Strategy & Science Plan 2020-2025

NIOZ
Royal Netherlands Institute
for Sea Research

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NIOZ Royal Netherlands Institute for Sea Research is part of the institutes organisation of NWO (Dutch Research Council).

INTRODUCTION

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About NIOZ

NIOZ Royal Netherlands Institute for Sea Research is the national oceanographic institute, and is the largest of the NWO (Dutch Research Council) family of research institutes. It principally performs academically excellent multidisciplinary fundamental and frontier-applied marine research addressing important scientific and societal questions pertinent to the functioning of oceans and seas. Second, NIOZ serves as national marine research facilitator (NMF) for the Netherlands scientific community. Third, NIOZ stimulates and supports multidisciplinary fundamental and frontier-applied marine research, education and marine policy development in the national and international context.

Royal NIOZ performs academically excellent multidisciplinary fundamental and frontier-applied marine research

NWO-NIOZ performs independent, often sea-going, fundamental, curiosity-driven and frontier-applied, (inter)disciplinary and transdisciplinary marine research. NIOZ integrates all relevant marine scientific disciplines in a holistic fashion with an emphasis on fundamental, process-oriented research. NIOZ connects researchers from the various disciplines, from across the entire knowledge chain, and brings researchers and societal partners together and provides sea-going research facilities. NIOZ invites partners from other research institutions, industry, the government and other societal organizations to contribute with their own knowledge agendas, and questions to the programming, realization, and co-funding of marine research.

Royal NIOZ operates from two strategic locations in The Netherlands, on Texel (TX), and in Yerseke (YE) and facilitates a Dutch research station at Sint Eustatius (the Caribbean Netherlands Science Institute, CNSI) in the NL Caribbean, in all with some 50 junior and senior permanent scientists, on a total of up to ~350 fulltime and part-time employees including students. Some twenty NIOZ Principal Investigators (PIs) have honorary or part-time chairs at, and teach at, the various national universities and HBOs (higher professional education) with marine programs. The NIOZ education officer accompanies and aligns the various BSc and MSc courses on a national level (integrated programs on the NIOZ website), and e.g., co-organizes the national Marine Masters Summer Course that NIOZ provides on an annual basis. NIOZ also facilitates maritime technological research by providing knowhow and sea-going and onshore experimental infrastructure. NIOZ is typically regarded as the natural (inter)national scientific portal to Wadden Sea, North Sea and Southwestern Delta research, and the Dutch Caribbean, besides having strength and globally acknowledged expertise in open ocean sciences including the deep sea.

Royal NIOZ operates from two strategic locations in the Netherlands, on Texel and in Yerseke

NIOZ research

In essence, in recent times, NIOZ research was and is inspired by three major notions: seas and oceans (1) *as unknowns*, (2) *in trouble*, and (3) *as source*. Oceanographic institutions focusing on these issues and the required fundamental, process-oriented, innovative marine research such as NIOZ clearly have a pivotal societal role. This most notably so in the upcoming UN IOC proclaimed 'Decade of the Ocean 2021-2030'. Hence, clearly, NIOZ Mission 2014-2019, called *Blue Planet* should be continued. We should push further in generating innovative, and ever more needed critical multidisciplinary expertise, fundamental knowledge, and new insights vital to underpin and improve longer-term sustainable and responsible marine management of our changing seas and oceans in an internal and external cooperative spirit. We framed this for 2020-2025 as *Our Ocean, Our Coast, Our Future*, further discussed below in terms of next level research.

Decade of Ocean Science for Sustainable Development 2021-2030

NIOZ Roadmap 2020-2025

In the following, coupled research and strategic goals for the coming five years are discussed along a format adapted from NWO:

- **Strategy & Research:** NIOZ as national hub for marine sciences and national research programs focusing on critical outstanding issues
- **People:** perspectives for marine researchers
- **Infrastructure:** accessible and sustainable marine scientific infrastructure
- **Nexus:** connecting marine agendas, science and society

Most NIOZ departments and facilities are located on the Wadden Island of Texel, with two key research areas at our doorstep: the unique tidal environment of the Wadden Sea and the economically and ecologically important North Sea.

