found in abundance in an organ of this system known as the Polian vesicle. Hemocytes can be easily discriminated from other coelomocytes by their characteristic red pigmentation. It has long been assumed that this pigmentation is due to the presence of hemoglobin and that these cells may play a role in oxygen transport, which would be useful for species living in anoxic environments. However, a recent study has highlighted the crucial role of hemocytes in encapsulating foreign particles (Caulier *et al.*, 2020). In another study, it was shown that stress related to predator exposure led to an increase in the number of hemocytes (Hamel *et al.*, 2021). According to these findings, these cells appear to be involved in the immune system. Moreover, our analysis of pigments, using spectrophotometry and High-performance liquid chromatography (HPLC), revealed a high concentration of carotenoids in the hydrovascular fluid, Polian vesicle and hemocytes isolated from hydrovascular fluid. Carotenoids have been identified in various forms, including astaxanthin, canthaxanthin, echinenon, and β-Carotene but the pigment that was the most abundant was canthaxanthin. This strongly suggests that these are the class of pigments responsible for the pigmentation of the hemocytes! Carotenoids play a key role in marine food chains, they are transferred from phytoplankton to zooplankton and other small marine organisms, becoming integral components of their tissues. These compounds have also a range of functions beyond their role as pigments. They may be used as indicators of the nutritional quality in the marine ecosystems, as their presence and diversity can reflect the health and productivity of aquatic environments. Additionally, they contribute to various physiological processes, such as antioxidant defense mechanisms (Liaaen-Jensen, 2012). Thus, carotenoids are essential for maintaining the health of marine organisms and the balance of the marine environment. The discovery of this class of pigments opens new perspectives on the function of these reddish cells in the immune response of sea cucumbers. Finally, these pigmented cells could be wrongly interpreted as hemocytes, when in fact they would be a different type of cell that could be called carotenocytes. References Caulier, G., Hamel, J.-F., & Mercier, A. (2020). From coelomocytes to colored aggregates: cellular components and processes involved in the immune response of the holothuroid Cucumaria frondosa. The Biological Bulletin, 239(2), 95–114. Hamel, J.-F., Jobson, S., Caulier, G., & Mercier, A. (2021). Evidence of anticipatory immune and hormonal responses to predation risk in an echinoderm. Scientific Reports, 11(1), 1-10. Liaaen-Jensen, Synnqve. (2012). Marine carotenoids. Marine Natural Products, Chemical and Biochemical Perspective. (Scheuer, PJ ed.) Vol, 2, 1-73.

Keywords
Echinodermata; Sea cucumbers; Immune system; Hemocytes; Pigments; Carotenoids

Population genetic structure of *Octopus mimus* in the East Pacific

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The East Pacific can be divided into biogeographic provinces, which potentially impact the population genetic structure of marine species. *Octopus mimus* Gould, 1852 is a shallow-water species with significant fishery value. Therefore, identification and understanding of the genetic population structure of this species is essential for effective fishery management. A total of 240 *Octopus* COI gene sequences from Mexico (*n* = 10), Nicaragua (*n* = 96), and Peru (*n* = 134) across three biogeographic provinces (Cortez, Panamanian, and Peru-Chilean) and the Equatorial front region were analysed. A BLAST analysis at GenBank identified all sequences as *O. mimus* with a high similarity value (99.70-100 %). The Maximum likelihood phylogenetic tree grouped *O. mimus* and *O. hubbsorum* Berry, 1953 together (bootstrap value

= 96), suggesting these two species are the same. The Equatorial front population showed the highest haplotype and nucleotide diversity (h = 0.77, π = 0.48). Population expansion was observed in Panamanian and Peru-Chilean provinces. The haplotype network revealed two distinct haplogroups differing by four mutational steps. Significant population genetic structure (Φ_{ct} = 0.67, $p < 0.001$) was detected. The first group included populations from Cortez and Panamanian provinces, while the second group encompassed populations from the Peru-Chilean province. A similar result was obtained when populations within the Equatorial front range were grouped separately.

Additionally, 176 samples from the Panamanian province (*n* = 129), the Equatorial front (*n* = 17), and the Peru-Chilean province (*n* = 33) were further investigated using six nuclear microsatellite markers. In contrast to the COI sequences result, the microsatellites result shows the highest allelic richness and effective alleles (Na = 18.50, Ne = 7.90) in the Panamanian province, while the Equatorial front shows the lowest allelic diversity (Na = 11.83, Ne = 7.29). The initial AMOVA analysis from the microsatellite markers revealed a finer population structure with four groups of populations (F_{ct} = 0.037, $p < 0.01$), including two groups within the Panamanian province and the other two groups from the Equatorial front and Peru-Chilean provinces, respectively. This is in concordance with the four clusters of populations (Evanno's ΔK = 4) obtained from the STRUCTURE clustering analysis. These outcomes show a slight difference from COI genes AMOVA results.

The next step in this study is to delve deeper into the microsatellite results and examine the population genetic structure based on all the COI sequences from both *O. mimus* and *O. hubbsorum* available on the GenBank database. Through the analysis of a more extensive dataset and comparing results from two different genetic marker approaches, we expect to gain better insight into the population genetic structure of *O. mimus* and present more informed ideas for fishery management and conservation in this area.

Keywords
Cephalopod; Marine Fisheries; El Niño; Ocean Currents

Saponins: multitasking chemical signatures in asteroids and holothuroids

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Organisms live in a world of odors and flavors where each living or inert entity releases distinct molecules in the environment. Marine organisms, in particular, rely on environmental chemical cues during their entire life, from early developmental to adult stages. Particularly, the phylum Echinodermata presents specific chemicals for each class. Saponins are triterpenic or steroidic glycosides that are produced by all investigated species of holothuroids and asteroids. Due to their amphiphilic properties, these molecules can interact with sterols in biological membranes, rendering saponins noxious and repellent to most organisms (e.g., ichthyotoxic effect). Despite this role of chemical defense, sea cucumbers and seastars harbor diverse symbiotic communities composed of crustaceans, polychaetes and even carapid fishes that developed biological adaptations to resist to saponins. Not only symbionts may benefit from the chemical defense of their hosts to reduce their predation rate, they can also use saponins as kairomones to specifically recognize their host by chemical communication. Recently, we even discovered that holothuroids use saponins as an aggregation pheromone, having a particularly important role in their reproduction.

This study highlights the diverse functions of saponins in seastars and sea cucumbers, ranging from repellent allomones to attractive pheromones and kairomones. These essential metabolites have been strongly selected throughout evolution, with each species possessing its unique chemical signature allowing it to interact with the environment.

Keywords
Chemical Ecology; Saponins; Echinoderms

Tracking labelled faecal pellets and their effect on carbon dynamics in offshore wind farms sediments

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Offshore Wind Farms (OWF) have become a constant presence in the marine environments of the North Sea. Their existence contributes to the imperative transition toward more sustainable energy production, a necessary step to achieve the European Union's carbon neutrality objective by 2030. By then, at least 32% of the energy consumed in Europe should be derived from renewable sources. In this regard, the North Sea already stands as a world-leading area.

In addition to energy production, the presence of these turbines in marine environments means an increased availability of artificial hard substrates for fouling organisms, such as blue mussels (*Mytilus edulis*). This species is a dominant colonizer of wind turbines, feeding by removing particles from the water column. However, they also produce considerable amounts of faecal pellets, likely serving as an additional carbon source to the environment and impacting benthic communities near the turbines. Given that the number of blue mussels per turbine is approximately hundreds per square meter, understanding how this carbon is processed in the environment and partly assimilated by fauna is crucial.

In an experiment, we investigated the fate of these faecal pellets in the benthic environment. We collected cores with sediment impacted by the OWF and sediment from outside the influence of the OWF. We added 180 mg of ^{13}C-labeled mussel faecal pellets per core, corresponding to an estimated weekly carbon deposition in the OWF area. We tracked these labeled faecal pellets in different carbon pools, including dissolved (in)organic carbon resulting from respiration, bacterial pool, faunal biomass, and the remaining faecal pellets in the sediment. This comprehensive approach will enable us to close the carbon budget.

We present the experimental setup and initial results on carbon respiration. Preliminary results regarding oxygen consumption during closed- core incubations indicate different responses from both sediment types. Non-impacted sediments from outside the OWF showed a faster respiration rate during the incubations, implying more rapid degradation processes compared to impacted sediment. Upcoming results should further elucidate whether bacterial and faunal communities from non-impacted sediments respond faster response to the organic input from the faecal pellet rain than OWF sediments that are already used to continual organic input from faecal pellets.

Keywords
Mytilus Edulis, Faecal Pellets, Stable Isotopes, Fouling Fauna, Organic Matter Dynamics, Carbon Flows, Offshore Wind Farm

Fluorescent tagging of sexual cell type identity in a marine diatom

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Diatoms are extraordinary diverse unicellular algae that play an essential role in global nutrient cycling, carbon sequestration and vastly contribute to the primary production on Earth. Unlike the organic cell walls and membranes of most eukaryotic species, diatom cell walls are made of inorganic silica, a rigid structure that limits their capacity to grow and impacts their cell division and life cycle. As a result of their peculiar cell division mechanism, the average cell size of diatom populations tends to decrease with successive vegetative divisions. Most species can only escape cell death by restoring their cell size through the production of a unique expanding cell called the auxospore during sexual reproduction. Despite their global significance, the genetic basis and regulatory mechanisms underlying their evolutionary and ecological success remain largely uncharted territory.

We performed single cell RNA sequencing (scRNA-seq) during sexual reproduction of *Cylindrotheca closterium*, a benthic and tychoplanktonic diatom species that is common on intertidal mudflats and in coastal waters in Belgium and the Netherlands. Through this approach, we identified 16 sexual cell clusters with a distinct expression profile, which cover all major steps of sexual development: mate finding, meiosis, gametogenesis, zygote formation and finally the formation of an expanding auxospore to restore maximum cell size. In addition, we report detailed in vivo molecular validation of scRNA cell cluster identity through transgenic transcriptional and translational reporter lines. Through fluorescent tagging of specific sexual cell types using the regulatory sequence of cluster-specific marker genes, we could confirm the identity of multiple scRNA-seq clusters.

Together, these results suggest several novel experimental approaches to allow a deep functional understanding of the developmental process of sexual reproduction, which is a crucial step for the survival of diatom populations. As such, our findings contribute to a better understanding of the evolutionary biology and ecological success of diatoms and can be leveraged to monitor and control natural diatom populations in the future.

Keywords
Diatoms; Cylindrotheca Closterium; Sexual Reproduction; ScRNA-seq; Transformation; Reporter Lines

Investigating the impact of anthropogenic underwater noise on benthic communities

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The increase of anthropogenic underwater noise (AUN) has altered the marine acoustic environment significantly. AUN can harm a variety of taxa by impairing an individual's physiology directly, as well as interfere with fitness relevant behaviours such as communication, orientation, predator avoidance and foraging, all potentially leading to increased mortality and decreased reproduction. Benthic and planktonic invertebrates play a key role as a dynamic link between lower and higher trophic levels in the worlds oceans. For benthic systems, we anticipate that low-frequency noise will affect the behaviour and species interactions of ecosystem engineers, which in turn will result in a modification of the bioturbation potential of benthic communities, and thus affect biogeochemical cycles.

Here, we introduce the aim of the JPI Oceans project 'ORCHESTRA' (ecOsystem Responses to Constant offsHorE Sound specTRA) and present our planned experiment involving the ecosystem engineer *Lanice conchilega* and the prevailing meiofauna.

Keywords
Underwater Noise; Experimental Marine Biology; Benthic Communities

Towards a toolbox for automating the AUV Barabas data flow embracing FAIR principles

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Marine Autonomous Systems have been developing at a fast pace over the last few years, boosting our ocean observing capabilities in different sectors (e.g., ocean science, offshore energy, and defense) and directions (e.g., improved data quality, better spatial coverage, and new solutions for near-real-time data transfer) [1]. Particularly, Robotics Systems are playing a key role in rapidly feeding a new generation of datasets due to their autonomy, adaptative nature, and ability to explore harsh and remote regions [2]. At the same time, new strategies for data management, including data processing and data flow, must be implemented to fully embrace FAIR (Findability, Accessibility, Interoperability, and Reusability) principles [3,4]. Only by doing so, this new generation of datasets will be fully usable by end-users and, therefore, contribute to major initiatives such as Operational Forecast Systems [5, 6] and the Global Ocean Observing System (GOOS) [7].

As part of the Flanders Marine Institute's robotic fleet, the Autonomous Underwater Vehicle (AUV) Barabas (a vehicle from Teledyne Gavia) has already contributed to different research projects, gathering a broad range of datasets, from side scan sonar imagery and optical measurements (backscattering and fluorescence) to key environmental parameters (temperature, conductivity, and currents). However, the journey into the ocean's depths is not without challenges, particularly in the field of AUV data processing. The intricate nature of file formats and the disparity between scientific and navigation time stamps present challenges. To address these challenges, this work explores solutions towards a toolbox for automating the AUV Barabas data processing and data flow.

Inspired by already suggested frameworks for FAIR robotic datasets [1], and established tools that have been broadly used by the marine robotics community (e.g., PyGlider) [8], we are developing a Python toolbox to streamline the generation of standardized NetCDF files, serving as a cohesive repository of information from various AUV modules and sensors. The NetCDF format provides users with a unified, broadly used format for accessing comprehensive AUV-measured variables alongside essential metadata. The toolbox also categorizes data into processing levels, distinguishing between Level A1 (unaltered data) and Level A2 which features processed AUV data enriched with derived parameters calculated from measured data. This automated approach ensures systematic data manipulation, fostering efficiency and precision. The toolbox is structured in a way that it can be improved by external contributors, as an open-source development, and extended to other robotic devices in the future.

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Keywords
Autonomous Underwater Vehicle (AUV); Marine Robotics; FAIR; Data Processing; NetCDF

Small estuary, big insights: Mapping water level and temperature variability in the Alvor estuary under climate change scenarios

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Accurate prediction of water temperature is crucial for informed decision-making in aquaculture, influencing factors such as fish growth, feeding rates, and disease occurrence. Coastal numerical models are employed for this purpose, but predictions are susceptible to uncertainties in input data. Additionally, water level prediction is vital for optimizing pumping operations in aquaculture systems, where tank water renewal is accelerated through pumping [1].

This work highlights a study conducted in the Alvor estuary, in the Portugal's southern region, focusing on improving the quality of water level and temperature predictions by analyzing physical forces, particularly meteorological and oceanographic factors, influencing residual tides. The research also evaluates the impact of rising sea levels and air temperatures on water levels and temperatures in the context of global climate change.

The study's two primary objectives are: analyzing different datasets for various variables, validating them, and comparing model errors under different meteorological and oceanographic conditions; and utilizing the hydrodynamic model MOHID to create realistic climate change scenarios for the Alvor estuary. These scenarios include increases in mean sea level, air temperature, and river flow.

Data from January 2019 to April 2021, obtained from monitoring stations and the MOHID model [2] via the AquaSafe platform, were analyzed [3, 4]. The model underwent validation and sensitivity analysis, revealing minimum RMSE values of 0.11 m for water level and 0.74 °C for temperature.

The study revealed that sea level rise significantly influences water level increase in the Ria de Alvor, and the response of water temperature is directly influenced by the rise in air temperature. These findings not only enhance comprehension of estuarine hydrodynamics in the region but also enable an assessment of the potential impacts of climate change on water temperature, water level, and velocity.

The study provides valuable insights into the hydrodynamic behavior and tide propagation within the Alvor estuary, addressing a significant knowledge gap in the region where literature is scarce. The climate change scenarios developed using MOHID contribute to an improved understanding of potential future impacts on water temperature, water level, and velocity in the estuarine system.

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Keywords
Numerical Modelling; MOHID; Alvor Estuary; Hydrodynamics; Climate Change Scenarios; Harmonic Analysis

Investigating the interplay between microplastic pollution and ocean warming

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The ocean, covering over 70% of the Earth's surface and intertwined with the lives of billions, faces unprecedented stress from human- induced pressures breaching critical planetary boundaries (Kummu *et al.*, 2016). Climate change, overfishing, pollution, and habitat destruction collectively jeopardize marine ecosystems and the services they provide to coastal communities (Abram *et al.*, 2022; Cooley S *et al.*, 2022). Among these stressors, plastic pollution emerges as a pervasive threat, with plastics permeating marine environments from the sea surface to the deep sea (UNEP, 2021).

My thesis investigates the combined impacts of microplastic (MP) exposure and ocean warming (OW) on *Nitokra spinipes*, a crucial benthic copepod, unraveling their effects on metabolism, growth, development, and population dynamics. The investigation spans realistic and high MP concentrations (10^2 and 10^4 particles mL^{-1}) alongside varying temperatures (22°C vs. 25°C). The study probes into the vulnerability of different life stages of *N. spinipes*, addressing mortality rates and developmental impacts.

Intermediate Results
Based on the preliminary findings, there is a noticeable difference in the average feeding rates of copepods at two different temperatures. For the initial treatment (10^2 PTCs mL^{-1}), the average feeding rate stood at 281.3 cells $copepod^{-1}$ h^{-1} at 22°C and 902.7 cells $copepod^{-1}$ h^{-1} at 25°C. In the second treatment (10^4 PTCs mL^{-1}), the average feeding rate was 512.7 cells $copepod^{-1}$ h^{-1} at 22°C and 961.7 cells $copepod^{-1}$ h^{-1} at 25°C. Notably, at 25°C, the feeding rates appear to have shifted towards higher values in comparison to the 22°C experiment ($p = 0.0551$).

Employing a Dynamic Energy Budget-Individual Based Model (DEB-IBM), this study integrates empirical filtration rate data to simulate copepod population dynamics over a year, illuminating the theoretical effects of OW and MPs on *N. spinipes*. The ecological relevance of these findings for marine ecosystems, particularly the Belgian North Sea coast, is elucidated. Implications on carrying capacity, intrinsic growth rates, and ecosystem functioning are assessed.

Nitokra spinipes serves as the focal model species due to its ecological significance in nutrient cycling, acting as a crucial link between primary producers and higher trophic levels. These benthic copepods, susceptible to MP ingestion, play a pivotal role in the vertical transport of organic matter, influencing carbon storage and nutrient distribution in aquatic ecosystems (Giering *et al.*, 2014; Turner, 2015).

This investigation strives to fill existing knowledge gaps concerning the impacts of MPs on benthic fauna, aiming to unveil the broader implications for marine ecosystems. By unraveling the intricate interplay between MPs and OW on *Nitokra spinipes*, this research contributes to understanding multi-stressor scenarios in aquatic environments, helping to understand the real-world impact of MPs on marine organisms. Stressors, encompassing ocean warming, acidification, deoxygenation, and marine heat waves, often interact in complex ways, influencing biological systems differently compared to single stressors (Catarino *et al.*, 2022; Griffen *et al.*, 2016).

Keywords
Plastic Pollution; Microplastics; Ocean Warming; Multiple Stressors; *Nitokra Spinipes*; Feeding Rates; Population Dynamics; Ecological Impact; Benthic Copepod

The Plastic Pirates Go Europe! Initiative in Belgium: a citizen science project for the observation of riverine and coastal litter

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Litter, in particular stranded plastics, is present in the environment, with known and documented negative environmental impacts (entanglement, gut blockage of aquatic biota, potential ecotoxicological effects). Litter sources can be land-based, and items are readily transported via inland waterbodies to the coast and sea. To be able to act and establish informed mitigation measures to decrease the input from land and riverine waters to the sea, local authorities require reliable and high-quality data. However, litter is a very diverse waste solid product, which is mostly (but not only) composed of plastic of different sizes, shapes, densities, sources etc. To monitor and quantify the spatial-temporal distribution of litter in the environment, experts require cost-effective approaches that can cover a diversity of environments, sampling methods and areas, and that enables an overview of litter accumulations zones. The goal of the Plastic Pirates Go Europe! in Belgium (www.plastic-pirates.eu/dt) is to set up and manage a long-term local project partnership between experts (researchers and data managers) and local schools, for riverine and coastal litter observations, and data publication. The project includes a component of teachers' training, who will lead sampling campaigns with local school students, synchronised with other European project partners, to manage data validation and submission (open access), and to coordinate local data analysis and communication tasks. The observations of the participating school groups in Plastic Pirates (2022, Pilot Phase) have led already to interesting scientific conclusions. For example, the observations in Nieuwpoort have complemented scientific ongoing projects findings by indicating accumulation zones of macro-litter in the bank of the river Ijzer, in the Nature Reserve (Natuurreservaat De Ijzermonding), which was substantial: 4.5 Kg [in 20 x 50 m] and 1.3 Kg [in 60 x 20 m]. This accumulation is of environmental concern, considering that this reserve is an important area for bird nesting, and these organisms can be particular vulnerable to litter entanglement and ingestion. The project has also an important educational component by raising awareness and promoting knowledge about plastic pollution. Schoolchildren can learn about the sources, consequences, and potential solutions to plastic litter through hands-on involvement in data collection, promoting environmental literacy and fostering a sense of responsibility and environmental stewardship among participants. The collected data, which will be made open following the FAIR (findability, accessibility, interoperability, and reusability) principles, will inform policymakers and the public about plastic pollution, promoting societal behaviours and practices that contribute to prevention of litter.

Keywords
Plastic Pirates; Citizen Science; Macroplastic; Litter; Pollution; Data

Insights into the evolution of bioluminescence in echinoderms

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Bioluminescence — the emission of visible light by living organisms — relies on the oxidation of a luciferin substrate catalysed by a luciferase enzyme. The bioluminescence of brittle stars has long fascinated scientists and it's not over yet! Recent research found that the luciferase enzyme of the brittle star *Amphiura filiformis* shares homology with the luciferase of the sea pansy Renilla (Cnidaria).

Surprisingly, these enzymes share high sequence identity and structural similarity with haloalkane dehalogenases that are mostly microbial enzymes that cleave carbon-halogen bonds in diverse halogenated hydrocarbons. This suggests that ancestral non-luciferase enzymes were convergently co-opted into luciferases in cnidarians and echinoderms. Using chromosome-scale genome and extensive transcriptome analyses, we identified multiple luciferase genes in the brittle star and studied their expression during development and arm regeneration. Luciferase mRNAs and proteins were detected in the light-emitting spines and the central nervous system of adults, and the peak of luciferase expression corresponds to the differentiation of spines during regeneration. In parallel, recombinant protein expression and biochemical experiments confirmed the bioactivity of two luciferase candidates. One of which exhibited a dual function, supporting the idea that Renilla- type luciferases evolved from haloalkane dehalogenases, the second one exhibited a clear luciferase activity comparable to the one of Renilla. This research provides valuable insights into the comprehensive characterization of echinoderm bioluminescence and enhances our understanding of how this fascinating ability evolved within the tree of life.

Keywords
Bioluminescence; Marine Invertebrates; Molecular Evolution; Echinoderms; Brittle Stars

Nature-based solutions: evaluating dune development with brushwood fences and marram grass along the Belgian coast

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Introduction
The Belgium coast consist of a sandy beach, providing a natural flood protection. However, during strong wind conditions, wind-blown sand accumulates on coastal infrastructures. Every year, a lot of effort goes into cleaning the road and tramway tracks, especially in Raversijde, Belgium. Jerseys blocks already present on the dike are able to stop a part of this wind-blown sand but are insufficient during high windspeeds. To mitigate this sand nuisance, a dune-in-front-of-a-dike solution was implemented, marram grass and brushwood fences were planted on the upper beach in front of the seawall, strengthened the traditional sea dike. This nature-based solution created a more natural vision, higher ecological values and at the same time a higher level of coastal safety. The overall aim of this study is to relate dune volume changes and changes in dune parameters to forcing factors (e.g., windspeed and -direction), parameters of vegetation and brushwood fences (e.g., cover and density) and sand supply.

Methods
In Raversijde, Belgium a new artificial dune area of 1.5 ha is constructed 20 m in front of the traditional sea dike in Raversijde in the spring of 2021. The new dunes are designed in an area of 750 x 20 m² where vegetation (*Ammophila arenaria*) is planted in a split-plot design of 10 x 10 m² blocks. This vegetation is planted in different spatial distributions (regular, random and clustered) with low and high densities.

Occasionally, vegetation is surrounded by brushwood fences with low and high densities at an original height of 1.5m. Images of these brushwood fences are captured to assess their porosity. These images undergo a binarization process to determine the ratio of black pixels, corresponding to the openings in the brushwood fences, to the overall pixels within the image. Topographical changes are monitored by means of monthly drone surveys, simultaneously with local and regional wind conditions. Analyses are done along 12 cross-shore profiles and 8 divided zones.

Results
Preliminary results show a clear difference in cross-shore development for the different zones during the initial months of development, the influence of vegetation combined with brushwood fences is much more prominent than vegetation on itself. At the end of the first year the dune captured a volume of 18-26 m³/m in the zones characterized by the combination while the vegetation zones captured 12-14 m³/m. These brushwood fences are able to capture a larger amount of sand, but their trapping efficiency decreases over time as several combined zones become completely saturated by the end of the first year. When considering vegetation alone, the landward dune toe moves landward at a faster rate compared to combined zones. Yet, within the combined zones, the dune toe shifts more rapidly toward the land as porosity increases. Furthermore, in vegetation-only areas the dune crest is lower than those in combined zones, as the dune crest's elevation is influenced by vegetation and brushwood fence heights. The interaction between transport-limiting factor heights and the maximum sand accumulation level is always occurring. However, compared to vegetation, these fences are unable to grow and consequently capture sand in the future, so new planting in these combined zones will be necessary.

Keywords
Early-stage Dune Development; Dune Morphodynamics; Nature-based Solution; Field Measurement

Fishing for seafloor sustainability: navigating the impact of Belgian bottom trawling on benthic habitats using an integrative approach (Benthis Nationaal 2)

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The Belgian sea fishery transitioned from the exploitation of sprat and herring in the 1970s to its current focus on bottom trawling (81% of the fleet) for sole, plaice and shrimp. Ecological concerns surrounding beam trawling, a key technique in this demersal fishery, have been raised, particularly regarding its impact on the benthic habitat due to gear penetration of the seafloor. It has been shown that bottom trawling leads to a reduction in benthic biomass, diversity, and species body size, and alters the functional traits of the community, with varying effects across gear types and habitats. Therefore, managing and assessing the health status of the seafloor ecosystem is an essential part of the EU conservation policy (E.g. EU action plan on ban of bottom trawling, EU biodiversity strategy, the Marine Strategy Framework Directive) Consequently, research for understanding the extent of beam trawling's impacts on the seabed is crucial.

To comprehensively evaluate bottom trawling's impact on the seafloor, two major groups of benthic indicators were developed: (1) "risk" indicators (e.g. ICES-FBIT and OSPAR BH3) which estimate potential effects through modelling and (2) "state" indicators which are used to judge the actual benthic community state based on monitoring data. While these indicators provide valuable insights into the state and ecological integrity of the seafloor, caution is warranted. Notably, one indicator doesn't capture all ecosystem responses, thus the use of multiple indicators is encouraged. Additionally, indicator selection could influence the outcome of the analysis, potentially leading to different management strategies being set in place. Hence, appropriate indicator comparability research is needed for selecting the most suitable set of indicators for assessing fisheries' impact.

In our ongoing study, we propose a novel approach to enhance the sustainability of bottom trawling by integrating benthic indicators into a sensitivity map for real-time onboard decision-making. We aim to identify the most comprehensive suite of parameters which represent the state and sensitivity of benthic habitats through the analysis of multiple indicators. A preliminary comparison between OSPAR and ICES FBIT-based benthic habitat sensitivity for some regions relevant to Belgian fishery revealed a lack of correlation between both sensitivity classifications. This outcome doesn't imply the inaccuracy of either method but underscores the importance of a precautionary approach when using these methods interchangeably. Additionally, this finding emphasizes the need for further comparisons across multiple indicators and fishing regions, a crucial next step in our research. Based on these findings, we will select a set of indicators representing different aspects of the benthic habitat in relation to fishing pressure and integrate them into a sensitivity map suitable for onboard purposes. Based on this map, they are informed on which areas (high sensitivity) to avoid to reduce their impact on the seafloor ecosystem. By creating this onboard tool, we aim to encourage the fishing community to make informed, sustainable decisions by themselves.

Keywords
Benthic Indicators; Marine Strategy Framework Directive; Bottom Trawling; Seafloor; Benthic Ecosystems

Exploring mode of action and immunomodulating effects of marine toxins using in vitro human cell line models

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Marine toxins are a diverse group of natural toxins produced by marine micro-algae. They occur in high amounts during harmful algal blooms and cause human intoxications by consumption of contaminated shellfish. Moreover, marine toxins also end up in sea spray aerosols, causing an inhalational exposure route associated with several effects including respiratory symptoms. High concentrations of these natural molecules are linked with shellfish poisoning. However, low concentrations have been associated with health-promoting effects, such as anti- Alzheimer, anti-inflammatory or anti-cancer properties. We investigated the human health effects of marine biotoxin exposure by in vitro (immuno)toxicity testing. A sub selection of marine toxins with high potential were selected, namely yessotoxin and homoyessotoxin. Two human cell line models, A549 and THP-1, were exposed to different concentrations of the phycotoxins. Various types of colorimetric and fluorescent assays provided insights into the mode of action and immune-modulating effects of the phycotoxins. At low doses, both yessotoxin and homoyessotoxin selectively impact lysosomes, preserving metabolic activity and cell membrane integrity. Furthermore, they exhibit a concentration-dependent modulation of cytokine expression.

Keywords
Marine Toxins; In Vitro (immuno)toxicity

Extreme variation in reproductive strategy: tropical seagrass superclone unveiled

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Enhalus acoroides is a large-sized seagrass species that is regionally threatened, yet considered widely distributed across the Indo-Pacific region. Despite its robust fruit dispersal capacity and slow rhizome growth rate favoring sexual reproduction, recent studies revealed substantial variation in the reproductive strategy for *E. acoroides*. The interplay between sexual and asexual reproduction significantly influences the resilience of seagrass beds to environmental change. As a result, there is a pressing need to enhance our comprehension of the reproduction strategy and dispersal capacity of *E. acoroides*, and the environmental drivers that control these life history traits. In this study, we investigated the clonal richness, genetic diversity, and genetic connectivity in 33 populations across diverse islands in the Andaman Sea (Phuket), the Gulf of Thailand (Koh Samui, Koh Phangan, Phu Quoc), the Camotes Sea (Leyte), and the Western Pacific Ocean (Guam). Our findings underscore substantial local and regional variability in the reproductive strategy of *E. acoroides* which has profound implications for the effective conservation of seagrass beds. Strikingly, we found unprecedentedly high levels of clonality in Guam where one exceptionally large and old clone of *E. acoroides* spans the entire island.

Keywords
Seagrass; Clonality; Dispersal; Conservation; Genetics

Assessing the population genetics and connectivity patterns of reef fauna in Sri Lanka to define conservation priorities

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Sri Lanka, a tropical island nation, is home to diverse coral reef communities that offer a multitude of reef resources and livelihood opportunities. Nevertheless, they are degrading at an alarming rate due to multiple natural and anthropogenic stressors. Incorporation of population genetics is imperative to manage the coral reefs as well as to guide the establishment of marine protected areas (MPAs). So far, only a handful of molecular studies on corals and their associated biota are available in Sri Lanka. On a broader scale, a critical information gap is identified in the central Indian Ocean to understand the contemporary geographic distributions and connectivity of reef communities in the Indo-Pacific. Therefore, this study aims to address this data inadequacy by providing baseline information derived from population genetics to comprehend the connectivity among reefs in Sri Lanka. Additionally, it seeks to explore the possible contribution and connectivity to the rest of the Indian Ocean regions. A total of 455 branch tips of *Pocillopora damiconis*, 123 mantle tissue of *Tridacna* spp., and 136 caudal fin clips from *Amphiprion clarkii* were collected non-lethal manner and genomic DNA was extracted. DNA barcoding was performed using mitochondrial open reading frame (mtORF) and mitochondrial cytochrome C oxidase subunit I (mtCOI) molecular markers in *P. damiconis* and *Tridacna spp.* respectively. The population genetics and connectivity will be assessed using single nucleotide polymorphisms (SNPs) in all three species. The results will be compared with the published data to elucidate the large-scale connectivity and phylogeography that prevailing in the Indo-Pacific. The data and information generated will be crucial in making informed management decisions for the sustainable administration of MPAs.

Keywords
Population Genetics; Marine Protected Areas (Mpas); Connectivity; Molecular Markers

Nature-based solutions for restoring and developing new mangrove habitats through eco-engineering

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Jan De Nul Group has a long-standing presence in Ecuador, particularly since 2018, when a 25-year concession contract began for performing maintenance dredging for the Access Channel to the port of Guayaquil. This area is part of the Guayas river delta and is covered by mangrove forests that provide important ecosystem services. However, in the last few decades there has been significant loss of mangroves in the area, which intensifies coastal safety problems, as the land around the Guayas river delta becomes more exposed to floods and coastal erosion. In response to this, the AquaForest innovation project was introduced in 2023. Dredged material from the Access Channel of Guayaquil will be reused for the first time in a circular and sustainable way to create a new mangrove habitat on a new intertidal flat created in the Guayas river delta, located 15km NE of Posorja. AquaForest will become a 'Nature-based-Solutions' (NbS) Living lab where important mangrove ecosystem services will be demonstrated and monitored such as protection against floods, biodiversity gain, carbon sequestration and socio-economic benefits for the local communities. The AquaForest project concept is based on the development of "green-grey infrastructure". This approach combines conventional engineering techniques for land reclamation with the circular reuse of dredged material to create mangroves through assisted afforestation. At the same time, the initial conditions will be created (e.g. sediment characteristics, hydraulic and hydrodynamic conditions) that are ideal for the growth of mangrove propagules, the proliferation of new accompanying tree seeds and the colonization process of associated biodiversity (micro and macro fauna), though suitable eco-engineering of the project site. Part of the project also focuses on the study of upscaling of this type of Nature-based-Solutions. As such, knowledge obtained from this pilot project regarding the implementation and monitoring of mangrove NbS will be employed in the upscaling of the AquaForest concept in future projects across the region and around the world, particularly in areas where mangrove forests serve as vital components of local ecosystems. AquaForest demonstrates co-creation between private companies, public institutions, international organisations, local communities and citizens, NGOs, universities and researchers. The project is a collaboration between Jan De Nul Group, Mantis Consulting, HAEDES, Escuela Superior Politécnica del Litoral, Free University of Brussels, University of Antwerp, South Pole, and the Calisur Foundation. The project furthermore has the full support of the Ecuadorian Ministry of Environment, Water and Ecological Transition (MAATE) and all other important local stakeholders. Acknowledgements: AquaForest is supported by the Government of Flanders (NL: "Departement Omgeving") through the G-STIC Climate Action Programme 2022, and The International Union for Conservation of Nature (IUCN) through the 'Blue Natural Capital Financing Facility'.

Keywords
NbS; Mangrove; Restoration; Ecuador; Eco-engineering

eDNA metabarcoding reveals horizontal and vertical patterns of the fish communities in a shallow and well-mixed marine environment

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While human-induced stressors such as climate change, habitat disruption and overfishing continue to pose a substantial threat to the health of our oceans, monitoring efforts became critically essential for the sustainable management and conservation of marine environments. EU marine policy centered on the Marine Strategy Framework Directive (MSFD) highlights the importance of establishing monitoring and assessment activities for achieving the goals of maintaining biodiversity and good environmental status. Traditionally, biodiversity assessment has relied on methods such as catch-based surveys and visual surveillance. Catch-based surveys, in particular, have detrimental effects on benthic habitats leading to mortality of the benthos, physical disturbance of the seabed, and changes in biogeochemical characteristics. Additionally, identification of the species by these techniques generally requires taxonomic expertise and can be time consuming. In contrast to the conventional methods, environmental DNA (eDNA) metabarcoding emerged as a non-invasive and cost- effective approach for assessing biodiversity that utilizes DNA extracted from the environmental samples. eDNA metabarcoding substantially contributed to the monitoring efforts by detecting elusive and low abundance species that would otherwise go unnoticed.

eDNA metabarcoding has also been proven effective to describe the horizontal spatial patterns of the fish communities with a fine-scale resolution, ranging from a few meters to a few kilometers. However, research on the vertical eDNA profile has been predominantly focused on stratified open ocean waters or regions with a distinct halocline, where vertical eDNA dispersal is limited. The studies about the vertical eDNA signatures in shallow and well-mixed areas are very scarce. To understand the spatial fish eDNA patterns and how these patterns correspond to traditional beam trawl data in such hydrodynamically active areas, we collected water samples from 17 stations within the Belgian Part of the North Sea (BPNS). The samples covered both surface and bottom depths across three zones (coastal, transition and offshore) associated with distinct fish communities established through long-term trawl monitoring.

Our results showed that eDNA was able to detect the majority of the fishes found in the catch data (81%) and detected 23 additional species. While a few species persisted in being exclusively identified through trawl catch data, eDNA metabarcoding significantly contributed to the detection of the species-level taxonomic diversity by 53%. The species richness and Shannon diversity index were not significantly different between the two depths (p-value > 0.05), but showed significant differences between the zones (p-value < 0.0001). Both alpha diversity measurements were significantly lower for the coastal zone compared to the other zones. Community composition was not significantly affected by the depth factor (pseudo F= 1.3, p=0.25). Zone, on the other hand, had a significant effect on fish community composition (pseudo-F= 32.19, p=0.0001). Post hoc analysis showed that communities of coastal, transition and offshore zones were significantly different from each other (p-value = 0.0001).

These results demonstrate the effectiveness of eDNA metabarcoding in reconstructing the fish community patterns that are closely aligned with the long-term beam trawl data within the BPNS. Moreover, we showed that shallow and well-mixed waters of the BPNS lack distinct vertical eDNA patterns corresponding to the depth preferences of the fish species. Sampling at different depths has no impact on the alpha and beta diversity assessment within the area, suggesting that sampling at one depth should be adequate to capture the majority of fish diversity. Our study represents one of the first efforts to elucidate the vertical eDNA profiles in shallow and well-mixed marine environments.

Keywords
Monitoring; EDNA Metabarcoding; Beam Trawling; Belgian Part Of The North Sea; Spatial EDNA Patterns; Fish Communities

Reassessment of mud crab (*Scylla* spp.) taxonomic identity in Segara Anakan Lagoon, Cilacap, Indonesia

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Due to high morphological similarity, taxonomic misidentification of the commercially important mud crabs from the genus *Scylla* is common. Studies from Segara Anakan Lagoon (SAL) (Cilacap, Indonesia) mostly recognised *Scylla serrata* as the only existing mud crab species in the area. Misidentification of *Scylla* spp. derived from only using a morphological approach to identify the species. This study aimed to reassess mud crabs (*Scylla* spp.) in SAL using morphometrical analysis, complemented with DNA barcoding. One hundred and seven specimens were collected from SAL in March-June 2021. Fourteen morphometric parameters were measured using a digital vernier caliper (0.01 mm). The DNA barcoding targeted a fragment of the mitochondrial cytochrome oxidase I (mtCOI) gene, which was amplified by PCR using the primers mtd10 5'TTGATTTTTTGGTCATCCAGAAGT 3' and C/N 2769 5' TTAAGTCCTAGAAATGTTRGGGA 3'.