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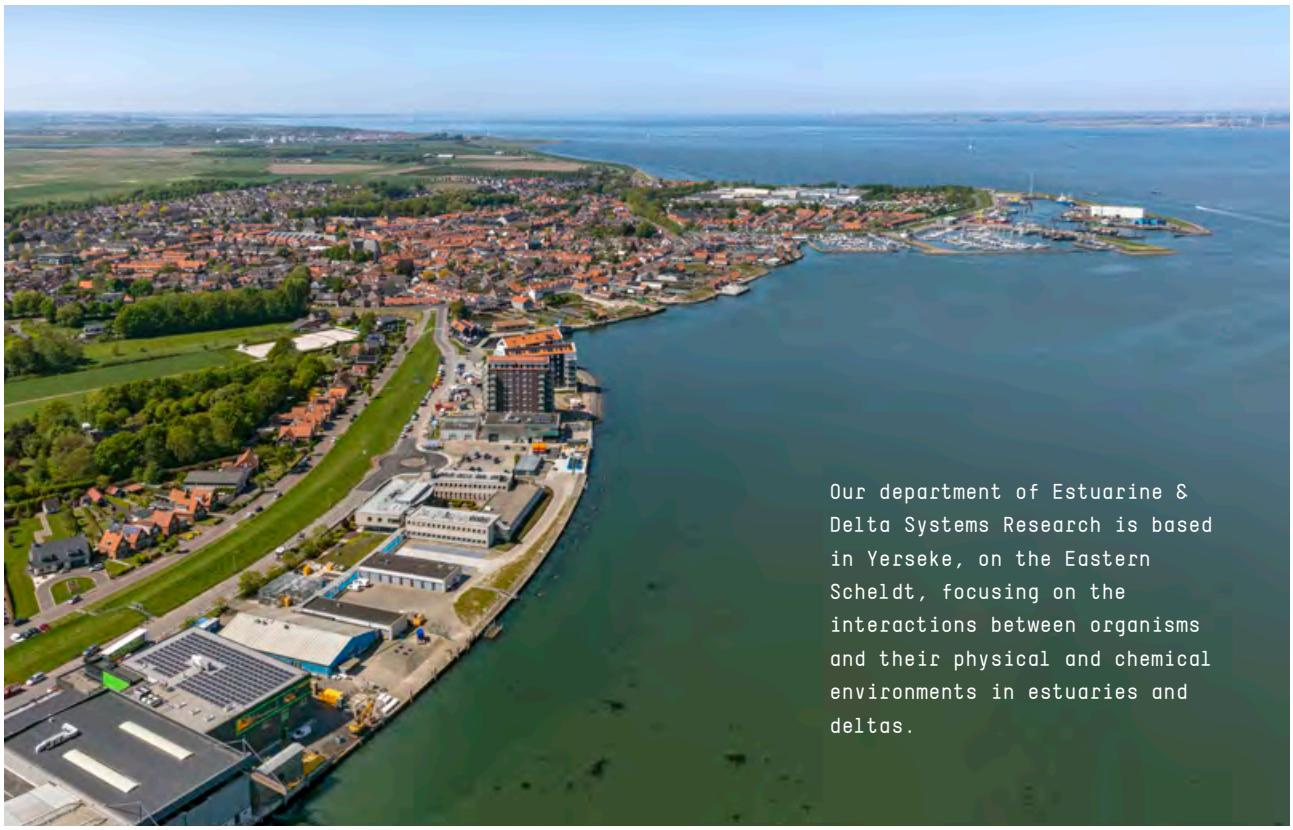

Our department of Estuarine & Delta Systems Research is based in Yerseke, on the Eastern Scheldt, focusing on the interactions between organisms and their physical and chemical environments in estuaries and deltas.