The Neighbour-Joining Tree (NJT) of the COI sequences clustered the four species of Scylla. However the Non-Metric Multidimensional Scaling (nMDS) showed no clusters of the morphometrical data. Regardless the similarity in the morphometrics, the mtCOI sequences revealed that four species of Scylla spp. were present in SAL, contrasting previous findings that only *Scylla serrata* is present. Sequences- based NJT showed four distinct clades (bootstrap value = 100). Each clade corresponded to different Barcode Identifier Number (BIN) codes obtained from the Barcode of Life Data System (BOLD) during genetic identity verification. The genetic distance (Ds) values between species were higher compared to the within species (0.068-0.173 > 0.002 to 0.004), confirming there were no cryptic species found in the samples. This study indicated that all four *Scylla* species, i.e *S. serrata, S. olivacea, S. tranquebarica*, and *S. paramamosain* were present in SAL.

Keywords
Taxonomic Misidentification; Morphometrical Analysis; DNA Barcoding

Microplastic intake by deep-sea fishes of the Western Indian Ocean

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Deep-sea fishes exhibit diel vertical migrations, moving from the sea surface to deeper depths at dawn. This behavior plays a crucial role in the transport of organic carbon and nutrient recycling in the global ocean, facilitating the release of organic material through faecal deposition, which then sinks from the upper surface to the deep ocean layers. The connection between the epipelagic and mesopelagic layers is vital, as it accelerates the downward flux of carbon and nutrients.

However, the pervasive issue of plastic debris in the marine environment raises concerns about its impact on deep-sea organisms. Despite the prevalence of plastic contamination, particularly in the Indian Ocean, significant knowledge gaps persist. This project aims to address these gaps by investigating microplastic contamination in the digestive tracts of hyper-abundant and widespread deep-sea fishes in the Western Indian Ocean.

Deep-sea fish were collected during previous research cruises at various locations, including the shallow seamounts La Pérouse, MAD- Ridge, Walters Shoal, and around Reunion Island. These underwater topographic features are crucial habitats for a diverse array of micronekton species, including mesopelagic fishes, crustaceans, squids, and benthopelagic fishes.

The general objective of the project involves dissecting 150 deep-sea fishes collected from previous cruises, taxonomically identifying them, and analyzing their gut contents for potential microplastic particles. Specific objectives include:

- Investigating the differences in microplastic intake by deep-sea biota among La Pérouse, MAD-Ridge, Walters Shoal seamounts, and Reunion Island.
- Examining the potential influence of species, stomach fullness, and the depth at which fish were caught on the amount of microplastics found in their gut contents.
- Analyzing how the type, shape, and size of microplastics in the guts of deep-sea fishes differ between study sites.
- Assessing whether the mouth size and morphology of deep-sea fishes play a role in influencing the amount and type of plastic ingested.

Despite the significant fishing pressures and environmental impacts faced by marine ecosystems at these locations, no previous studies have explored the impact of plastic on deep-sea fishes inhabiting these seamounts and oceanic areas. This research aims to fill this knowledge gap and contribute to a better understanding of the interaction between microplastics and deep-sea ecosystems in the Western Indian Ocean.

Keywords
Microplastics; Deep-sea Fish; Fenton Reaction; Microscopy

Comparative evaluation of techniques for extracting bioactive compounds from brown seaweed

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For centuries, marine seaweed has been a vital food source, valued for its abundant bioactive compounds that exhibit antitumor, antiviral and antioxidant properties [1]. Seaweeds stand out as a sustainable resource for these compounds, thriving without the need for land or fertilizer and outperforming terrestrial plants in productivity [2].This study focused on brown seaweed, particularly the species *Ascophylum nodosum.* This species was chosen due to its high polysaccharide content (approximately 50 wt%), especially the sulfonated polysaccharide fucoidan, which is more prevalent in this species compared to others. Three extraction techniques, i.e., ultrasound-assisted (US), microwave-assisted (MW) and conventional (CV) techniques, are evaluated in this study for their efficiency in cell wall disruption and the yield of desired components (i.e., alginate, fucoidan, laminarin, polyphenols and proteins).

Traditionally, research in this field has focused on extracting single compounds, predominantly alginate. However, this study introduces a novel cascaded extraction process designed to selectively extract and separate multiple products, including polysaccharides (alginate, fucoidan and laminarin), proteins and polyphenols. To recover polysaccharides, food-grade chemicals are employed, such as ethanol, sodium bicarbonate and citric acid, avoiding the use of harsher, toxic substances such as HCl and formaldehyde. This approach opens the door for potential applications in food and feed products.

A novel biphasic system is evaluated in this study, combining ethyl acetate and an aqueous citric acid solution. This system works in combination with the extraction techniques previously mentioned (i.e., US, MW, and CV), which enables the simultaneous solubilization and separation of polyphenols and pigments into the organic phase, while retaining the polysaccharides and proteins in the aqueous and solid phases for further separation. This innovative approach reduces the number of steps involved in the extraction process. Traditionally, a pretreatment step using organic solvents is necessary to remove polyphenols and pigments, which are then discarded [3]–[5].

The process involves centrifugation to separate the solid and liquid phases and decantation to separate the organic and aqueous phases. As a result, the initial extraction step yields three distinct phases: organic, aqueous and solid. Following this, sodium bicarbonate is added to the solid phase to derive (soluble) sodium alginate. in the final step, ethanol is introduced to the aqueous phase and the sodium alginate solution to precipitate the individual polysaccharides.

Results indicate that the use of microwave and ultrasound assisted extraction increase the yield of alginate by 37.72% and 47.70% respectively when compared to conventional extraction. It was observed that after the initial extraction step instead of three phases: organic, aqueous, and solid; a fourth gel-like phase appeared. This gel-like phase contained a higher nitrogen content than all other products, indicating a high concentration of proteins in this phase.

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Keywords
Seaweed; Extraction; Ultrasounds; Microwaves; Cascade; Alginate ; Fucoidan; Laminarin; Polyphenols; Proteins

Sand extraction affects the functioning of benthic ecosystems

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In light of the EU mission to restore and protect our oceans by 2030, a solid understanding of how human activities affect the marine environment is imperative to ensure their sustainable management. As our natural ecosystems provide many beneficial services, it is important to understand the physicochemical and biological processes that maintain the ecosystem itself (ecosystem functions). Additionally, investigating how these ecosystem functions may change under various human pressures is therefore crucial for better informed management strategies. An example of such human pressure is marine sand extraction, which plays a vital economic role worldwide. These marine sands serve as raw materials for concrete and asphalt production and are used for beach nourishments to protect coastal areas against the effects of climate change. Despite providing important marine resources, the extraction process significantly impacts the marine environment. While previous studies explored the effects of sand extraction on the seabed structure and composition and on benthic biodiversity, the impact on carbon and nitrogen cycling, which relate to important ecosystem functions such as carbon sequestration and nutrient recycling, remains largely unknown. To address this gap, we sampled three sand extraction areas characterized by different extraction regimes in the Belgian Part of the North Sea: the Thorntonbank (continuous extraction of large sand volumes), Oostdyck (continuous extraction of small sand volumes) and Noordhinder (intermittent extraction of large sand volumes). For each area, we defined an impact and reference zone where we measured sediment, chemical and biological parameters by means of box core sampling. Nutrient and carbon fluxes over the sediment-water interface were measured by using closed-core incubations.

Our first results revealed that the mineralization processes are primarily driven by the total organic carbon (TOC) content in the sediment. No direct impact of the extraction activity (expressed in days extracted) on the mineralization processes was found. However, TOC content and extraction activity showed a weak, but significant, positive correlation ($r(28) = 0.37$, $p < 0.05$), suggesting that sand extraction may indirectly stimulate the mineralization in the sediment by increasing TOC content. Conversely, the variation in the nitrification rates (process whereby ammonia is sequentially oxidized to nitrite and nitrate) was explained by sand extraction and not by TOC content or other sediment variables. Considering that faunal activities in the sediment (particle reworking and burrow ventilation) positively influence nitrification, it is possible that sand extraction activities promote nitrification through the direct physical disturbance of the sediment as it actively brings oxygen to deeper layers.

This study is the first to investigate the impact of sand extraction on the benthic ecosystem functioning. Initial results indicate that sand extraction affects different processes in the benthic carbon and nitrogen cycles through two distinct mechanisms: either by changing sediment properties or by directly disturbing the sediment. A better understanding of how sand extraction affects essential ecosystem functions, such as nutrient cycling, carbon storage or mineralization, can support the development of new sustainable extraction practices in the future.

Keywords
Marine Sand Extraction; Human Impact; Seabed; Ecosystem Functioning; Nutrient Cycling; Carbon

Effects of plastics leachates on the larvae settlement of *Crassostrea gigas* in a multiple stressor environment

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In 2022, global plastic production soared to 400 million tons, and a substantial portion of these plastics finds its way from inland areas to water systems, ultimately reaching coastlines through various entry points like rivers. Within aquatic environments, these plastics undergo physical degradation, propelled by factors such as UV radiation and mechanical processes, breaking down into microplastics (MPs; <5mm). The ingestion of these MPs by aquatic organisms, such as oysters, has been linked to adverse effects, including a reduction in the success of oyster larvae settlement which is a concerning issue for oyster production. With the climate change, these larvae face a mixed effects of microplastics and temperature fluctuations. To our knowledge, no studies have evaluated the impacts of these two stressors on the settlement success of *Crassostrea gigas'* larvae yet. Therefore, this study aims to assess the influence of a multi-stressor environment—specifically, increased water temperature and plastics leachates—on the settlement of *C. gigas'* larvae. First, Plastic items will be sampled from the Iser estuary in Nieuwpoort, Belgium, using an aquatic drone and a manta net in triplicate transects. Then, the polymeric composition of plastics in the water column will be identified to determine the most abundant polymer type. From the environmentally sampled plastic particles, leachates will be extracted for ecotoxicological assessments, allowing the investigation into the combined effects of microplastic leachates and increased temperature on pediveliger larvae (8 days post-fertilization) and their settlement. Four treatment conditions will be evaluated, each conducted simultaneously over a seven-day exposure period composed of 1 control group (C), 1 treatment with plastics leachates at control temperature (L), 1 treatment with an increased temperature of ± 3 °C (T), and the final treatment with the multiple stressors conditions involving the plastics leachates and a higher temperature of ± 3 °C (MSC). Ultimately, statistical tests will be employed to determine if the variables significantly impact the settlement of larvae and to clarify the potential correlations between the two variables. The anticipated outcome is a substantial reduction in the settlement success ratio of *C. gigas*' larvae when both microplastic leachates and elevated temperatures coexist in the environment, presenting a potential challenge for oyster farmers in the future.

Keywords
(Micro)plastic Leachates; Crassostrea Gigas; Larvae Settlement; Multiple Stressors

The social structuring of recreational visits to the Belgian coast in 2022

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Coastal destinations are highly popular for leisure, yet the effects of spending time at the coast on mental and physical health have remained underexplored. There is particularly a lack of knowledge about who performs what types of visits to the coast, i.e. how coastal visits are socially structured. Therefore, we aimed to increase our understanding about the social structuring of coastal visits and to give context to the effects of the coast on human health.

We compiled a dataset via a survey data from a sample (N = 1939) of the adult Flemish population about their visits to the Belgian coast. The survey queried the respondents' number of day visits and/or longer stays per season in the previous year and the following characteristics of their visits: how often they performed specific activities, which of the 14 municipal seaside resorts they visited, who they were with, what they mentally and physically experienced, and what reasons they had for not visiting the coast more often. The respondents' geo- demographic (including residential proximity to the coast), socio-economic, and health profile was also inventoried. Then, we focus on distinguishing orthogonal dimensions that structured the variation in coastal leisure activities and the social company using specific multiple correspondence analysis. Lastly, we distinguished clusters of individuals who are located at aggregated locations in the multidimensional cloud using ascending hierarchical cluster analysis.

Four relevant dimensions were retained. They structured the data on the basis of the level of engagement (47.36%), the natural vs. urban environment of the activities (10.00%), the social company during the visit (i.e. differentiating visitors with partners and kids from those visiting the coast alone, with friends, or with a club; 5.53%), and the purpose of visiting (i.e. differentiating visitors of family and friends from explorers; 4.27%). Five clusters of individuals were defined: visitors with a 'generalist' activity pattern are typically middle-aged, higher educated adults who visit the coast with partners and kids; 'engagers in nature' typically have the coast embedded in their lives and are highly socially and physically active; 'engagers in the city' are typically young (18-29y) or old (>=65y), physically active, higher educated, and frequent visitors of the coast and do so mainly alone, with friends, or with a club; 'disengagers in nature' are typically young, socially isolated individuals with a low income; and 'disengagers in the city' are typically retired (>= 65y) off-season visitors with a partner that often go eating out at the coast. The 'engagers in nature' and 'engagers in the city' gained positive experiences from their visits exceptionally often.

The data and social structuring of leisure activities highlight the importance of considering both individual and activity related factors in assessing the effects of the coast on human health. We anticipate that the acquired data will contribute to unravelling and quantifying the mechanisms behind relationships between the ocean and human health in Flanders. The data is openly available at https://doi.org/ 10.14284/625.

Keywords
Coastal Visits; Human Health; Experiences; Tourism; Recreation

The sky is the limit... How high can zooplankton go?

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The effects of global warming spread to all trophic levels in the marine environment. Consequently, the reaction of zooplankton to increasing temperatures and heatwaves is extra important, as this might induce cascade effects that enhance effects for higher trophic levels. As main transferers of nutrients from primary producers to secondary consumers, copepods play a key role in the connection between low and high trophic levels in marine food webs. Therefore, it is highly important to investigate how the nutritional value of copepods, aka the fatty acid profiles, change with rising temperatures. During our research, the nutritional value of copepods changed drastically after several generations of high temperature exposure. In parallel, DNA methylation patterns were monitored to link stress levels and epigenetic changes to different temperature treatments. Interestingly, when temperature increased slowly over the course of four generations, mimicking future global temperature rise, methylation patterns deviated strongly from control conditions, while the fatty acid profiles remained similar to those of the control. This shows that a slow increase in temperature allowed the copepods to properly adapt to climate change, in strong contrast with their response to rapid temperature increase. The outcome of this research highlights the importance of short, local variations and heatwaves, in comparison to the mean global temperature increase.

Keywords
Copepoda; Climate Change; Temperature Stress; Fatty Acid; Epigenetics

Myth or fact: does a coastal walk reduce stress? A physiological study with wearable technology

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Chronic stress, identified by the World Health Organization as the "Health Epidemic of the 21st Century," significantly impacts human mental and physical well-being, putting substantial pressure on the health care system and increasing health care costs. Exposure to natural environments has been associated with positive health outcomes, including a reduction in physiological stress. A natural environment that has been deemed healthy for centuries is the coast. However, research on the physiological health effects of coastal exposure is sparse. Field studies on this topic are not often performed, although a real-life approach is a more environmentally valid method than studying people in a laboratory environment.

This study aimed to fill this knowledge gap by exploring the impact of an outdoor coastal walk on objective physiological parameters related to stress with innovative technologies. A randomized cross-over design was used, in which 15 participants (21-56 years, 53% female) walked in a coastal and an urban environment. During these walks, wearable technology (the NeXus-10 MKII) was used to continuously measure high-frequency heart rate variability (HF-HRV) as a proxy for the parasympathetic nervous system (PNS) activity. Self-reported mental health parameters and movement data were acquired as well. Linear mixed models were used to analyse HF-HRV and each self-reported parameter, while controlling for physical activity, weather conditions and the stress level of participants in the week prior to the experiments.

Results revealed a more pronounced reduction in PNS activity due to the coastal walk compared to the urban walk. Moreover, perceived stress levels decreased more due to the urban walk. Both of these results suggest a significantly higher stress-reducing effect of the urban walk. However, this was possibly influenced by participants' familiarity with the urban environment, which should be addressed in future research. Additionally, analysing distinct environmental components (e.g. the dunes for the coastal walk, the shopping streets for the urban walk), as opposed to a holistic method of studying the environments, proved crucial in understanding their varying physiological effects.

The initial hypothesis that the coastal walk would have a higher stress-reducing effect than the urban walk was rejected. The small sample size and relatively simple test design might be an explanation for these unexpected results. Despite these challenges, this study emerged as a pioneer in using the NeXus-10 MKII during an outdoor walk. As such, the results of this study not only provide essential methodological information regarding the constraints and applicability of this specific device, but also highlight the need for wearable technology designed for outdoor use and physical activity. Furthermore, while this study did not yield an univocal conclusion on the (mental) health effects of coastal exposure, this research provided some valuable insights by integrating diverse physiological, self-reported, and movement data.

Keywords
Oceans And Human Health; Stress; Physiology; Wearable Technology

Searching for seismic and sedimentary evidence for proglacial lakes during the last glaciation: first observations in the areas south of Dogger Bank and Oyster Ground (southern North Sea)

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The southern North Sea is characterized by a complex and long geological history. During the Quaternary, the area was affected by increased climatic instability that led to regional sea level oscillations and extensive glacial-interglacial cycles[1,2]. In the past 500,000 years, the region has witnessed three major glacial phases, referred to as the Elsterian (MIS 12), the Saalian (MIS 10-6), and the Weichselian (MIS 4-2) glaciations. Former studies proposed that large proglacial lakes must have developed close to the ice margins during each of these glacial periods due to glacial meltwater and the drainage of numerous northern European rivers[3,4]. Focusing on the last glacial-interglacial cycle, the sea-level record illustrates a period of a rising sea level towards the last interglacial period, the Eemian (MIS 5e), reaching values close to the present, followed by a drop of 40-50 m during the last glacial period, the early Weichselian (MIS 4). These climatic changes contributed to the periodic erosion and infill of the southern North Sea, the record of which is preserved in the offshore deposits.

This study is focused on mapping the geomorphological features and finding sedimentary evidence for the occurrence and exact location of the proglacial lakes during the last glacial cycle. In the southern North Sea, glaciolacustrine sediments and sedimentary remnants of a small proglacial lake (750 km²) have been identified on Dogger Bank[5,6] but no other convincing sedimentological and geomorphological evidence of the presence of a large regional-scale proglacial lake has been identified yet. Based on the theoretical locations of this lake and the projected maximum extent of the last ice sheet, we focused our research on the areas south of Dogger Bank and Oyster Ground[7,8]. Our methodology includes analysis and interpretation of high-resolution seismic reflection data and sediment cores, data collected through the WALDO project offshore campaigns in 2022 and 2023. The WALDO ("Where are All the (proglacial) Lake seDiments in the NOrth Sea Basin?") project, funded by BELSPO has the goal of examining the hypothesis that proglacial lakes existed in the southern North Sea during the Middle and Late Pleistocene glaciations.

Preliminary results in the areas south of Dogger Bank and Oyster Ground depict stratigraphic and geomorphic indicators that point to a complex and dynamic environment during the last glacial cycle. Through the examination of the newly acquired data, we hope to provide new insights into the glacial landscape evolution of the southern North Sea and provide regional palaeo-environmental and palaeo-geographic reconstructions during the last glaciation.

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Keywords
North Sea; Quaternary; Seismic Stratigraphy; Weichselian Glaciation

AI in marine sciences: an open-access integrated environment for automated classification of phytoplankton images

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Phytoplankton, the single cell algae at the basis of marine food webs and an important indicator of ecosystem health, is continuously being monitored at a number of stations in the Belgian Part of the North Sea under the LifeWatch research infrastructure. To process monitoring samples in a fast and automated manner, we make use of automated imaging techniques like FlowCam. By aligning particles in the sample in a continuous fluid stream and capturing each particle in a picture as it passes a camera, this device can produce an image library of a sample in under 30 minutes. While FlowCam has significantly sped up time spend in the lab, it delivers about 350 000 images on a yearly basis and calls for an automated approach to handle high data loads. To speed up taxonomist's job of labeling all these images manually, we build semi- automated data pipelines and implemented machine-learning algorithms, more specifically Convolutional Neural Networks, to classify the images. Over the years this combination of automated imaging and machine learning has helped us built a set of over 2,2 million annotated FlowCam images and trained classifiers fine-tuned by taxonomists correcting wrong model predictions. This dataset and the trained classifiers have proven to be a huge benefit in our marine monitoring, and we wanted to share this asset with other researchers.

Under the Horizon Europe iMagine project, we aim to not only publish the image set and classifiers, but to build a user-friendly module where users can both predict FlowCam images using pretrained models and train classifiers on their own image input. The iMagine platform hosting this module offers an integrated environment with all source code as well as a graphical user interface for users with less coding experience. Computing resources for the services are also available to the user though the platform. The FlowCam module further provides tools for post-hoc analysis of model performance and code for image transformation and augmentation to deal with different image resolutions and class imbalances in training sets. More information on the project and the FlowCam service can be found via https:// www.imagine-ai.eu. In the next coming years, we hope to facilitate many marine researchers in the application of automated classification of phytoplankton imaging data. We actively encourage researchers and monitoring programs to make use of the FlowCam service and the iMagine platform to contribute to more efficient biomonitoring.

Keywords
AI; ML; CNN; FlowCam; Phytoplankton; IMagine

The sea on prescription: investigating the link between sea spray aerosols and human health benefits

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In blue spaces related health research, focus has primarily been on environmental determinants as drivers and contributors to disease onset and negative health effects, while the positive health effects still largely have to be clarified. Most progress on positive effects of marine environmental determinants has been made in the field of psychology where positive associations were established between the presence of blue spaces, and mental health and wellbeing. Current research however fails to explain the possible physiological health effects associated with living near blue spaces. Therefore, the present study aims to expand our fundamental mechanistic knowledge on how exposure to coastal environments, via inhalation of marine microbiota and biologically produced organic molecules (i.e. biogenics), contributes to physiological health benefits.

Oceans produce sea spray aerosols at the air-sea interface by bursting bubbles from breaking waves. These sea spray aerosols contain a mixture of microbiota and biogenics and can be inhaled by coastal populations. This research builds on the hypothesis that inhalation of these low concentrations of marine microbiota and biogenic molecules by acute and/or chronic exposure to coastal environments potentially interacts with cell signaling pathways, leading to positive health effects. To test this hypothesis, this study is currently recruiting healthy adults between 18 and 50 years old. Three different groups will be tested: (1) a group living inland and exposed to a coastal environment during this study, (2) a reference group living at the coast for more than 1 year and (3) a reference group living inland for more than 1 year.

The total coastal exposome of the participants will be taken into account. The exposome concept contains three overlapping domains: a general external exposome, a specific external exposome and an internal exposome. The general external coastal exposome will be investigated based on climate data from weather stations and geographical mapping methods. The specific external coastal exposome will be analyzed based on questionnaires of the participants. Lastly, the internal coastal exposome comprises the imprints of the coastal exposures in the human body and will be analyzed by using innovative minimally invasive microsampling methods and swabs to characterize key biomarkers of coastal exposure.

This research will provide for the first time insights into the role of sea spray aerosols as potential contributors to positive health outcomes of coastal environments. It applies a transdisciplinary approach, combining the strengths of marine ecology and human health, to map the coastal exposome. The results will form a solid base for the next decade of transdisciplinary research within 'Oceans & Human Health' and exposome research. It can furthermore inform future health promotion efforts through exposure to coastal environments.

Keywords
Ocean; Human Health; Exposome; Sea Spray Aerosols

Assessing of plastic and biota removal by plastic clean-up mechanisms in artificial flume settings

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Due to mismanaged and wrongly disposed plastics, and due to the unwanted accumulation of plastic litter in multiple environments, several technologies have been designed and deployed to remove the litter from rivers, beaches, ports, lakes and coastal areas. These are novel technologies with multiple and diverse collection mechanisms to assist in removing plastic litter from aquatic systems. However, their positive and negative effects in the environment where they are deployed are, so far, largely unknown. Plastic clean-up technologies are crucial innovations aimed at mitigating plastic pollution and are referred to in the draft of the international and legally binding treaty from the United Nations Environment Assembly that aims to target plastic pollution by 2024. Therefore, empirical data is currently needed to assist the users and key stakeholders in guiding the in the deployment of these clean-up technologies. The goal of this work was to experimentally investigate the individual effect of four selected parameters, i.e., flow velocity, biota shape, plastic-type, and plastic load, on the removal of plastic and biota when interacting with plastic by two clean-up mechanisms. We independently tested two generic, non-commercial, custom- made plastic clean-up mechanisms, and without aiming at reproducing the exact design of any specific company or technology. The empirical data were gathered in a laboratory flume in which the settings of each of the selected parameters were controlled and independently assessed. For instance, four plastic categories (bottles, films, foams, and a mix of the three plastics) were separately tested, while other parameters (flow velocity, plastic load and biota shape) were kept constant. Our preliminary results suggest that the individual interaction with each of the four plastic categories (bottles, films, foams, and a mix of the three plastics) does not affect the proportion of biota removed. Empirical studies such as this allow testing the effect of each single parameter, which is important when parametrizing hydrodynamic and ecological models and set up the bases for field tests. Field studies are a necessary complement to experimental studies and are required to test each technology in each specific location.

Keywords
Plastic Pollution; Clean-up Technologies

Greenhouse gases gradients from Southern Greenland fjords to subpolar North Atlantic Ocean

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Since the beginning of the industrial era, the atmospheric greenhouse gases (GHG) have increased continuously (around +50% for carbon dioxide (CO_2) and +150% for methane (CH_4), for the two most important), causing the current climate change. In November 2023, the World Meteorological Organization (WMO) highlighted once again there are still significant uncertainties about the carbon cycle, its fluxes, and they stressed the importance to follow the non-CO_2 GHG with greater global warming potential.

The ocean, as a sink of anthropogenic CO_2, plays a crucial role in climate regulation, whereas the surface seawater is naturally supersaturated in CH_4, and shallow coastal waters are a source of CH_4 to the atmosphere. However, the air-sea CO_2 and CH_4 fluxes are driven by different key processes depending on the region of the open or coastal ocean.

To improve the understanding of the processes driving the air-sea exchange of GHG, we investigate the CO_2 and CH_4 concentrations and fluxes in open ocean and coastal areas affected by sea ice, glacier runoff and riverine inputs within the context of the European project GreenFeedBack. To do so, we measured CO_2 and CH_4 concentrations and calculated the fluxes, in surface water during a summer cruise (July-August 2023) conducted on board the RV Belgica in the subpolar North Atlantic Ocean, between Iceland and Southern Greenland Fjords. The data were obtained using a custom-made air-water equilibration system, that was connected to the vessel's non-toxic seawater supply (equilibrator and Cavity Ring Down Spectrometer) and discrete sampling.

Our first results show a pronounced gradient of CO_2 and CH_4 concentration between open ocean and the fjords. The oceanic CO_2 concentration is minimal in the fjords where the CH_4 concentration is maximal, indicating a potential impact of freshwater discharge on the GHG exchanges.

Keywords
Observations; Greenhouse Gases; Carbon Cycle; Subpolar North Atlantic Ocean

Influence of temperature on acute and chronic toxicity of marine algal toxins — a case study with copepod *Nitokra spinipes*

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Harmful algal blooms (HABs) – proliferated algae densities with often a toxin producing ability – have been found increasingly in both northern and southern oceans. Recent studies have established that increasing temperatures contribute to HABs occurrence. But the broader influence of climate change on these outbreaks is less well quantified. Of particular concern is the limited research on HABs toxin effects under varying temperatures, especially concerning zooplankton, a crucial component of aquatic ecosystems. They do not only consume algae but also serve as prey for organisms at higher trophic levels, hence, are pivotal in energy transfer and nutrient cycles in aquatic food webs.

Therefore, we examined the impact of marine toxins on marine zooplankton in the context of climate change. We designed a series of laboratory experiments using filtered seawater to assess the toxicity of four commonly occurring algal toxins, purified and sourced from CIFGA Laboratory, on a model organism for ecotoxicological studies, *Nitokra spinipes*, exposed to three different temperatures. We evaluated acute toxicity of domoic acid and yessotoxin, respectively. Adult females were exposed to these toxins at 15, 20, and 25°C for 48 hours. EC50 values of domoic acid arranged from 11.08±3.81 to 88.51±164.89 µg/L, respectively. Also, juveniles, aged 48 to 72 hours, were exposed at 18, 20, and 22°C for the same duration. The EC50 of domoic acid in this case arranged from 65.36±10.66 to 102.76±9.52 µg/L. Mortality rates across temperatures showed no significant difference. In chronic toxicity test, larval development ratio (LDR), brood size and inter-brood time of domoic acid, yessotoxin, saxitoxin, and microcystin-LR were examined at 18, 20, and 22°C. We observed that with increasing temperatures, LDR for domoic acid increased, whereas brood size significantly decreased as toxin concentration rose. While these results are preliminary, they indicate a temperature dependent sensitivity of copepods towards toxins produced by HABs.

Keywords
Climate Change; Harmful Algae; Marine Toxins; Zooplankton

Acute toxicity of harmful algae on marine zooplankton in the context of climate change

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The increase in human activities and their expansion into oceans and lakes have significantly disturbed aquatic environments. For instance, continuously increasing greenhouse gas emissions have resulted climate change, affecting the temperature, salinity, and pH levels in water bodies. Additionally, the overuse of agricultural fertilizers has altered the nutrient content in most of these environments. Harmful algal blooms are proliferated algae densities that are often able to produce different kinds of toxic metabolites. An increasing number of harmful algal blooms have been recorded in the last decades due to anthropogenic pressure. Some studies have even found that cyanobacteria that originally lived in freshwater environments are invading estuaries. Research has established that sudden increases in nutrients contribute to HAB occurrence and it has also linked warming temperatures to individual events. Zooplankton, vital to aquatic ecosystems, connect producers and higher-level organisms in food webs as both consumers and prey. Not much is known about the toxicity of these toxic blooms on zooplankton communities in different climate change scenarios. Therefore, in this study, we investigated the impact of climate change proxies on the toxicity of harmful algae to a harpacticoid and a calanoid copepod—*Nitokra spinipes* and *Acartia clausi*, respectively . We constructed a series of laboratory experiments with relevant temperature, salinity, pH and nutrient conditions, focusing on two microalga species the dinoflagellate *Alexandrium ostenfeldii* and the cyanobacteria *Microcystis aeruginosa*. After collecting algae, grown in these different scenarios, we assessed their toxicity in these copepods, studying mortality, swimming behaviour and ingestion rate. First, we observed variations in mortality rates, swimming speeds, and swimming distance between *N. spinipes* and *A. clausi* exposed to the same toxic algae, indicating an interspecies difference in sensitivity towards HAB blooms. Moreover, both *N. spinipes* and *A. clausi* exhibited varying sensitivities to algae grown under different conditions, suggesting that environmental factors indeed influence algal toxin production. These results provide better insights into environmental consequences of harmful algae blooms on the marine food web in the warming future.

Keywords
Harmful Algae Blooms; Ocean Acidification; Eutrophication; Ocean Warming; Copepods; Marine Food Web Dynamics

Unveiling offshore wind farms' impact on southern North Sea fisheries using ecological models: Exploring threads, opportunities and trade-offs

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Society today faces major global challenges, such as climate change, biodiversity loss and increasing demands for food. As a result, Europe has set clear but ambitious targets in its EU Green Deal to produce 120GW and 300GW of renewable offshore wind energy by 2030 and 2050 respectively to mitigate the effects of climate change. Offshore wind is widely regarded as one of the most credible sources for increasing renewable energy production. At the same time, the United Nations predicted we must produce 70% more food by 2050 to meet global food demands. Seafood will play an important role in meeting this demand, as it is a healthy source of protein and micronutrients, emits less CO2 and uses less water and land compared to conventional livestock. However, the increase in human activities at sea not only lead to competition for marine space, but may also impact our ecosystem as a whole and the biodiversity it holds. Yet, currently, the impacts of offshore wind farms towards marine food webs and fisheries remain poorly understood inserting huge uncertainty in the long-term sustainability of these developments. To address this knowledge gap, it is crucial to investigate how wind farms interact and impact marine food webs and commercial biomass, ensuring that the fishery sector is not put at risk. To this end our study will establish a spatial-temporal ecological model for the Southern North Sea. Ecopath with Ecosim (EwE) software, a well-established tool for investigating fisheries impacts on marine food webs, will serve as a foundational framework. Employing this ecological modelling, we aim to assess the impact of both existing offshore wind farms and anticipated developments on the fisheries sector. This involves exploring the effects on the Southern North Sea foodweb structure induced by offshore wind farms and how different commercial fishing fleets can operate in this changed system. One of the main tasks to do so, will be to implement the structural, biological and policy impacts induced by OWF developments into the spatial- temporal ecological model. The modelling approach additionally allows us to compare several development scenarios in terms of fishery impact and sustainability. Besides ecology, our study will investigate possible fishery options using the EwE platform. This exploration extends to the assessment of the economic impacts on the fisheries sector, providing valuable insights into the influence of offshore wind developments and how the fisheries sector can be guided though these changes in a sustainable manner ensuring both ecological balance and economic viability. By combining ecological and economic dimensions, our research aims to offer detailed insights of the threats, benefits and trade-offs the offshore wind sector might pose on the North Sea fisheries sector.

Keywords
Ecological Modelling; Fisheries; Offshore Wind Farms; Food Web; Marine Spatial Planning

Host separation syndrome and chemical dependency of four echinoderm obligate symbionts

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Symbiotic relationships, characterized by an intimate and long-lasting association between at least two distinct species, which usually involve a host and a symbiont. Some symbionts have evolved remarkable dependencies on their hosts, manifesting various adaptations. Recent research has introduced a novel dimension of dependency wherein symbionts rely on the chemical environment created by their hosts (Brasseur *et al.*, 2018, Lourtie *et al. In Prep*). This host dependency can lead to a condition called "host separation syndrome" defined as a health alterations , and potential mortality when symbionts are isolated from their hosts. Our investigation focuses on the study of this syndrome. We investigated four symbiotic associations. Firstly, the sea urchins *Echinometra mathae*i, and its symbionts, namely *Arete indicus* and *Tulеariocaris holthuisi*. We extend our inquiry to two other decapod-echinoderm associations: the interaction between the sea star *Culcita novaeguineae* and the sea star shrimp *Zenopontonia soror*, and the crinoid *Phanogenia distincta* and the pistol shrimp *Synalpheus stimpsonii*. Our experimental design incorporated three conditions: (i) symbionts remaining on their hosts (control), (ii) symbionts isolated from their hosts, and (iii) symbionts isolated in water containing semiochemicals produced by their hosts. Results indicate that all symbionts experienced the host separation syndrome, with chemical dependency observed only in *Arete indicus*, *Synalpheus stimpsonii* and *Tulеariocaris holthuisi*. Our study shed light on chemical dependency in symbiotic associations, offering deeper insights into the dynamics of the host separation syndrome and the importance of the nature of the chemicals produced by echinoderms.

Keywords
Crustacean; Ectosymbiont; Coloration; Mimicry; Host Dependency

Genetic population structure of the bubble- tentacle anemone *Entacmaea quadricolor* in the Indo-Malay Archipelago

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The Bubble-tentacle sea anemone (*Entacmaea quadricolor*) is known to be one of the ten sea anemones species that host anemonefish. Additionally, their symbiotic relationships with zooxanthellae, which provides carbohydrates to the anemone for their nourishment and growth, has been well studied previously. Currently, sea anemones populations are facing two major issues: low tolerance to increasing water temperature, and overexploitation for the marine ornamental aquarium trade, which are leading to bleaching events across the Coral Triangle. Due to their pelagic larval stage and (semi)-sessile adult life these invertebrates are ideal candidates for larval dispersal studies, that has previously showed being an important tool to assess genetic exchange between populations. Samples of 106 individuals have been collected at 10 sites across the Indo-Malay Archipelago from 2004 to 2018. The aim of this study is to investigate the genetic population structure and connectivity of *E. quadricolor* using six microsatellite loci as molecular markers.

Keywords
Microsatellites; Larval Dispersal; Molecular Markers; Coral Triangle.

Ultrasound assisted and ultrasound assisted enzymatic extraction of seaweed valuable compounds: potential, challenges and guidelines

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Seaweeds are important sources of polyphenols, polyunsaturated fatty acids, proteins, vitamins and polysaccharides which grant them applications in various industries, including food, cosmetics, pharmaceuticals, and agriculture (Jung *et al.*, 2013). Seaweed is a very complex biomass. Its composition is highly variable between species, season harvesting time and location. This poses a challenge to its efficient utilization, specifically to the efficient and selective extraction of its components (Kraan, 2012). The current traditional extraction techniques are time consuming and rely on high temperature and high amounts of organic solvents (Garcia-Vaquero *et al.*, 2017). Hence, developing novel greener and more efficient extraction methods is necessary to boost the development of this growing industry.

Among the non-conventional extraction methods that have been investigated for biomass treatment, enzymatic and ultrasound techniques gain attention for their various advantages, namely high efficiency, shorter and easier operation, sustainability and scalability potential (Terme *et al.*, 2020). Lately, ultrasound assisted enzymatic extraction (UAEE), which combines both enzymatic and ultrasound techniques, receives more and more attention from researchers for the treatment of biomass (Le Guillard *et al.*, 2016; Yachmenev *et al.*, 2009). This technique involves the use of carbohydrases, proteases and ultrasound waves to break down or puncture the seaweed cell wall and allow the release of the compounds of interest. This process is characterised by a great variability given by the high number of factors affecting the ultrasonic and enzymatic process, including wave frequency (kHz), amplitude (µm), power (W), sonotrode tip area (cm^2), treated mass (kg), treatment time (s), pH, solid-liquid ratio and the application of batch or continuous processes (Córdova *et al.*, 2022). These variables, together with the ultrasound generator brand and model, are often mistakenly omitted or unclearly reported in many publications, hindering proper reproducibility of the process, of the results and hence, of their comparison. Therefore, this study is focused on drawing guidelines and fair principles for designing and reporting experiments and processes involving ultrasound and ultrasound-assisted enzymatic treatment of biomass, focusing on seaweed. Two experimental - ultrasound specific - parameters have been put forward (i.e., ultrasonic intensity (W/ cm^2) and energy input (W·s/g)) to enable the comparison between different processes and subsequently identify the most promising ones. Based on the results of this work, further experimental studies will be designed and conducted to develop ultrasound assisted enzymatic extraction methods of valuable compounds from seaweed.