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STRATEGY & RESEARCH

NIOZ as national hub for marine sciences and national research programs focusing on critical outstanding issues – towards defining national marine research programs

Status Quo

Following a major reorganization in 2016, NIOZ now operates successfully from two strategic locations in the Netherlands, on Texel (TX), and in Yerseke (YE), and facilitates a research station on Sint Eustatius (CNSI) in the Dutch Caribbean, in all with some 50 tenured marine scientists, on a total of up to ~350 fulltime and part-time employees, including PhD students. Currently, NIOZ performance, including NIOZ NMF (~6 M€/yr) is based on a baseline NWO funding of ~20 M€/yr, with a gross overturn of ~35 M€/yr (= base funding, including Utrecht University contribution 2,4 M€/yr, and various research projects). NB that current basic-expenses need some 10% additional overhead from projects.

The research and other plans for 2020-2025 imply foremost to continue our successful activities, and to continue to improve various aspects, reaching targets and aims mentioned further below, along the lines of the NIOZ 2.0 concept. This will entail to continue seeking funding via 'regular sources' in competition, from national (NWO, Waddenfonds, etc.) to international (ERC, Horizon Europe) sources; say: 'business as usual'. Given its current (2.0) size, albeit often strained and overstretched, the organization has demonstrated its capability to perform very adequately indeed (cf. all reviews 2011-2018), and NIOZ has received the label *world leading institute* from external peer review. Importantly however, it should be noted that the largest portion of 'new science' of NIOZ is realized through the agreement between UU-NIOZ-NWO, providing 2,4 M€/yr since 2015. We expect this

situation to continue until 2025 at least. Another – rather ominous – important element is the concomitant necessary renewal of the national research fleet, including the replacement of the ~30 years old RV *Pelagia* and even older RV *Navicula* (see further below, 'infrastructure', for further information).

NIOZ Strategy

Regarding strategy, one critical element is the required size and funding levels of a national oceanographic institute with the ocean-going and 'national hub' mission, ambition, scope, and quality like NIOZ, in general. With its broad mission, carried out by merely ~50 scientists only, and the required technology, instruments, facilities and other support, NIOZ base line ('direct funding') budget appears limited when compared to e.g., our nearby EU partner institutions. One may argue that the same holds for the national marine research landscape in its entirety. While the national maritime industry, and applied marine research community is relatively large, the number of FTEs active in more fundamental oriented marine research (and teaching) at universities is comparatively small. This may be regarded as reflection of the (low) national funding levels for fundamental marine sciences in general. One way forward is to steer towards even further increasing coordinating and concentrating cooperative efforts, notably in the shape of rather formalized **national marine research programs**. The successful recent *Netherlands Initiative Changing Oceans* or NICO program (2018), with >40 national partner institutes, NGOs and industry participating is taken as a good example, leading the way towards more formalized national programs, coordinated by NIOZ.

The next step: towards building national research programs with Utrecht University

Besides continuing our '*business as usual*' scenario, considering the above, NIOZ strategy 2020-2025 will be directed towards establishing, at first together with Utrecht University (UU), a set of programs solving critical outstanding questions which we will announce as national marine research programs, attractive not only to UU, but also to many other partners, by

open invitation. Linked to our own research rationale and strategy, the strategic agenda of UU, and to the agendas of our various stakeholders, together, and coordinated by NIOZ, we can **increase scope, size and impact**.

With UU overall strategy, notably with the faculties of science and geosciences, we have a major interconnecting theme in their *Pathways to Sustainability* program, with most pertinent hubs like 'water, climate and future deltas', 'future food', but also towards 'industry with negative emissions'. Additionally, matches are within the climate adaptation institute UU-CCCA.

Necessary funding for such, to be formulated national programs, apart from UU-NIOZ funding, may be typically sought in programs such as NWA (the Dutch Research Agenda) and KIC (Knowledge and Innovation Convenant), besides Zwaartekracht and also ad hoc funding and contributions from cooperating partners. This besides EU and other major international sources. The UU-NIOZ constellation has been in operation for five years, and now is ready to fully expand on important mutual, and also critical national or even international strategic and scientific missions.

Together with principal UU researchers we will organize 'sandpit' meetings with them, and preferably other stakeholders, with the central aim to establish programs of wide national interest geared towards solving critical outstanding research questions. Inspiration may be found in already existing quasi-national initiatives, proposals and programs, and/or early stage NWA initiatives such as:

- NiT: NorthSea in Transition (NWA)
- EarlySea (sea level; NWA)
- C2OCEANS (coupled ocean/atmosphere/geosphere Carbon cycling; NWA)
- Origin of Life (NWA)
- Sustainable Delta's (NWA)
- SIBES
- Waddenmosaic (Waddenfonds)
- Global Flyway
- 'Zwaartekracht' program NESSC

Central in all of the above will be the NIOZ science plan. To coordinate the programs, we aim to employ NIOZ, UU and/or potentially PIs from other stakeholders, with logistic support from NWO-I/NIOZ, and overall coordination by NIOZ. This besides linking these to our existing thematic virtual centers of expertise, where fitting. Having experimented with these centers in the past years as connecting vehicles with stakeholders, we now are ready to push further, and to interconnect associated (national) research programs with various stakeholders, where feasible.

The second step: connections with strategic agendas of principal stakeholders and increasing participation

The NIOZ stakeholder group entails major universities with marine programs (e.g., besides Utrecht University (UU): University of Groningen (RUG), Wageningen University & Research (WUR), VU University Amsterdam (VU), University of Amsterdam (UvA), Delft University of Technology (TUD), University of Twente (UT), Radboud University, universities of applied sciences (e.g., HZ University of Applied Sciences), marine TO2 institutions (e.g., WMR, Deltares, Marin, parts of TNO), other types of institutions like KNMI and Naturalis, besides ministries and their departments, various NGOs, and industry. Connecting to their agendas is pivotal in establishing programs and governance on a national level.

Pertinent examples other than Utrecht University include:

- **Wageningen University & Research / Wageningen Marine Research (WUR/WMR):** connecting themes: 'Circular and Climate neutral', 'Food security and Water', and 'Nature inclusive landscapes'
- **University of Groningen (RUG)**: multiple connecting themes within the Groningen Institute for Evolutionary Life Sciences (GELIFES), and within ESRIG - Energy and Sustainability Research Institute Groningen, and connections with their GCA Global Centre of mitigation and Adaptation.
- **University of Amsterdam (UvA):** multiple connecting themes within the Institute for Biodiversity and Ecosystem Dynamics (IBED), like Ecosystems and Landscape Dynamics, Evolutionary and Population Biology, Freshwater and Marine Ecology, and Theoretical and Computational Ecology.
- **TO2/Deltares:** multiple connecting themes like e.g., Flood Risk, Ecosystems and environmental, Food Nexus, Delta Infrastructure, Transition to climate adaptation and Climate Change Impact

Associated with the above strategy, efforts will be directed towards further increasing the significance and visibility of NIOZ, its stakeholders, and national marine science in general. This not only by professional and efficient networking and outreach on behalf of the Netherlands community (cf. NICO), but also in terms of rethinking national organization and governance.

A possible final step, a 'spot on the horizon'

As a corollary of establishing national research programs, NIOZ shall at the same time explore pathways to possibly eventually formally connect the institute with major stakeholders through such programs, i.e. not only with UU. This, for example, via a governance structure comparable to our NWO sister institute Nikhef, wherein many national universities embrace the national research programs, and together commit to them in various ways, coordinated by and through the institute.