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Keywords
Seaweed; Sustainability; Extraction; Ultrasound; Enzymes; Guidelines

Exploring solutions for plastic pollution: detecting, collecting, and preventing unwanted debris in the Scheldt River

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Riverine systems are pathways between terrestrial and marine ecosystems, transporting anthropogenic chemicals and pollutants, including plastic items and microplastics, from agricultural fields or cities to the coast and open sea. Plastic pollution, including items from nano to macro size range, has been detected in all Earth's ecosystems with observed negative socio-economic and environmental impacts. Therefore, there is a pressing demand for effective and innovative approaches to detect the number and mass of plastic transported by or accumulated in the rivers, and to find solutions to remove or prevent the litter input into these systems. The Scheldt River is an important water course that flows over France, Belgium, and the Netherlands, with its estuary at the North Sea. Through its journey until the sea, the Scheldt flows through urban clusters, industrial and agricultural areas, and is used for navigation, having several harbors, including the port of Antwerp- Bruges (Europe's largest petrochemical industrial cluster and Europe's second largest port), and it is known to have several areas of plastic litter accumulation (litter hotspots). Because of this, the Scheldt River was selected as one of six European rivers that are currently use cases in the Horizon Europe project Innovative Solutions for Plastic Free European Rivers (INSPIRE). With this specific use case, we aim to test innovative detection methodologies and collection technologies for macro-, meso-, and microlitter at an urban and industrial area in Temse (upstream from Antwerp) and in existing infrastructure in the port of Antwerp, in Doel. To achieve our goals, three different cleanup technologies will be tested in two selected locations to remove litter from the water surface/column and from the sediments at the riverbed. Citizen science activities will complement the technologies removal action, via cleanup events, but also by promoting community engagement and dissemination activities aimed at increasing awareness and the prevention of the consumption of single-use products and their incorrect disposal at their end-of-life. Local stakeholders, such as local retailers, authorities, schools, industries, among others, will be involved in the use case activities, enabling them to interact and get informed about alternative practices (e.g., use of biodegradable packaging and reduction of littering behavior). To assess the effectiveness and impact of the litter removal technologies and behavior change actions, the plastic pollution state of the Scheldt is going to be observed during the course of the project, by a combination of more well- established plastic collection methodologies and technological observations that use artificial intelligence (AI) models to identify and quantify floating litter. The data collected will also be used to optimize the cleanup technologies, with the assistance of modelling tools. The cost-benefit and sustainability of the approach selected for the Scheldt will be evaluated and compared with the results obtained from the other five INSPIRE use cases. This will enable the development of improved action plans, and ultimately a modular master plan for litter mitigation actions applicable to riverine areas in Europe.

Keywords
Plastic Pollution; Microplastics; Water; Sediments; Sampling; Citizen Science; Prevention

Where meiofauna? An assessment of interstitial fauna at a Belgian beach

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Meiofauna are frequently overlooked in biodiversity assessments, resulting in a lack of understanding regarding their current status and the potential impact of anthropogenic activities on these animals. This study marks a new effort to characterize meiofaunal communities along the Belgian coast, an area largely unexplored in this respect. The intertidal zone of the Small Beach in Ostend serves as a first case study for this purpose. Sampling was carried out on five separate occasions throughout the year, with abiotic data collected during each sampling event. Collected specimens were sorted under a stereomicroscope according to their taxonomic group, resulting in a retrieval of 1,742 organisms.

Among these, Platyhelminthes and Nematoda were the most abundant taxa. Through metabarcoding of the 18S ribosomal region, a preliminary biodiversity assessment was conducted, yielding a total of 106 Amplicon Sequence Variants (ASVs). After filtering out rare reads, 65 metazoan ASVs were retained: 12 representing Polychaeta, 17 Proseriata (Platyhelminthes), 15 Copepoda, 4 Acoela, 16 Nematoda and 1 representing Rhabdocoela. Identification of the ASVs through blasting, generated a rather low species richness. The highest species richness was observed among Proseriata and Nematoda, each comprising six different species. Additionally, four different species of Polychaeta and Copepoda, two species of Acoela, and one species of Rhabdocoela (Platyhelminthes) were identified. Comparing these findings to what has been reported on similar beaches, it appears that the meiofaunal communities on Ostend beach exhibit an overall low richness. This could be linked to the potential impact of beach nourishments and human trampling on these organisms. However, confirming this hypothesis requires further research.

Keywords
Biodiversity; Ostend; Metabarcoding; 18S RDNA; Platyhelminthes; Acoela; Copepoda; Nematoda; Polychaeta

Imagine a world without plastic, what a TREASURE!

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Targeting the **re**duction of pl**as**tic o**u**tflow into the No**r**th S**e**a or TREASURE

It is now well known that a large share of marine litter reaches the sea via inland waterways, posing a serious threat to the environment and human health. In order to have a better vision and a better force of impact, 5 countries got together to tackle this issue and imagine a world without plastic in our Ocean.

TREASURE is a North Sea interreg project launched in June 2026 with 15 partners from Germany, The Netherland, Belgium, Denmark and France. The innovation of the project lies in a cross-sectoral approach, which is needed to successfully identify, prevent, and remove litter from inland waterways. The core of the project consists of Living Labs at different river-sea interfaces: the Frisian Peninsula (Germany), Dutch Deltas (The Netherlands), Nieuwpoort Yser estuary (Belgium), French ports and harbours on the English Channel (France), and Westcoast watersheds (Denmark).

These 5 Living Labs are spaces for collaboration, exchange and cocreation to tackle plastic pollution through 4 interdependent pillars:

- Governance & policy: improvement of policies at different levels for waste prevention.
- Data collection & analysis: Use of surveying and observation methods, e.g. citizen science, drone technology, to expand knowledge about composition, distribution and sources of waste, and harmonise methods.
- Prevention & behaviour change: Education and training for schools, professionals and the general public to reduce plastic pollution.
- Removal of plastic waste: Application of different innovative techniques for the collection and removal of plastic debris from rivers and harbours and getting insight of their effectiveness.

Keywords
Plastic Pollution; Living Lab; Cooperation

Mission Clean Water!

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Inhabitants of Riverville, you are experiencing increasingly frequent flooding and drought as a result of climate change. This is affecting water quality, so together you need to find solutions to address this problem! It is possible to implement alternative, accessible, and sustainable measures to adapt to climate change and reduce related risks. These measures are called “Nature based Solutions”.

We usually ear about the damaging effects of climate change, environmental emergencies, extreme and catastrophic weather events and not so often about existing solutions that can actually help us through it all.

As part of the H2O: Source2Sea project, funded by the Interreg France - Channel - England programme, Nausicaá and partners launched a board game for publics aged 12 years and older: “Mission Clean Water”. It is an innovative educational resource for science communication activities and for secondary school classes that allows them to learn while having fun. Players must save a city, Riverville, from climate alerts by choosing the right nature-based solutions to mitigate climate change in a cooperative manner. The game is played in small groups (3 to 8 players) and is also suitable for a classroom. Each full game lasts 45 minutes and can be shortened to 15 minutes for the classroom requirements.

Participants will leave this session with an increased understanding of how Nature based Solutions can mitigate the effect of climate change and how games can be very useful tools for science education and learning processes.

Keywords
Nature Based Solution; Water Quality; Climate Change; Education

Amplicon sequencing using the portable Oxford Nanopore MinION for fish DNA reference database: a fast, reliable and promising approach

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Tanzania hosts fish diversity in the coral reefs and seagrasses that are threatened by overfishing, calling a need for effective and rapid monitoring. Application of molecular techniques enables biodiversity assessment through environmental DNA applications. Unfortunately, in developing countries there are incomplete reference databases and no readily available sequencing services. We used the portable Oxford Nanopore's MinION Sequencing device to analyse 190 fishes from Tanzania (with reference photographs). In addition to the standard COI based identification, we employed a novel approach to amplify two variable regions of the 12S gene in one PCR product covering the fragments recommended for eDNA studies.

We successfully amplified about 670bp of the 12S region ("miFish" and "teleo") across a broad range of fish taxa and sequenced at the ZMT- Biolab. Amplification success of this novel 12S fragment was higher as in COI. For the 655bp COI fragment we obtained 131 high quality barcodes of 665bp (+24 low quality barcodes) giving 117 exact BLAST matches within the OTU threshold (identity >= 99%, query Coverage >= 80%) and 14 close matches (94-98% identity) by BLAST searches. Close matches were from Perciformes, Beloniformes and Clupeiformes, indicating species lacking reference sequences. For 12S we gained 171 valid barcodes with length 661-741bp (mean 670bp). Only 58% of the barcodes revealed >99% identity, 67 close match (90-99% identity), 4 weak match (<90% identity), highlighting the importance of generating a regional reference database in advance of eDNA metabarcoding.

Using the protocol from DNA extraction to sequence data can take up to two days, and with further experience one day can be possible. In conclusion, the portable and affordable MinION Sequencing provided comparable results to the traditional sanger sequencing method. These promising results suggest that the device can be adapted by managers to rapidly uncover biodiversity for protection and sustainability.

Keywords
MinION; Barcoding; Sequencing; Gene; Database

Tidal wetland restoration for the generation of optimal ecosystem service delivery: nitrogen cycling in the Scheldt estuary

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In terms of ecosystem service provisioning, tidal wetlands are considered to be among the most productive ecosystems. However, over the last three centuries significant global wetland area has been lost. Nowadays, a trend of large-scale wetland restoration is in place in many countries. Wetland reclamation has the potential to restore ecosystem service delivery, but whether restored wetlands actually deliver a comparable quality and quantity of these services remains an important question. That is why it is crucial to continue the monitoring of restored ecosystems. Additionally, the optimal circumstances for tidal wetland restoration with respect to ecosystem service delivery within the estuarine environment are still unknown.

In this study, we will investigate optimal tidal marsh restoration circumstances with regards to water quality and nutrient cycling by focusing on wetlands in the Scheldt estuary that have been restored recently, or will be restored in the near future. This PhD research proposal aims to gather insights in the effect of organic soil amendments in restored wetlands on water quality and nutrient cycling capacities through the study of N cycling. Building further upon pioneering research conducted in our research group, we will prepare the technique of soil amendments for widespread implementation in wetland restoration by performing a lab experiment, a mesocosm experiment and a field experiment. Focus will be laid on soil and water nutrient concentrations as well as on gas fluxes, including emissions of the potent greenhouse gas N_2O. First, a lab experiment will be conducted on the effects of a variety of parameters ranging from salinity, to inundation frequency and duration on tidal marsh nutrient cycling capability. Next, the long-term effects of these organic soil organics on the nutrient cycling capacity of restored tidal marshes will be evaluated using a mesocosm installation in the Scheldt in Kruibeke. Last, a field experiment will take place on the Ketenisseschor in the context of the Bankbusters project. Here, organic soil amendments will be implemented on a large scale during the restoration of a tidal marsh to assess their effect on ecosystem service delivery. Last, a lab experiment will be conducted on the effects of a variety of parameters ranging from temperature, over salinity, to inundation frequency and duration on tidal marsh nutrient cycling capability. All together, these experiments should grant novel insights into the effects of organic soil amendments on tidal wetland nutrient cycling, and help determine the feasibility of its future application.

Ultimately, the knowledge base gathered by this research project could be used to optimize the conservation and restoration of these valuable ecosystems.

Keywords
Tidal Marsh; Ecosystem Services; Nitrogen Cycling; Soil Amendments

Unravelling climate-driven habitat suitability for pelagic fish in European seas

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Pelagic fish species hold immense ecological and economic significance in European seas, playing a vital role in the region's marine ecosystem and contributing significantly to the local economy. Understanding their migration patterns and habitat preferences is crucial for developing sustainable fisheries management strategies that balance resource utilisation and environmental protection. This study employed a novel mechanistic niche modelling approach to predict the distribution of three commercially important pelagic fish species in European seas: Atlantic herring (*Clupea harengus*), Atlantic mackerel (*Scomber scombrus*), and European seabass (*Dicentrarchus labrax*).

This study investigated the impact of climate change on pelagic fish habitat suitability in European seas using habitat suitability models and climate prediction data. This was done by employing a mechanistic modelling approach as per Westmeijer *et al.* (2019) by incorporating a mathematical description of the species' niche to predict suitable habitats based on their interactions with environmental factors. Specifically, the study focused on three economically important pelagic fish species with distinct regional distributions. Species-specific response curves for temperature and salinity were then derived from a thorough review of existing literature and expert knowledge to capture the unique habitat preferences of each species. Employing fuzzy logic principles, which permit habitat suitability values to span any real number between 0 and 1, the models considered both worst-case and best-case scenarios to explore the full spectrum of habitat conditions and their influence on fish distribution. These insights were integrated into the mechanistic models, allowing for predicting habitat suitability indices (HSI) under various conditions. The HSI produced provided a holistic view of the habitat suitability across European seas and allowed for comparisons between different species and scenarios. To assess the impact of climate change on these species, the study utilised climate prediction data for temperature and salinity from Bio-ORACLE (www.bio-oracle.org). What-if scenarios based on the five Shared Socioeconomic Pathways (i.e., SSP126, SSP245, SSP370, SSP460 and SSP585) were used to simulate the habitat suitability of the selected species between 2020 and 2090. We validated our models with fish occurrence data from various literature and OBIS data (www.obis.org).

The study's findings reveal substantial alterations in habitat suitability for all three target species under the SSP585 climate change scenario (worst-case scenario), which predicts the most extreme temperature and salinity shifts. Currently, based on the temperature only, the average suitability index for Atlantic mackerel is 0.419 but decreases respectively to 0.292 and 0.413 for the worst-case (SSP585) and best-case scenario (SSP119). As expected, all three fish species have a northward shift in habitat suitability driven by thermal changes. Notably, a 1°C rise in temperature is projected to cause the *S. scombrus* suitable habitats to shift 315 kilometres northward, aligning with the findings of Chust *et al.*, (2023) who observed a similar acclimatisation pattern for *S. scombrus*. Climate change-induced salinity and temperature changes are driving complex and contrasting shifts in fish distribution. While salinity shifts push fish southward, temperature increases favour northward expansions. Additionally, regional disparities in habitat suitability are evident, with the Mediterranean Sea, once a stronghold for *S. scombrus*, becoming unsuitable due to projected sea-surface temperature increases.

The developed mechanistic niche modelling approach provides valuable insights into the intricate relationship between pelagic fish species, environmental conditions, and habitat suitability. The HSI offers a powerful tool for visualising and predicting potential distribution shifts under climate change scenarios, enabling proactive management strategies that adapt to the challenges posed by a changing environment and promote the sustainable exploitation of pelagic fisheries in European Seas.

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Keywords
Climate Change; Mechanistic Niche Modelling; Pelagic Fish; Habitat Suitability; Species-specific Response Curves

Fusional marines hues: exploring the shared colors of the *Zenoponotnia soror* shrimp and starfish

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The phenomenon of color change is frequently observed in the marine environment, particularly in cryptic organisms or those using passive/ active camouflage, such as cephalopods. When there is a symbiotic association between two organisms, this can result in a similarity of color, favoring their survival by reducing the risk of predation. It has been observed that the asteria shrimp, *Zenopontonia soror*, living in Moorea (French Polynesia), adjusts its coloration to match that of its host. In order to reveal the mechanism by which the symbiont acquires pigments, stable isotope analysis and pigment extraction were carried out on both partners. The aim was to demonstrate the potential link between pigment acquisition and the coloration of these organisms. The results of the pigment extraction revealed the presence of similar carotenoids in host and symbiont tissues. Furthermore, data from stable isotope analysis indicate that the symbiont feeds the host, and that the host and symbiont share a common food source. This study presents, for the first time, the chemical composition of pigments present in symbiont tissues. It thus contributes to a better understanding of the influence of host association on symbiont coloration.

Keywords
Symbiosis ; Colors; Carotenoids ; Stable Isotopes

Effective citizen science, playing a role at marine conservation

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Florida / Caribbean barrier reef has already been lost. Great barrier reef of Australia lost around 65% of its corals, there are immense efforts exerted by scientists and marine biologists to protect and maintain the remaining 35%. Red Sea/ Eastern Africa and Arabian Gulf are highly threatened as well. The philosophy of “protection is always preferred over restoration” is a luxury that no longer applies to most regions. NOW Restoration is necessary to preserve the biodiversity and functionality of reefs and ensure the sustainability of their resources.

Environmental Education for a Sustainable Future:
The proposed "Effective citizen science program" consists of 2 directions: (a) Raising awareness, and (b) Practical efforts. The Program is designed to give students / volunteers an introduction to coral reef ecology & awareness; how to view the reef scientifically by assessing key biotic and abiotic reef components; teaches the volunteers how to use real world scientific sampling, conduct reef survey techniques and create new artificial reef. (Creating new life, NEW Reef)

By the end of the program, students / volunteers should have full knowledge about climate change and its impact on marine life, conservation strategies and how to contribute in restoration efforts. The volunteers should leave a positive impact by creating a new marine life (artificial and/or natural habitat).

Program structure

Raising Awareness: over four sessions / workshops, it includes four theory presentations:
(1) Introduction and Reef Check Method, Fish, Invertebrates
(2) Human Impact, Substrates including Coral, Algae, Reef Rock and Sands
(3) Informative talks about sharks, dolphins and dugongs in Arab Gulf
(4) Explain about the flora and fauna around Arab Gulf coast

Practical efforts
- Identifying corals to their taxonomic levels
- Identifying Biodiversity of corals in an area
- Monitoring threats such as predation, bleaching, or diseases;
- Monitoring corals for health condition and status
- Conducting advanced research and / or restoration projects
- Identifying rare or endangered species of coral
- Create new habitat for corals –artificial and / or natural
- Growing corals as initiative to create new habitat for marine animals

We take an ecosystem learning / educating holistic approach, focusing on the long-term sustainability and adaptability of the ecosystem rather than just trying to add more corals into areas where they will not survive. Finally, we also adhere to the code of ethics outlined by the Coral Restoration Consortium.

Keywords
Corals ; Restoration ; Citizen Science

Constructing an offshore tsunami event stratigraphy for the Shetland Islands

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Offshore tsunami deposits have received considerably less attention than their onshore counterparts, despite the fact that they have a higher likelihood of being preserved in the sedimentary record, especially in sufficiently deep marine environments, below the storm wave base. Here we provide the first results from our study of Holocene tsunami deposits offshore the Shetland Islands. The region is characterized by an irregular coastline with fjords and numerous embayments, and relatively deep waters (up to 100 meters in depth), providing a sheltered environment, and by an extensively studied and well-documented onshore record of tsunami deposits, which should facilitate correlations between onshore and offshore event deposits.

Within the NORSEAT Project (North Sea Tsunami Deposits Offshore Shetland Island), we aim to identify and trace tsunami deposits offshore, thoroughly study their characteristics and extent, and determine whether the offshore record holds evidence of events additional to those already known from the onshore record (i.e. the Storrega tsunami and two events at ca. 5500 yr and ca. 1500 yr BP), which would offer new insights into recurrence intervals. Two surveys with RV Belgica have already been conducted, during which high-resolution geophysical data (multibeam bathymetry and backscatter, geoacoustic and seismic data) were collected, along with several vibrocores, in three embayment areas around the Shetland Islands.

Bathymetric data and sub-bottom profiles reveal a complex geomorphology, including a.o. elevated features, like bedrock exposures, and isolated depressions that function as sub-basins. The sedimentary sequences infilling these sub-basins are characterized by a complex stratigraphy and comprise several different sedimentary units. Along the west and east fjords of Sullom Voe, three distinct sub-environments (inner, middle, and outer voe) exhibit a diverse and well-preserved stratigraphy, potentially including a significant event deposit. A set of prominent strong reflectors at a depth of 1-2 m below the seafloor is interpreted as dynamic shallow marine deposits, which is supported by the results of the vibrocores retrieved at these sites. Out of the total 31 sediment cores taken, many contain coarser-grained layers sandwiched between finer-grained deposits. These coarser layers, often with sharp basal contacts and normal grading patterns, suggest temporary interruptions of the steady-state sedimentary regime and are interpreted as possible event deposits based on their contrasting textural and lithological characteristics.

In the next phase of our analysis, we aim to obtain the exact timing and detailed information about the depositional setting based on radiocarbon dating, grain size analysis, geochemical analysis, mineral distribution patterns, and the distribution of microfossils within the sediment cores, which should help us to build a robust tsunami event stratigraphy for the region, combined with planned sea-level reconstructions, assess their run-up heights based on the onshore-offshore connection and the fundamental research on sedimentary signatures and facies patterns of offshore tsunami deposits.