We shall investigate if, when and how such a new governance can be implemented. This may even involve potential expansion of the number of NIOZ sites, e.g. at campus locations of universities with major marine programs, all in close communication and cooperation with our stakeholders.

Note on (renewed) NIOZ centers of expertise

Historically, a large portion of our, and stakeholder efforts has been directed to the nearby Dutch marine systems like the North Sea, the Wadden Sea, the Southwestern Delta, but also the Dutch Caribbean. Given also widely recognized societal necessity to provide high quality fundamental and frontier applied knowledge towards large scale national and international engagements within these economically important regions, we established the concept of NIOZ virtual centers of expertise. For these efforts, and principally as external portals, we will maintain or (re)introduce the Wadden, Sea Level, North Sea, Delta and, and Mariculture (future marine food) centers of expertise. In addition, and linked to our research into a 'marine future', including adaptation and mitigation, recent times have also seen more and more NIOZ activities associated with so-called 'nature based solutions' projects and restoration efforts of various scopes and scales. Therefore, we establish a virtual NIOZ marine nature-based solutions and restoration center. Other centers may also involve setting up networks related to various NWA routes, and may also be solely fundamental in nature (e.g., focused on the 'origin of life' or marine bioinformatics).

Concomitantly, we aim to intensify our activities involving literally in-depth studies into the vast open oceans, with all stakeholders cf. the NICO program notably focusing on discovery and better understanding the interlinked biodiversity, geochemical cycling, and ecosystem architectures and

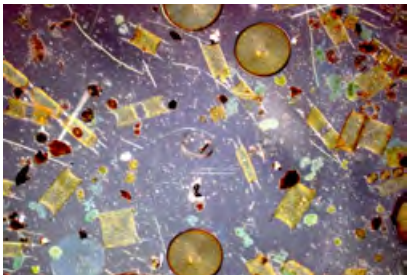
dynamics during the past, present and future (Anthropocene). Hence, for our ocean research including employment and further development of NMF, an NIOZ Ocean Science and Technology center of expertise may be expected to be instrumental, internally and externally, nationally and internationally, connecting to a multitude of stakeholders.

The centers have been, or will thus be installed in view of enhancing internal and external cooperation in general as a connecting external portal. These may, where feasible, be associated with the coordination of the to be established national programs, including e.g., ensuing proposals to NWA, EU and others. This besides the principal task of enhancing visibility and outreach. The centers are hence also a conduit to augment interaction with societal partners. Each center has at least one senior PI (initially from NIOZ, or UU) as its coordinator, who will bring together relevant expertise from all scientific departments and elsewhere when and where opportune, and will act as an ambassador of NIOZ on these topics.

Examples of possible NIOZ virtual centers of expertise 2020-2025 related to coordinating national programs may be:

Wadden systems

Delta systems

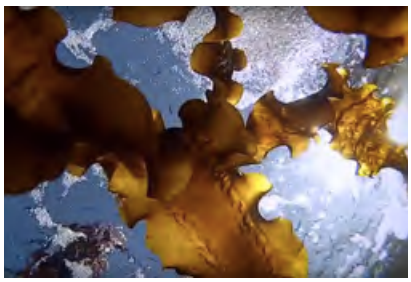


North Sea system

Sea Level

Caribbean Ecosystem Dynamics

Ocean Science and Technology



Sea Mariculture – Future Marine Food

Marine nature-based solutions and restoration

Marine bioinformatics

NIOZ SCIENCE PLAN 2020-2025

Critical outstanding issues concerning Our Ocean, Our Coast, and Our Future

Introduction

Our oceans and seas cover approximately 70% of our planet and over 50% of the human population lives near the coast or along river deltas. The oceans play a key role in ecological and biogeochemical processes at a global scale and in the climate system, yet remain the least known environment on earth.

Marine systems provide key ecosystem services including the provision of food, minerals and energy.