Keywords
Offshore Tsunami Deposits; Shetland Islands; RV Belgica; Geophysical Data; Sediment Cores

Quantification and characterization of riverine plastic litter outflow into the North Sea within the international TREASURE project

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Plastic pollution is ubiquitous in the environment and has been shown to have negative effects on aquatic organisms. The effects have a wide range from the entanglement of marine mammals to microplastic ingestion-led effects in other biota which can have cascading effects throughout the food web, ultimately resulting in polluted food items for human consumption. Moreover, rivers are known to be an important source of plastic litter which can accumulate both in estuarine and coastal areas, before being transported to the open sea. These hotspot areas can be vulnerable to extra pressure due to plastic accumulation and may need additional attention from local authorities and key stakeholders in terms of mitigation measures targeting litter. Within the project *Targeting the REduction of plAStic oUtflow into the noRth sEa* (TREASURE), an international research partnership funded by the European program of the Interreg North Sea, we aim to quantify and characterize the riverine plastic litter outflow into the North Sea to advise on suitable measures to reduce it. Under the TREASURE framework, researchers from the University of the Littoral Opal Coast (ULCO) and the Flanders Marine Institute (VLIZ) are joining expertise to apply the most effective technics and methodologies for plastic litter assessment. In the estuary of the River Yser, located around the area of Nieuwpoort (Belgium), plastic litter is going to be sampled at five different sampling sites ('*Spaarbekken'*, *Yser upstream*, *estuary downstream*, *marina area*, *estuary mouth*). To account for litter variation over space and time, samples are going to be taken at four different zones (*shoreline*, *water surface*, *water column*, *bottom sediment*) and three different seasons (*spring*, *summer*, *autumn/winter*). Sampling methodologies are going to consist of using manta net, an aquatic drone, ferry box and Van Veen grab. To be able to compare riverine and marine litter samples, sampling will additionally take place at sea in front of the Nieuwpoort coast at an existing monitoring site from the LifeWatch Belgium monitoring project. Subsequently, the samples will be analyzed using Fourier transform infrared (FTIR) spectroscopy and fluorescence microscopy to identify the quantity of plastic particles and their polymer composition. Another important part of the international research collaboration within TREASURE is going to be a common data management plan that facilitates the standardization of data format and data consolidation, to compile one harmonized dataset for improved interoperability. Finally, the common dataset is going to be published on the European Marine Observation and Data Network (EMODnet) and therefore made available not only for the research community, but also for governance, society and business. The open access data can thus be used as basic information for cross-sectoral and integrated action plans at local level in Nieuwpoort, but also at global level. Moreover, the results of the TREASURE project will be fed to a hydrological model to estimate accumulation areas which can then be targeted for cost-efficient actions for litter removal.

Keywords
Plastic Pollution; Microplastics; Hydrology; Methods; Research Collaboration; Data Management

Combined effects of increased temperature and microplastics on the population dynamics of a harpacticoid copepod

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Global warming and plastic pollution are prominent anthropogenic stressors which can impact ocean health. While the ubiquitous presence of microplastics (1 µm – 5 mm) in marine environments is well-established, our understanding of their effects at organism and population level, particularly in the context of a warmer marine environment, remains limited. In this study, our goal was to assess the combined effects of microplastics exposure and global warming (increased temperature) on the harpacticoid copepod *Nitokra spinipes,* a benthic copepod with a key role on aquatic food webs, and estimate the impact at population level. To do so, we adopted a two-step approach: we exposed the copepods to Poly (lactic-co-glycolic acid) (PLGA) microbeads (5 µm) at both control (22 °C) and elevated (25 °C) water temperatures [+3°C, according to the 8.5 Shared Socioeconomic Pathways (SSPs) projection of the Intergovernmental Panel on Climate Change (IPCC)]. To assess the effects on individual *N. spinipes*, we analysed shifts in filtration rates on microalgal prey, which served as a proxy for energy assimilation. Subsequently, we simulated the dynamics of *N. spinipes* populations under projected global warming conditions (+3 °C), i.e. the empirical filtration rate data were incorporated into an individual-based model based on the dynamic energy budget theory (DEB-IBM model) to infer potential theoretical population-level effects. Preliminary results indicate that PLGA microbeads at 0.1% food content significantly reduced the filtration rate of *N. spinipes* at elevated water temperatures (25 °C) ($P < 0.05$, ANOVA). Notably, all *N. spinipes* exposure treatments at increased water temperatures exhibited a higher filtration rate compared to the control temperature (22 °C). Our results indicate that the combined exposure to microplastics and elevated water temperatures can lead to reduced energy assimilation, especially in a high-emission scenario (RCP 8.5, IPCC). These findings contribute to assessing the vulnerability of marine populations in the face of both current and future environmental conditions, in particular of climate change and microplastics exposure.

Keywords
Microplastics; Population Effects; DEB Model; Global Warming; *Nitokra Spinipes*

New light on the diversity of photoreception types in sea cucumbers

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Vision is a primordial sense in animal evolution, and it has been mainly studied in species that developed complex eyes such as chordates and arthropods. Except for the starfish eyespots, echinoderms do not have complex visual organs, but many species exhibit a great photosensitivity mediated by some opsin types (photoreceptor proteins also found in other bilaterian groups). Recent studies on sea urchins, sea stars, and brittle stars, have revealed the presence of a large opsin diversity located in various body parts such as tube feet, spines, and the nervous system (Ullrich-Lüter *et al.*, 2011; Delroisse *et al.*, 2014). Some species have even demonstrated low-resolution extraocular spatial vision (e.g., Sumner-Rooney *et al.*, 2020). However, photoreception in sea cucumbers was largely unexplored, with only sporadic data available, such as observations of species moving away from a light source or retracting their oral tentacles under strong light exposure. To fill this knowledge gap, we conducted a comprehensive investigation of sea cucumber photoreception using a multidisciplinary approach.

Firstly, we analyzed genomes and transcriptomes of multiple holothuroid species, revealing the presence of six ancestral opsin types in this group. Secondly, we highlighted the expression of rhabdomeric opsins, commonly found in protostome eyes, in oral tentacles and tube feet of *Holothuria forskali*, a European species belonging to the Holothuriida order. Our investigation also focused on the Apodida order, a group of sea cucumbers with snake-shaped bodies lacking tube feet. Previous authors have proposed the presence of visual-like structures at the base of the tentacles and/or in association with the oral nerve ring in different species (e.g., Ludwig, 1889; Yamamoto & Yoshida, 1978). Our study revealed the expression of ciliary opsins, typically found in vertebrate eyes, in the neuroepithelial structures forming eyespots at the base of tentacles in the tropical species *Euapta godeffroyi*. We also detected the expression of ciliary opsins in the sensory cupules of *Oestergrenia digitata*, a burrowing European species. Until now, the functions of these cupules located on the inner surface of tentacles had remained unexplored. Finally, ethological tests conducted on both Holothuriida and Apodida species revealed that *H. forskali* and *E. godeffroyi* moved away from a light source, while *Synapta maculata* (another Apodida species) exhibited a movement toward it, specifically in response to blue and green lights. These findings provide new insights into the evolution and the diversity of photoreception mechanisms in sea cucumbers.

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Keywords
Sea Cucumber ; Holothurian ; Opsin ; Photoreception

Understanding climate impact on seaweed cultivation in the Belgian Part of the North Sea

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Open-sea seaweed cultivation offers a promising avenue in many applications as a source of sustainable biomass. Its production does not require arable farmland, fertilizers, or fresh water and can in some cases even have a positive environmental effect by removing excessive nutrients and carbon sequestration. Currently, scientists have been investigating the possibility of offshore seaweed cultivation within wind parks in the Belgian Part of the North Sea. However, one of the main challenges in open sea cultivation is that the cultured 'crops' are exposed to the same stressors as the wildlife residing there (e.g., eutrophication, pollution, climate change). Climate change is already rapidly affecting our oceans and seas, leading to increases in water temperature as well as changes in ocean chemistry, sea level, and oceanographic currents. Recently, the North Sea was even found to warm the fastest in the entire Atlantic for the period 1980–2020, with a warming of the sea surface temperature of 0.39 ^{o}C per decade (a total 1.58 °C change).

So far, few studies have examined the impact of these heat waves on marine biodiversity, especially in an aquaculture framework. In this study, we want to investigate the impact of realistic climate change scenarios on the growth and nutritional value of the commercially interesting species *Porphyra umbilicalis.* The experiment is set up using a multivariate testing approach where different temperature, salinity, and acidity conditions are taken into account. For the nutritional value, we look at multiple types of bioactive compounds including carbohydrates, protein, lipids, and pigments.

Understanding the impact of climate stressors on seaweed cultivation will shed light on the vulnerability of open-sea seaweed cultivation systems, as well as their broader significance towards human health.

Keywords
Aquaculture; Oceans And Human Health; Seaweed Cultivation; Nutritional Value; Climate Change

Where did Nemo come from? Exploring the genetic population structure of three clownfish species (*Amphiprion clarkii, A. nigripes*, and *A. sebae*) using next-generation sequencing throughout the central and eastern Indian Ocean

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Clownfish, members of the family Pomacentridae, are iconic inhabitants of coral reefs, characterised by intricate social structures. Despite its importance for conservation, the mechanisms driving dispersal of coral reef fishes is still not fully understood. Previously, genetically highly differentiated populations of *Amphiprion clarkii* have been documented, possibly implying the occurrence of cryptic species. Additionally, human induced stress, both direct (overexploitation) and indirect (climate change), resulted in decreased population sizes, thereby increasing the risk of local extinctions. In order to protect clownfish species, it is essential to unravel the genetic population structure and connectivity among populations, enabling the development and implementation of effective management strategies. This study aims at investigating the genetic population structure and the presence of cryptic diversity of three different clownfish species (*Amphiprion clarkii*, *A. nigripes*, and *A. sebae*). Samples from four distinct geographical regions will be used: Taiwan (10x A. clarkii), Sri Lanka (135x A. clarkii, 25x A. nigripes, 60x A. sebae), the Indo-Malay Archipelago (203x A. clarkii), and the Maldives (to be sampled). Representative genetic diversity is assured by examining approximately 700 individual samples scattered across these regions. Next-generation sequencing (NGS) techniques, using single nucleotide polymorphisms (SNPs) will be applied with the intention of assessing genetic diversity and connectivity in the poorly documented Central Indian Ocean as well as performing species delimitation tests. This research aims to discover critical insights into cryptic diversity and population dynamics of clownfish subpopulations, facilitating conservation and management decisions for marine protected areas in which Coral reef species can thrive.

Keywords
Population Genetics; EzRAD Sequencing; Connectivity; Anemonefish; Indo-Pacific; Marine Protected Areas (MPAs)

Habitat suitability mapping of epibenthos and demersal fish communities in the Belgian part of the North Sea

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To protect and restore the health of our oceans, as outlined in the European Union mission 'Restore our ocean and waters', it is key to gain comprehensive knowledge on the distribution of seabed communities, as these are important bio-indicators of marine ecosystem health.

Elucidating the original distribution of communities, facilitates investigating the impact of human activities, such as for example the approaching construction of the Princess Elizabeth energy island. Typically, baseline conditions are determined based on point observations and are thus spatially-explicit. Habitat suitability maps offer an area-wide coverage by extrapolating biological point data information based on modelled inferences with environmental variables. This is essential for future ecosystem health assessments and marine spatial planning to conserve biodiversity.

The goal of our study was to develop a habitat suitability map for epibenthos and fish for the Belgian part of the North Sea (BPNS). This entailed a three–step process: first, clustering of density data was performed to define distinct epibenthos and fish communities; second, a predictive model was created linking the presence of these communities to a combination of environmental variables; and lastly, the predictive models were used to develop habitat suitability maps visualising the community distribution.

Based on epibenthos and fish density data of 449 beam trawl events in the BPNS from 2008 until 2020, four distinct communities could be delineated: two nearshore and two offshore communities. The nearshore communities are characterised by high densities of brown shrimp (*Crangon crangon*) and common sole (*Solea solea*), while the offshore communities typically have higher densities of lesser weever (*Echiichthys vipera*) and striped red mullet *(Mullus surmuletus*). Some species such as plaice (*Pleuronectes platessa)* and the common starfish (*Asterias rubens)* occurred in all communities. Distinction between both nearshore communities (i.e. mud and fine sand) is mainly based on differences in density for certain species with higher density of e.g. common dragonet (*Callionymus lyra*) and *Ophiura albida* in the fine sand community. Both offshore communities are distinguished because samples occurring on top of the sandbanks are entirely dominated by lesser weever. Overall, nearshore communities have a lower number of species (avg. 24.47 ± SD 4.14) and Shannon-diversity (avg. 1.123 ± SD 0.37) compared to the wide spread coarse sand offshore community (resp. avg. 28.10 ± 5.30 & 2.10 ±0.58).

Next, we modelled which environmental variables best predicted the presence of these four communities. Predictor variables included in the models were sediment, hydrodynamic (e.g. mean bottom stress), and water-related variables (e.g. salinity, chlorophyll, ...). Best predictor combinations varied depending on the community. Best models for the offshore coarse sand community always contained maximum bottom stress and the bathymetric position index (BPI) for explaining a significant part of the variation. For the fine sand community, variables mean bottom stress and mud fraction of the sediment were significant predictors. For the mud community, mud fraction, BPI, and maximum bottom stress showed significant p-values.

In a final step, we will calculate the probability of the presence of each of the four communities for each grid cell (200x200m) in the BPNS based on the developed predictive models in combination with BPNS-wide coverage maps of the environmental predictors. In this way, a habitat suitability map for each distinct community will be developed representing the distribution of the different communities in the BPNS. This type of information supports the sustainable management of our seas and oceans.

Keywords
Epibenthos; Demersal Fish; Belgian Part Of The North Sea; Habitat Suitability; Community Distribution Modelling

Every seed counts: improving the germination success of *Zostera marina* seeds

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Coastal aquatic plants, such as seagrasses, play a pivotal role in maintaining biodiversity and ecosystem function in marine environments by providing essential ecosystem services such as carbon sequestration, water purification, erosion protection, and support for biodiversity.

Regrettably, seagrass populations, particularly those of *Zostera marina*, the most widely distributed seagrass species, are facing significant declines globally.

Global efforts to restore these critical seagrass ecosystems are increasing in prevalence, with seed-based restoration emerging as a cost- effective method that facilitates the upscaling of *Z. marina* restoration initiatives. However, the success of seagrass restoration is hindered by remarkably low germination and seedling establishment rates, reported to be less than 5%.

To address these low germination challenges, our study investigated the effects of hormone priming, with the use of gibberellic acid (GA_3), on the germination of *Z. marina* seeds. We exposed a total of 1500 seeds to ten concentrations of GA_3, and monitored germination success over 60 days. Our results revealed a statistically significant increase in germination success of seeds exposed to GA3 compared to the control group. Interestingly, both low and high GA3 concentrations were found to be more effective in stimulating germination compared to intermediate levels of GA_3.

Our findings underscore the great potential of GA_3 priming to substantially improve germination success, providing valuable insights into potential applications of hormone priming as a strategic tool for enhancing germination success in restoration initiatives.

Keywords
Seagrass; Zostera Marina; Seed Germination; Hormone Priming; Gibberellic Acid

National T0 study of areas proposed for fisheries management measures in the Belgian part of the North Sea

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The benthic habitats in the Belgian part of the North Sea have been facing chronic anthropogenic pressure from bottom-contacting fisheries for centuries. The latest environmental status assessment showed that both soft (shallow sandbanks) and natural hard substrate (stony reefs) habitats are in unfavourable conditions. Although marine Natura 2000 sites were established to protect valuable and threatened species and habitats, the fishing pressure is still prominent over the entirety of their spatial extent. This urges to set additional management measures to achieve the desired protection level, allowing recovery and long-term sustainability.

In response, the new Belgian Marine Spatial Plan (2020-2026) proposed the establishment of designated search zones for seabed protection where bottom-disturbing activities would be restricted. In 2021, 3 areas were designed using an interdisciplinary approach integrating biological data, habitat distribution models, along with fishing type and intensity data. Two of them will be located in the Vlaamse Banken (one of the Natura 2000 sites) and one situated further offshore at the North-West. Reducing bottom-disturbing fisheries in these areas is anticipated to be highly effective, as these zones have been identified to contain large extent of biologically valuable habitats and species.

In order to assess the effectiveness of the upcoming proposed fisheries measures, an important first step is to design a comprehensive monitoring program, starting with a baseline (T0 study) followed by long-term monitoring after the closure of the areas to bottom fisheries. The current study design is aligned with the existing monitoring programs under the European Union's Marine Strategy Framework Directive (MSFD) and the Habitats Directive (HD). Emphasis is placed on the 1110 and 1170 habitat types, in particular stony reef biotopes and *Lanice conchilega* aggregations (sand mason worm). The ecological status evaluation, including community composition and functioning, involves analysing Van Veen grab samples for soft sediments and employing non-destructive underwater video imagery sampling for hard substrates due to their higher sensitivity to disturbance. To understand further these dynamic benthic habitats, multibeam echosounder (MBES) data were additionally gathered.

In 2023 within the T0 baseline survey framework, all samples from the three sites have been collected and are currently being processed to provide better resolution on the status of these habitats and their communities. Final results and report are expected to be published at the end of 2024.

Keywords
Stony Reefs, Belgium, Marine Policy, Soft Sediments, Fisheries Impact, Video Imagery, Hydroacoustics, Ecological Status, Conservation

Reaching the target: predicting the distribution of European marine species to support the implementation of Marine Protected Areas

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Climate change is causing multiple impacts on marine biodiversity, leading to the loss of species and distributional shifts (Poloczanska *et al.* 2013; Pinsky *et al.* 2020). As biodiversity is impacted, ecosystem functioning is impaired and with this their capacity to provide essential ecosystem services. Countries have committed to protect at least 30% of the world's land and sea areas by the year 2030. However, there remains a gap in our knowledge regarding the optimal locations for establishing Marine Protected Areas (MPAs) that would effectively conserve biodiversity. Additionally, it is crucial for protected areas to consider potential changes in species ranges due to climate change.

As part of the European Union Horizon project MPA Europe, we are using species distribution models (SDMs) to predict the current and future distribution of marine species occurring on European seas. Models will be used to forecast the potential range shifts according to five CMIP6 scenarios for the years 2050 and 2100: SSP1, SSP2, SSP3, SSP4 and SSP5. SDMs are being developed using occurrence data obtained from two major biodiversity platforms, the Ocean Biodiversity Information System (OBIS) and the Global Biodiversity Information Facility (GBIF), along with environmental variables from the latest Bio-ORACLE version (v3). Models will be generated for approximately half of all marine species in Europe (~15,000). Preliminary results suggest significant shifts in the range of species, regardless of the scenario (Principe *et al.* 2023). Models are currently being optimized to address potential spatial biases on occurrence data, and to consider alternative hypothesis for predictor variables. It is expected that by June 2024, models for all species will be accessible on the OBIS platform. In a second step, we will also predict the distribution of biogenic habitats, such as cold coral reefs, seagrass meadows and Polychaetes reefs, by grouping the individual distribution models. Biogenic habitats increase the structural complexity of the environment, supporting a higher diversity and abundance of organisms (e.g. Graham & Nash, 2013), and changes in its distribution can have cascading effects on the ecosystem (Teagle & Smale, 2018). Models for the biogenic habitats will also be available by June 2024.

In addition to the outputs for the project, it is expected that new products will become available for the general community through OBIS. These include enhanced pipelines for data integration between OBIS and GBIF, a framework for developing species distribution models based on presence-only data, and distribution maps for marine species in other regions. This will add to the toolbox available for researchers, creating new paths to understand how marine biodiversity is responding to Anthropogenic pressures.

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Keywords
Ecological Modeling; Biodiversity; Climate Change; Anthropocene

Mangrove browning trends in the semi-arid Southern Caribbean

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Mangroves are tropical coastal ecosystems threatened mainly by land cover change due to commodities. The effect of urbanization on mangroves has been overlooked due to the low percentage of area loss globally. However, it can be an important driver of mangrove loss at local scales. Besides, highly fragmented mangrove areas dominated by small patches might be more sensitive to natural and anthropogenic stressors as occur in terrestrial forests, specially in highly modified systems such as cities. However, little is known about the interactive effects of these drivers of mangrove loss and degradation, namely urbanization and fragmentation. Our objective is to analyze the mangrove ecosystem's response in terms of the greenness trend to urbanization and patch fragmentation metrics in the semi-arid Colombian Caribbean. To do so, our specific objectives are: i) Calculate the greenness trend from 2017 to 2023 during the dry season by analyzing the Normalized Difference Vegetation Index (NDVI) derived from Sentinel-2 satellite images; ii) Correlate the greenness trend in mangrove patches with fragmentation metrics at the patch level; iii) Evaluate the patch greenness trend along an urban-to-rural gradient, specifically focusing on Cartagena city. The objectives are achieved using remote sensing and GIS tools. This study emphasizes the significance of understanding the impact of urbanization and fragmentation on mangrove forests, as it is crucial for their persistence and for informing conservation efforts, especially in relation to vulnerable species and areas at risk.

Keywords
Urbanization; Fragmentation; Colombia

Marine ecosystem functioning under anthropogenic pressure: applying a food web approach

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Marine fauna communities are currently facing several threats due to climate change and anthropogenic pressures, triggering changes in biodiversity and subsequently impacting ecosystem functions and services. So far, studies investigating human impacts on the marine environment have mainly focused on community ecology. However, species are interconnected through trophic interactions and changes in the environment can modify these connections, influencing the stability of the communities and potentially impacting the overall function of the ecosystem. Therefore, a more comprehensive insight into the structural and functional aspects of human impacts can be obtained by considering a community as a network of feeding interactions.

Food webs, defined as ecological networks mapping trophic interactions and energy flows among species, offer a powerful tool to bridge the gap between community ecology and ecosystem ecology. They constitute a useful and feasible approach to asses the ecological state of the ecosystem through network metrics. Network metrics can extend the attributes of individuals and populations to ecosystem properties such as production and element cycling and therefore, can be used as a proxy of ecosystem functioning, health, and development. Lately, the Marine Strategy Framework Directive stressed the urgent need to develop ecosystem health indicators with the aim of reaching a good environmental status. As such, network metrics offer a feasible approach to tackle the ecological state of ecosystems as they link trophic interactions and ecosystem properties.

Through a combination of field sampling, experimental methods, and food web analysis in both spatial and temporal dimensions, this PhD project seeks to provide an holistic understanding of human impacts on the marine ecosystem in the North Sea. This project will investigate temporal succession patterns and carbon flows during the establishment of an offshore wind farm (OWF) in the Belgian Part of the North Sea (BPNS). In a following step, and adopting a collaborative framework, the project will integrate data from monitoring programs of various North Sea countries to examine the spatial variability of OWF impacts across the region. Through an experimental set up, the project will explore the role of habitat complexity in stability and resilience of the food web. Furthermore, food web modelling will be conducted to asses which habitats contribute most to ecosystem resilience and stability in the BPNS as a case study. The ultimate goal of this PhD is to provide valuable insights to guide conservation, restoration, and marine management efforts in the North Sea.

Keywords
Food Web; Network Metrics; Trophic Interactions; Anthropogenic Impacts; Offshore Wind Farms; Ecological Network; Ecosystem-based Management

Macro- and microplastics accumulation in natural and reforested mangrove stands and its impact on the associated macrobenthos at Matang, Malaysia

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Over the last few years, plastic pollution has been considered a rising global threat due to the negative ecological and socioeconomic consequences as well as the health risks that it imposes on the public. To date, studies related to plastic accumulation in coastal ecosystems like mangroves remain minimal. Moreover, the prevalence and impacts of microplastics (< 5mm) on macrobenthic organisms and other associated fauna are still examined considerably to a lesser extent. The study focuses on one of the world's longest-managed mangrove forests (for timber and charcoal), the Matang Mangrove Forest Reserve (MMFR), located on the northwest coast of Peninsular Malaysia. Different-aged mangrove forest stands were assessed to determine the distribution and composition of macroplastic pollution and thereby the ingestion of microplastics in selected brachyuran crab species as indicators. By observing both physical and chemical characteristics of the microplastics (using micro-Fourier transform infrared spectroscopy (micro-FTIR), scanning electron microscope (SEM) images, etc.), a possible relationship between the abundance of macro- and microplastics and their variation with respect to different feeding guilds of the brachyuran crabs will be assessed.

Keywords
Brachyuran Crabs; Plastic Pollution; Matang Mangrove Forest Reserve; Malaysia

Oysters as a model organism for settlement of reef-building organisms in response to complex sensory landscapes of chemical, tactile, and sound cues

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Colonization of substrates by planktonic larvae is a complex process. As larvae conclude their pelagic period, they rely on environmental cues to assess the quality of a habitat for permanent settlement. For many species, settlement cues have multiple origins and can affect larvae at different spatial scales. A better understanding of larvae responses to these cues can not only advance fundamental knowledge regarding larval settlement strategies but also provide critical information for informing habitat restoration projects, aquaculture practices, and antifouling efforts.

Through a series of controlled lab-based experiments, we investigate known or predicted settlement cues of Pacific oyster (*Magallana gigas*). We optimized research-scale larviculture of this species and, as ready to spawn adults are commercially available, highlight its suitability as a model organism for larvae settlement research.

In the first series of experiments, we focus on how larvae change optimization strategies under scenarios of multiple and conflicting cues (e.g. from conspecifics or predators). Based on our findings, we propose that larvae rank settlement cues and respond to conflicting cues based on this ranking, prioritizing highly ranked positive cues over negative cues from predators. Building upon these experimental observations, we develop a conceptual framework that is further refined by a mechanistic model.

In a second experiment, we explore how marine soundscapes influence larval settlement. We analyze sounds associated with oyster reefs, as well as anthropogenic noises from marine vessel traffic. Our findings indicate an increased settlement response to healthy reef noises. We propose the significance of acoustic diversity for larval settlement, emphasizing not only the decibel increase but also the acoustic characteristics of the different sounds.

In a third experiment, we investigate how changes in surface microtopography and subsequent alterations to the biofilm community can influence patterns of larvae settlement.

We conclude that while much can be learned about larvae settlement from sophisticated experimental designs, there is still a lack of conceptual frameworks that can explain the observed patterns. These concepts urgently are needed to generate novel hypotheses that can advance the research field.

Keywords
Oyster Larvae, Larvae Settlement, Invertebrate Ecology, Settlement Cues

Development of a forward genetic screen based on mitotic recombination in diatoms

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Diatoms are one of the most diverse types of microalgae, promising for wastewater treatment, bioremediation and production of numerous valuable compounds. However, functional information is missing for a big proportion of diatom genes and consequently their full biotechnological potential has not been unlocked yet. In order to fully harness their abilities, development of high-throughput methods for functional analysis of diatom genes is needed. To date, several factors precluded forward genetic screening in diatoms. The model species *Phaeodactylum tricornutum* has never been observed to reproduce sexually in laboratory settings, which makes the generation of homozygous cell lines challenging. Recently, our lab has observed high mitotic recombination rates between homologous chromosomes in cultures of *P. tricornutum*. Our data showed that the mitotic recombination rate is extremely high, occurring in 4.2 out of 100 diatom cell divisions. Random segregation of sister chromatids during mitosis results in loss-of- heterozygosity (LOH) regions in 50% of cases, allowing generation of homozygous cell lines (*Bulankova et al, 2021*). Within our project we want to make use of this phenomenon to develop forward genetic screens in diatoms as a novel platform for identification of genes of interest for biotechnology.

Keywords
Forward Genetic Screen; Diatoms; Biotechnology

Seaward nature-based solutions in sandy coastlines: Applying the DAPSI(W)R(M) Framework to the Coastbusters concept

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Coastal resilience is critical for soft-sediment ecosystems vulnerable to climate change and human-induced pressures (O'Leary *et al.*, 2023). Current engineering approaches fall short, prompting a shift toward Nature-based Solutions (NbS), which mimic natural ecosystem features and processes (Faivre *et al.*, 2017; Seddon *et al.*, 2020). NbS, defined by the United Nations Environment Program, offers a holistic approach by simultaneously addressing social, economic, and environmental challenges (UNEP, 2022). The European Commission aligns NbS with EU policies, emphasizing the need for legislative frameworks and international standards for effective implementation. EU Legislative frameworks, such as the EU Biodiversity Strategy, the Habitat and Birds Directives, and the Marine Strategy Framework Directive, as well as the Marine Spatial Planning Directive, play crucial roles in guiding NbS implementation. The DAPSI(W)R(M) framework (Drivers- Activities-Pressures-State change-Impacts (on human Welfare)-Responses (using Measures)) (Patrício *et al.*, 2016) can be employed to assess NbS in the context of the EU legislative landscapes, as explored by this study (Semeraro *et al.*, submitted). The framework connects human pressures (referring to the drivers e.g. coastal defence and the activities e.g. aquaculture coastal infrastructure, which enhances pressures on the environment), state changes in marine ecosystems (through criteria and indicators), impacts on human welfare (through ecosystem service indicators), and responses or measures to prevent or mitigate impacts for deploying a NbS. The application of this framework is illustrated for Nbs on sandy coastlines, with the Coastbusters project as a pioneering example (Goedefroo *et al.*, 2022; Coastbusters (2020); Coastbusters 2.0 (2023)). The Coastbusters concept exemplifies NbS application in the Belgian Part of the North Sea (BPNS), focusing on mussel beds and tube-worm aggregations. This public-private partnership induced mussel biogenic bed formation through innovative reef-facilitating systems. The DAPSI(W)R(M) framework allows us to illustrate the multifaceted challenges related to the integration of seaward NbS in sandy coastlines, as the Coastbusters concepts. The novelty here is that it also emphasizes the importance of integrating social concerns into environmental assessments, highlighting the scarcity of recent information on public perceptions of NbS.

Acknowledgements
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Keywords
DAPSI(W)R(M); Nature-based Solutions; Biogenic Reef; Subtidal; Coastal Resilience

Mindful at the sea: effect of engagement interventions at the coast on emotions, well-being, and pro-environmental behavior

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Virtual exposure to coastal environments can have beneficial effects on mental well-being and pro-environmental behavior. However, few studies have investigated the effects of real-life exposure and our understanding of how to maximize the potential benefits of the coast remains limited. Recent research suggests that being mindfully engaged during exposure to nature can enhance its restorative effects and increase nature connectedness and feelings of awe.

In this preregistered study, we aimed to investigate the effect of real-life exposure to the coast (vs. an urban landscape) on stress, worry, and mood, as well as pro-environmental behavior. Additionally, we aimed to evaluate differential effects of mindful engagement vs. mind- wandering vs. distraction at the coast. A total of 77 adults (22 to 78 years old) participated in a 20-minute guided walk at the beach or in an urban street. Those walking at the beach were instructed to either be mindful of their surroundings (mindful engagement; *n* = 18), let their mind wander (mind-wandering; *n* = 20), or engage in mental visualization tasks (distraction; *n* = 19). Those walking in the urban street (*n* = 20) received the same instructions as the distraction group. Participants were asked to report their perceived stress, worry, and mood before and after the walk. Pro-environmental behavior was measured with the use of the Work for Environmental Protection Task (WEPT; Lange & Dewitte, 2022), after the walk.

Non-parametric statistical tests did not reveal significant group differences in stress or worry reduction, nor in changes in positive or negative mood. However, it is worth noting that effect sizes ranged from small to medium, suggesting a lack of statistical power due to the small sample size. Performance on the WEPT did not significantly differ between groups. Exploratory one-way analyses of covariances did demonstrate that during the walk, the distraction group exposed to the urban landscape significantly experienced less awe compared to the mind-wandering (-26%) and mindful engagement (-25%) groups exposed to the beach. The urban distraction group also experienced less nature connectedness (-18%) and less adaptive emotion-regulating strategies (-14%) than the mindful engagement group (large effect sizes). The experience of nostalgia did not significantly differ between groups, but the effect size was medium.

Taking the effect sizes into consideration, we suggest to replicate the study with a larger sample size (i.e., >180 participants). Our exploratory results indicate that being mindfully engaged at the coast enables to experience the valuable emotion of awe, feel more connected to nature, and regulate our emotions. Further research should consider not only the type of environments that benefit our mental health, but also under which conditions these benefits can be optimized.

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Keywords

Restorative Environments; Well-being; Pro-environmental Behavior; Emotions; Mindful Engagement; Real-life Exposure

Genetic diversity of the mud crab *Scylla olivacea* in Pakistan and its connectivity throughout the Indian Ocean

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Scylla spp., commonly known as mud crabs, are large edible crabs well known for their importance in fisheries. Previously, both *S. serrata* and *S. olivacea* were described for Pakistani waters. Differentiation of both species based on morphology, however, is difficult, pressing the need for molecular identification. Furthermore, a better understanding of the genetic diversity and connectivity of mud crabs throughout the Indian Ocean is necessary for the optimal management of this resource. Sampling of 157 mud crabs was conducted from five different sites along the Pakistani coast. A fragment of 470 base pairs of the mitochondrial cytochrome oxidase subunit I gene (COI) was sequenced and aligned with 235 sequences retrieved from GenBank. Population structure in Pakistan was further analysed using 19 microsatellite loci. Based on the COI sequences, all collected individuals were identified as *Scylla olivacea*. In the data set of 392 COI sequences 268 haplotypes were identified. Nucleotide diversity was low, whereas haplotype diversity was high. Neutrality tests indicated a possible recent population expansion event in nearly all populations. We detected significant population structure using COI and identified five differentiated groups throughout the Indian Ocean: Northwest-Pakistan, Southeast-Pakistan, India/Bangladesh, Myanmar/Malaysia, and Indonesia. Population structure within Pakistan was confirmed with microsatellites. Possible explanations for these groupings are different environmental conditions on both sides of the Pakistani coast and physical barriers to dispersal, such as the Ganges River outflow and complex current pattern along the Indonesian coast.

Keywords
Mud Crab; Scylla Olivacea; Genetic Diversity; Phylogeography; Pakistan; Indian Ocean

Some strange sensing tools

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Pycnogonids are particularly understudied marine arthropods despite their wide distribution. The main reason is that they usually display low population densities. However, the northern pacific species *Ammothea hilgendorfi* is now considered invasive in Europe and a proliferating population was discovered in 2022 at the North Sea (Knokke-Heist, Belgium), reaching record breaking densities. A 24-month monitoring was consequently conducted to better understand the dynamic of this population. Such a great biological material quantity was the opportunity to deepen the understanding of these unique yet poorly known animals. Indeed, pycnogonids present quite specific ecology and morphology, including an abdomen and trunk reduction, which induced the extension of internal systems into the legs. Sea spiders also display ovigers, specialized egg-carrying appendages used by males to take care of their offspring; and a tubercle, periscope-like structure bearing the eyes and providing a 360° vision field. They also feature peculiar sensory organs (*i.e*., lateral sense organ, Gabelborsten, slit organ, hinged bristles) for which the functions remain hypothesized. Only the structure was described in model species. To provide insight on how such organisms perceive their environment, the aim of this study was to describe the sensory organs of *A. hilgendorfi*. In the same perspective, their chemotaxis was investigated in a set-up that would also help elucidate other stimuli (*i.e*. multimodal communication).

Keywords
Pycnogonids; Sea Spiders; Ammothea Hilgendorfi; Sensory Organs; Multimodal Communication

Food web models for ecosystem-based management in the Southern Bight of the North Sea

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The Southern Bight of the North Sea is marked by a vast range of commercial activities and a growing Blue Economy. However, intensive exploitation in this multi-use environment exerts pressures on the marine environment. The impacts of blue economy activities could be mitigated by an ecosystem-based management approach, which has yet to be developed for our study area. Ecosystem-based management requires comprehensive, quantitative assessment methods for the environmental impact of commercial activities. Ecosystem models enable the evaluation of anthropogenic activities' effects on the marine environment across current and potential future scenarios, facilitating the development of an ecosystem-based decision framework. For sustainable fisheries management in particular, food web models can be used to explore and quantify the effects of prospective policy changes on food web dynamics.

Food web models describe the predator-prey interactions between a set of functional groups. Estimates calculated by these models can be interpreted as ecological indicators, providing quantitative assessments of ecosystem health. By simulating potential future scenarios, the impact of policy changes can be investigated. However, to provide accurate predictions, a food web model must be tailored to reflect local conditions. Currently, the most specific models available for our study area cover both the southern and central North Sea. To date, no food web model has been tailored to the Southern Bight of the North Sea.

To enable ecosystem-based management, two mass-balanced snapshots of the Southern Bight of the North Sea have been developed, i.e. for 1991 and 2018, using Ecopath. These models describe the relationships between 32 functional groups across different trophic levels, ranging from harbor porpoise to phytoplankton. Biomass estimates for these groups were obtained from International Council for the Exploration of the Sea (ICES) reports. All data was quality controlled, and for species where accurate biomass data was not available, biomass was either estimated using the method of Sparholt (1990), extracted from scientific literature, or obtained from other models with overlapping study areas. Biomass data was complemented with dietary information adjusted from a model developed by Stäbler *et al.* (2016) based on fish stomach data from the Centre for Environment, Fisheries and Aquaculture Science (CEFAS). Productivity and consumption rates were estimated using empirical formulas (i.e., Pauly (1980), Nilsson and Nilsson (1976)). Fisheries information was integrated into the model as nine commercial fleets, five recreational fleets and mussel aquaculture.

The 1991 and 2018 Ecopath models for the Southern Bight of the North Sea developed in this study provide valuable insight into the local food web and its interactions with commercial and recreational fisheries fleets. A first analysis of the 1991 model using thirteen ecological indicators, as well as two fisheries indicators, suggests that the Southern Bight of the North Sea had not yet recovered from historical overexploitation. A comparison with ecological indicators from the 2018 model will be a first step towards understanding how this ecosystem has evolved. Model predictions can then be used to explore prospective policies' impacts on food web dynamics. Insights obtained from these models will provide guidance for ecosystem-based fisheries management in this economically and ecologically important marine region.

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Keywords
Trophic Interactions; Ecopath With Ecosim; Fisheries Management; Multi-use

More than one species? Exploring the possibility of cryptic species in the giant clam *Tridacna maxima* using complete mitochondrial DNA sequences

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Giant clams from the family *Tridacninae* are ecologically significant species that are currently threatened both by global changes and anthropogenic activities. Currently, there are seven extant species of giant clams distributed globally, all of which are listed under Annex II of the Convention on International Trade in Endangered Species and Flora (CITES). To effectively conserve these species, a proper species delimitation approach is needed. However, the most recent studies regarding the phylogeny of giant clams rely on the use of a certain number of mitochondrial and nuclear markers (i.e. COI, 16S, 18S), which does not allow for the detection of possible cryptic species. Additionally, deep divergent lineages have been detected in phylogeographic studies based on COI sequences in the small giant clam *Tridacna maxima*, suggesting cryptic species. This study will focus on the intraspecific genetic diversity in *T. maxima* using complete mitochondrial genomes generated by next-generation sequencing (NGS). Phylogenetic analysis will be conducted using Bayesian approaches, allowing us to investigate the presence of cryptic species.

Keywords
Species Delimitation; Next-generation Sequencing; Intraspecific Genetic Diversity; Phylogenetic Analysis; Bayesian

Unravelling the intestinal microbiome of killer whale Reveil stranded in De Panne, Belgium: insights into cause of death and anthropogenic pollution impact

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Infectious diseases stand out as the predominant cause of death among stranded cetaceans in the Southern North Sea. Although most infections are caused by host-associated pathogens, some studies reported on infections with human pathogens through contamination from land and river runoff. The exceptional depth of current sequencing technologies allows for an accurate and high-resolution identification of pathogens from human origin and a thorough profiling of whole microbial communities providing valuable insights into cetacean health and disease. However, investigations into the intestinal microbiota of stranded cetaceans, specifically for studying the cause of death and assessing anthropogenic impact, remain limited. This study represents a pioneering effort to explore the intestinal microbiome of a stranded killer whale (*Orcinus orca*) using a comprehensive whole metagenome sequencing approach. The goal was to understand if the intestinal microbiome of a diseased killer whale - strayed in the contaminated coastal waters of Belgium - could yield insights into cause of death and serve as an indicator of anthropogenic pollution. Samples of gut content were collected from the stranded specimen to identify bacterial pathogens with human origin, antibiotic resistance genes (ARGs) and pathways reflecting exposure to anthropogenic pollution. Contaminant DNA was removed and bacterial DNA was isolated for Nextera XT library preparation. The subsequent whole metagenome sequencing on the Illumina NovaSeq platform generated 22 million bacterial reads. Rarefaction curves demonstrated that the entire bacterial diversity was captured. Sequences were taxonomically classified using Kraken, aligned against genomes of both marine, as well as human pathogens and annotated using the comprehensive antibiotic resistance database (CARD) and using a custom database for microbial biodegradation of pollutants. This research establishes baseline knowledge regarding the killer whale intestinal microbiome and pathogens, and proves that the microbiome can give essential clues into cause of death and anthropogenic impact in stranded cetaceans.

Keywords
Microbiome; Killer Whale; Stranding; Cetaceans; Pollution; Pathogen; Antibiotic Resistance Gene

The European Atlas of the Seas: an ocean literacy tool powered by EMODnet for wider society

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The European Atlas of the Seas (www.european-atlas-of-the-seas.eu) is a user-friendly online map-based Ocean Literacy tool available in 24 languages developed at the initiative of the Directorate-General for Maritime Affairs and Fisheries (DG MARE) of the European Commission and powered by the European Marine Observation and Data Network (EMODnet) Secretariat. It makes it possible for people across Europe to explore a wide range of marine topics, such as the environment, marine life, nature conservation, sea surface temperature trends, sea level rise, marine litter, fisheries, aquaculture, tourism, energy, transport, and much more!

With a catalogue of more than 275 interactive map layers that is constantly updated and enriched and the possibility to create custom maps that can be printed, shared and embedded in websites and blogs, the Atlas is an easy and attractive way for everyone to connect to our blue planet and better understand how the ocean influences us and how we influence the ocean. Thematic predefined maps that combine selected map layers make it possible for users to learn about ocean observation and marine data as well as important pillars of the European Green Deal, in particular biodiversity, food from the ocean, clean energy and climate change. The recently developed 'My Maps' tool now also enables users to create their own working space in the Atlas.

EMODnet provides more than 50% of the map layers in the Atlas. Other data providers include, for example, the Copernicus Marine Service, the European Environmental Agency (EEA), Eurostat and the Joint Research Center (JRC).

The Atlas can be used in schools in multiple ways. The Teachers Corner (http://learn.european-atlas-of-the-seas.eu) provides ready to use map-based exercises in English, French and Portuguese for students of different age groups as well as fun activities such as a Treasure Hunt, two virtual boat races and a Geocaching Game!

Keywords
Atlas; Maps; Marine Data; Open Data; Ocean Literacy; Education; Communication And Outreach

Seabed mapping: no one-size-fits-all!

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Marine ecosystems are affected by a multitude of drivers and pressures, both natural and anthropogenic. Sustainable management therefore requires a diverse range of tools and approaches in which seabed mapping is an essential component. This is exemplified in the European Marine Strategy Framework Directive (MSFD, 2008/56/EC), prescribing monitoring of changes in broad habitat types (BHT) for the assessment of Good Environmental Status, and seafloor integrity (SI) in particular. The substrate part of the BHT mapping relies on estimating ratios of mud, sand, and gravel in seabed sediments, and is a common denominator for seabed mapping across Europe (i.e., Folk classification in EMODnet-Geology, Kaskela *et al.*, 2019). Within the constraints of this context, approaches need to be found that can cope with small-scale transitions between BHTs, but still build on datasets that are widely available for consistent seabed change assessments across regions.

Meanwhile, rapid evolutions in methodology take place in seabed mapping, mostly linked to the use of acoustic remote sensing and seafloor classification. Whilst at the smaller scale, highly detailed sediment maps can be produced with good predictive power, the confidence in the required regional BHT maps is typically much lower. This is related to integration of more fragmented data collected over a wide time span, and consequently also because of the variety of technologies and gear used over time. Amplification of uncertainties in the data chain is inevitable, complicating seabed change analyses. For BHT maps to be useful for management, these shortcomings need to be bypassed, e.g., by increasing the understanding of the nature and dynamics of the different sediment types. This is especially true for the coarse sediment habitats for which changing sand dynamics may lead to irreversible loss.

A new mapping approach was developed relying on differences in small-scale relief as a proxy of sediment type. This gives the advantage that also very-high resolution bathymetry can be used being available increasingly over vast areas. With relevance to the entire BPNS, data was used from Flemish Hydrography (agentschapmdk.be/en), and were analysed against a diverse range of other datasets (e.g., sediments, geology, biology) and morphodynamic information to map sediment types. To build up knowledge on seabed nature and dynamics systematically, whilst assessing human-induced changes as well, a new monitoring network (SI-NET) was designed, crossing gradients of seabed types and human-activity hotspots over the entire BPNS.

Original maps were produced at 50k scale and were then resampled to 100k, 250k at 1M scales following guidelines set by EMODnet- Geology. The sediment type polygons were attributed with seabed features providing relevant context on seabed nature and dynamics influencing confidence. The maps (e.g., Van Lancker *et al.*, 2023) were then integrated into the latest release of the pan-European seabed substrate maps and further translated into BHT maps (downloadable via EMODnet.eu, via the Geology and Seabed Habitats Lots respectively).

In next releases, incorporation of newest evolutions in the use of multibeam backscatter and machine learning approaches will be evaluated. Future developments will also incorporate new elements enabling change assessments (geological markers, seabed patterns and bedform complexity) and will benefit from detailed morphodynamic research (NWO BANX). Cross-fertilisation is further aimed at with international networks such as EMODnet.eu (Geology and Seabed Habitats), GeoHab.org, and the Geological Service for Europe (eurogeosurveys.org).

The research contributes to the Belgian monitoring programme on the implementation of the Marine Strategy Framework Directive, and ZAGRI (private revenues related to sand extraction); as well as to EMODnet-Geology. The developments align with RBINS' Research Strategy on 'Science for a Sustainable Marine Management' and 'Geology for Society'.

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Keywords
Sediment; Morphology; Geology; Seabed Mapping; Habitat Change Assessment; Sustainability; Decision Support

30 years of Belgian North Sea aerial surveillance: evolution, trends, and developments

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This poster describes the various missions and results, trends and developments of the Belgian program for aerial surveillance over the North Sea over a period of 30 years, from its start in 1991 up to and including 2021. These facts and figures outline that the substantive challenges of aerial surveillance above the sea are and will remain innumerable in the years to come: continuing the fight against sea and air pollution from ships in one of the busiest shipping areas in the world (including accidental pollution), ensuring dedicated airborne support in maritime emergency situations in the framework of the emergency and intervention plans for the North Sea, contributing to the sustainable management of the North Sea and sustainable use of living and non-living natural marine resources, the protection and conservation of marine biodiversity and ecosystems, the monitoring of human activities under a permit regime and/or organized within the framework of the new marine spatial plan, the efficient enforcement of a new European external border (post-BREXIT), promoting maritime security, offering support to search and rescue operations, and much more. The medium-term need for renewal of the remote sensing aircraft offers a unique opportunity for the Belgian Coast Guard structure to renew its strategic vision and increase its cooperation on airborne surveillance, and to modernise and expand its surveillance capacity with the aim to effectively deal with current and future needs at sea, in support of the various Coast Guard functions.

Keywords
Aerial Surveillance; MARPOL; Coast Guard

Microfossils of Testerep: Foraminifera, radiocarbon anomalies, and sedimentary enigmas

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The aim of the multidisciplinary Testerep project is to capture the evolution of the Flemish coastal landscape over the past 5000 years. The Testerep peninsula was once located on the Flemish middle coastal plain, between Ostend and Westend. During the Medieval period, the landward side of this peninsula was transformed into a polder landscape, while the seaward side, including the medieval city of Ostend, was swallowed by the sea. This project specifically aims to understand the past impacts and interplay of natural changes (e.g. sea- level rise) and human interventions (e.g. construction of dikes) on the evolving morphodynamics of this stretch of the coast.

In the framework of this study, micropaleontological specimens, specifically two mixed benthic foraminifera samples, were obtained from offshore sediment cores for the purpose of radiocarbon dating and paleoenvironmental analyses. However, both foraminifera radiocarbon dates gave unexpectedly old ages.

More specifically, the first sample yielded an age of approximately 7.4 thousand years before present (ka BP); however, the surrounding sediment was dated with the use of Optically Stimulated Luminescence (OSL) to c. 930 BP. The second sample was dated to c. 35 ka BP, which is noteworthy as the marine environment necessary for these foraminifera was absent in the region during this period. This discrepancy does not appear in radiocarbon dates derived from shells; these do correspond to the OSL dates within the same core. However, there are at present no radiocarbon dates from both foraminifera and shells from the same core or a similar unit.

We speculate that the foraminifera in the latter (older) sample represent a combination of reworked Pleistocene and more recent Holocene specimens. The apparent freshness of these reworked foraminifera suggests rapid deposition and short transport from a unit in relative proximity. The Pleistocene foraminifera are suspected to originate from the Last Interglacial deposits (117-130 ka BP), which have been reported near Ostend. This period also marked the last time the area represented a marine environment before c. 7.5 ka BP. If our hypothesis is correct, then it is likely that the former (c. 7.4 ka BP) sample may have been subject to the same reworking processes, hence resulting in older-than-expected radiocarbon ages.

This study underscores the necessity to apply caution in using foraminifera for radiocarbon dating. Furthermore, it poses important questions on the use of such samples for paleoenvironmental reconstructions in coastal settings. This outcome shows the importance of the use of a multi-proxy approach when reconstructing past dynamic coastal environments.

To address this issue, we propose to do a more detailed study comparing shell material versus foraminifera samples from single units.

Keywords
Testerep; Foraminifera; Micropaleontology; Carbon-14; Sedimentology; Paleoenvironmental-reconstructions

Liquid extracts of the brown seaweed *Ascophyllum nodosum* for the development of antimicrobial marine paints

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The transition toward more sustainable and environmentally friendly active chemical substances prompted the search for replacements of the banned tributyltin (TBT) (2008). TBT is a chemical often used as an antifouling agent in marine paints that, due to its toxicity, prevents the growth of algae, barnacles and other organisms from growing on the hull of a ship; however, when leached into the environment, TBTs exhibit an endocrine disruptive impact on marine organisms [1], [2], [3]. In the literature, antifouling, antimicrobial and antioxidant properties have been ascribed to certain seaweed compounds derived from brown seaweeds, including alginate, fucoidan, and fucoxanthins [4]. Hence, this study explored the potential of these compounds as antimicrobial agents for use in maritime paints. Several brown seaweeds (e.g., *Ascophyllum nodosum* and *Sargassum muticum*) were harnessed for component separation and extraction using a microwave-assisted extraction method [5]. A biphasic extraction system was used to separate the components of interest in the organic phase (e.g., polyphenols) and remove microorganism nurturing compounds (e.g., mannitol) via the water phase. Additionally, one-phase (organic solvent) extraction was also applied. Two organic solvents were investigated, which (i) have relatively low boiling points, (ii) are susceptible to microwave radiation, (iii) are immiscible with water and (iv) have good miscibility with common marine paints (e.g., Sigmacover 456). Both ethyl acetate (EthAc) and methyl isobutyl ketone (MIBK) were found to meet these criteria. First, seaweed extracts were produced according to the extraction method described in previous work, with a few modifications [6]. Briefly, a total volume of 400 mL (1:1 organic:water) was used, and 20 wt% dried seaweed powder was added to the mixture, which was extracted at 120°C for 15 min. Next, the extracts were concentrated by evaporation until 15 mL of organic solvent remained, after which the mixture was subsequently processed (16.7 v%) into a commercially available two-component resin marine paint (Sigmacover 456). The antimicrobial and antibiofilm characteristics of the samples were evaluated using a plating assay and an MTT (3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide) assay on one gram-positive (*S. aureus*) and one gram-negative (*P. aeruginosa*) bacterium, respectively [7]. The results showed inhibitive effects on *S. aureus* (5-10 times fewer cells) treated with one-phase *Ascopyllum nodosum* and *Sargassum muticum* EthAc extracts; however, an antibiofilm effect was not demonstrated. Further research is needed to optimize the dose of the extract used to treat paints and elucidate the underlying mechanisms involved.

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Seaweed; Biphasic System; Marine Paints; Antimicrobial

Understanding the paleogeographic evolution of the North Axial Channel, Southern North Sea

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During the last 500 000 years, ice sheets occupied parts of the North Sea during three major glaciations (Graham *et al.*, 2011). The existence of these ice sheets was accompanied by a large fall in sea level, causing the Southern North Sea to emerge and become isolated from the Atlantic Ocean (Böse *et al.*, 2012; Graham *et al.*, 2011). In this area a complex drainage system was created by river water of the West- European rivers (e.g., Thames, Rhine, Meuse and Scheldt) and glacial meltwater during periods of low sea level (Gibbard 1995, Hijma *et al.*, 2012). Furthermore, most offshore studies support the idea of the formation of large proglacial lakes in front of these ice sheets, which may have caused high-magnitude outburst floods at the end of each glacial period (Gibbard and Cohen, 2015). The existence of such a proglacial lake is used in the argument that glacial outburst floods during the Elsterian (500-450 ka) created erosional features still preserved nowadays in the Dover Strait (Collier *et al.*, 2015; Gupta et el., 2007). A remnant of this large, complex fluvial and glacial drainage system is the (North) Axial Channel, a prominent geomorphological feature seen on the present-day sea floor of the Southern North Sea. Its formation and evolution are still uncertain (e.g. Garcia-Moreno, 2017; Hijma *et al.*, 2012; Liu *et al.*, 1992). Currently, only a relative chronology of potential erosional events has been established, which are subject to large uncertainties (Garcia-Moreno, 2017). Understanding the paleogeographic changes that affected the region also increases the knowledge on how early humans may have settled in and/or migrated through the region (Gaffney *et al.*, 2007).

In the framework of the WALDO project ("**W**here are **A**ll the (proglacial) **L**ake se**D**iments in the N**O**rth Sea Basin?"), a survey has been conducted in October 2023 during which high-resolution geophysical data (multibeam bathymetry and backscatter, acoustic and seismic data) combined with ground-truth data (vibrocores) have been acquired. One of the reflection-seismic grids was conducted ~40 km east of the East of England coast, over the western edge of the North Axial Channel, where also four sediment cores were taken. Here, we present the first interpretation of these new data, which allow us to evaluate, update and improve the relative chronology of the formation of the (North) Axial Channel.

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Keywords
Southern North Sea; Axial Channel; Reflection-seismics; Sediment Cores; Stratigraphy

Present-day current activity in an inactive canyon-channel system: the Gollum Channel System offshore southwest Ireland

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The Gollum Channel System is a land-detached large-scale canyon-channel system situated offshore southwest Ireland on the Northeast Atlantic margin. The system is considered to have been inactive since the Last Glacial Maximum (LGM) (Wheeler *et al.*, 2003), but newly acquired geophysical seafloor and shallow subsurface data do suggest recent activity. To test the hypothesis of present-day (in)activity, high- resolution side-scan sonar, photography and bathymetry data were collected using an autonomous underwater vehicle (AUV) in the upper slope (350-1000 m water depth) section of two of the channels. These data are presented alongside current meter data from a mooring station in one of the channels (Verweirder *et al.*, 2021), which were used for quantification and validation of the AUV results. The presence of current ripples on the channel floor indicates that bottom currents acting here are capable of the (re)distribution of sediments. Additionally, some features in the AUV data are interpreted as patches of cold-water corals that depend on nutrient influx as well as a hard enough substrate to grow on, both of which may be promoted by bottom current activity. The current meter data show bottom currents had an average velocity of 15.1 cm/s and reached a maximum of 53.7 cm/s during the measurement period. Therefore, collectively, these datasets allow interpretation of the channel floor features visible within the AUV data with respect to the current regimes they represent, and vice versa. At present, bottom current activity seems prevalent in the channels, while activity from gravity flows has not been observed.

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Canyon; Channel; Autonomous Underwater Vehicle; Side-scan Sonar; Bathymetry; Bottom Current; Internal Tide

Using sea cucumber coelomocytes as stress indicators? The case of lipopolysaccharide endotoxin

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Marine invertebrates make up the vast majority of the biomass of marine metazoans. Among them, sea cucumbers (holothuroids) occupy a special place in marine ecosystems, performing much the same function as earthworms but in the sea. More specifically, by ingesting sediments, they help to recycle sedimented organic matter and oxygenate soils. This ecological position makes holothuroids ideal organisms for studying the effect of pollution on marine fauna, as they are directly exposed to the disturbing elements that settle on the seabed [1]. In addition, certain species of holothuroids are of great economic interest because they are exploited as seafood in Asian countries. In recent decades, as a result of the growing demand for their consumption, numerous holothuricultures (i.e. holothuroid aquacultures) have been developed around the world. Gaining knowledge of how these organisms respond to various stresses in their aquaculture facilities has also become an important issue in the development of this green economy.

The response of sea cucumbers to stress factors is mainly ensured by the equivalent of vertebrate leucocytes, called coelomocytes in echinoderms. These cells are involved in a wide range of mechanisms, including the humoral response, wound healing and the clearance of biotic and abiotic foreign materials by phagocytosis or encapsulation processes [2]. But while we know that these cells have a global immune function, how they recognise and respond to stress factors remains poorly understood. To better appreciate these processes and assess the potential value of coelomocytes as sentinels of environmental stressors, we studied the response of these cells to lipopolysaccharide (LPS) exposure, an endotoxin produced by Gram-negative bacteria. Two species were investigated: the first species is Holothuria forskali, a temperate species living on European rocky shores; the second species is Holothuria scabra, a tropical species living in Indo-Pacific waters and aquacultivated for export to Asian countries. More concretely, 24 hours after injections of LPS, coelomocytes were collected from the body fluids, the proportion of coelomocytes was assessed to compare with that of control individuals, and differential RNA-sequencing analyses were carried out to identify marker genes that are up-regulated in individuals that have been exposed to the toxin. In parallel, morphological characterisation of coelomocytes was carried out to better define the coelomocyte cell types in these two species.

Our results revealed 6 main cell types in H. forskali and 5 in H. scabra. Changes in the coelomocyte concentration and proportion were highly variable between individuals, making it difficult to identify a clear stress response at the cellular level. Nevertheless, for both species, it was possible to discern a certain increase or decrease in the proportion of cells, suggesting a clear response for at least part of the cell populations, and in particular in the hemocytes of H. forskali. Finally, differential gene expression analyses revealed a wide diversity of immune genes that were overexpressed following stress. In particular, NOD-like receptors (NLRs) were particularly abundant, with around 300 genes annotated as NLRs and around 10% of them differentially expressed in endotoxin-exposed individuals. NLRs are important pathogen recognition receptors that induce inflammation and stimulate the immune response.

In summary, this study identifies the main molecular and cellular actors in the response to lipopolysaccharide exposure in holothuroids and could serve as a basis for developing tools for monitoring stress in these ecologically and economically valuable organisms.

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Health Monitoring; Stress Response; Aquaculture; Immune Cell; Echinodermata; Transcriptomic