Marine systems (comprising the Open Ocean, shelf and coastal seas, and estuarine deltas) provide key ecosystem services including the provision of food, minerals, and energy, the sustenance of biodiversity and they facilitate transport. As a result, our coastlines and deltas host the economically most valuable ecosystems of our planet.

The complex functioning of marine systems continues to trigger scientific curiosity, but the realization that they are changing rapidly, not in the least because of human activity, renders their understanding also of utmost societal relevance. These global changes include overfishing, destruction of shoreline habitats, sea level rise, ocean acidification, deoxygenation, eutrophication, plastification, warming and natural-resource extraction for which new ways of responsible exploitation (including dealing with the food and energy transition) are required. The resulting alteration of biogeochemical cycles, food webs, ocean currents and atmospheric systems puts

The complex functioning of marine systems continues to trigger scientific curiosity.

marine life under increasing pressure. Unravelling the fundamental links and regionally varying feedbacks between the different components of the coupled global climate-marine (eco)system, both in the past and in the present is imperative for understanding how marine systems function.

The NIOZ science plan 2014-2020 (Mission Blue Planet) focused on two broad themes: 1) The changing ocean system, past, present and future, and 2) Adaptability of the marine ecosystem in a changing world. With these themes, NIOZ addressed important outstanding scientific challenges, while at the same time providing society and industry with fundamental knowledge to improve sustainable use and management of the sea, often in close co-operation with private and public sector partners.

While our understanding of the dynamics and biota in marine environments continuously improved, many questions still need to be answered to better understand the role of our oceans, coasts and deltas, and how these are influenced by current and future changes. This includes both an understanding of natural processes as well as the consequences of anthropogenic effects, such as improved knowledge of the impact of (relative) sea level change.

Facing current challenges in marine research requires a truly multidisciplinary approach.

In order to understand the physical and biochemical functioning of the various marine systems, including abiotic-biotic interaction, as well as the consequences of changes therein, we must better understand both local and global fluxes, notably land runoff, air-sea exchange, benthic-pelagic coupling and transport within the ocean, and including associated (micro) biological processes. Especially the different biological, chemical, physical and geological processes regulating these transfers must be better understood and predicted. Important lessons may be learned from Past Ocean dynamics, notably from warm intervals in the geological past that can be used as a future Earth analogue.

Facing current challenges in marine research requires a truly multidisciplinary approach - an intrinsic capability of NIOZ. This endeavor will require to further unravel processes across different scales in time and space, i.e. from past to present to future, from nanoseconds to millennia and beyond, as well as from the tropics to polar regions, from the surface to the seafloor, from the deltas to deep sea and from molecules to ecosystems (from past to future, from local to global, and from individual components to complex systems).

NIOZ aspires to perform excellent multidisciplinary fundamental and frontier-applied marine research.

As an NWO institute, NIOZ operates from the axiom that it is our joint societal responsibility to ensure that our Oceans and our Coasts will be in good shape for Future generations. Therefore, NIOZ aspires to perform excellent multidisciplinary fundamental and frontier-applied marine research addressing important scientific and societal questions pertinent to the functioning of our oceans and our coasts to ensure a sustainable future.

Framework

Our research and strategic vision 2020-2025 framework involves critical scientific and societal issues concerning all marine systems; it concerns Our Ocean, Our Coast, and Our Future.

Our Vast Ocean:
The (deep) oceans are the final frontier and constitute the largest unexplored areas of our planet. What is out there and what happens deep down? How has life evolved? Are there resources to be explored? And if so, how to do this sustainably and responsibly? What happens with pollution? What is going on far away in the ocean that affects our country and our planet? The oceans are the great climate regulators and hold more than 98% of all bioavailable carbon of the planet; minute changes in circulation can have larger effects than any human carbon (CO_2)mitigation effort. But what do we really know and understand of coupled oceanic-atmospheric carbon cycling?

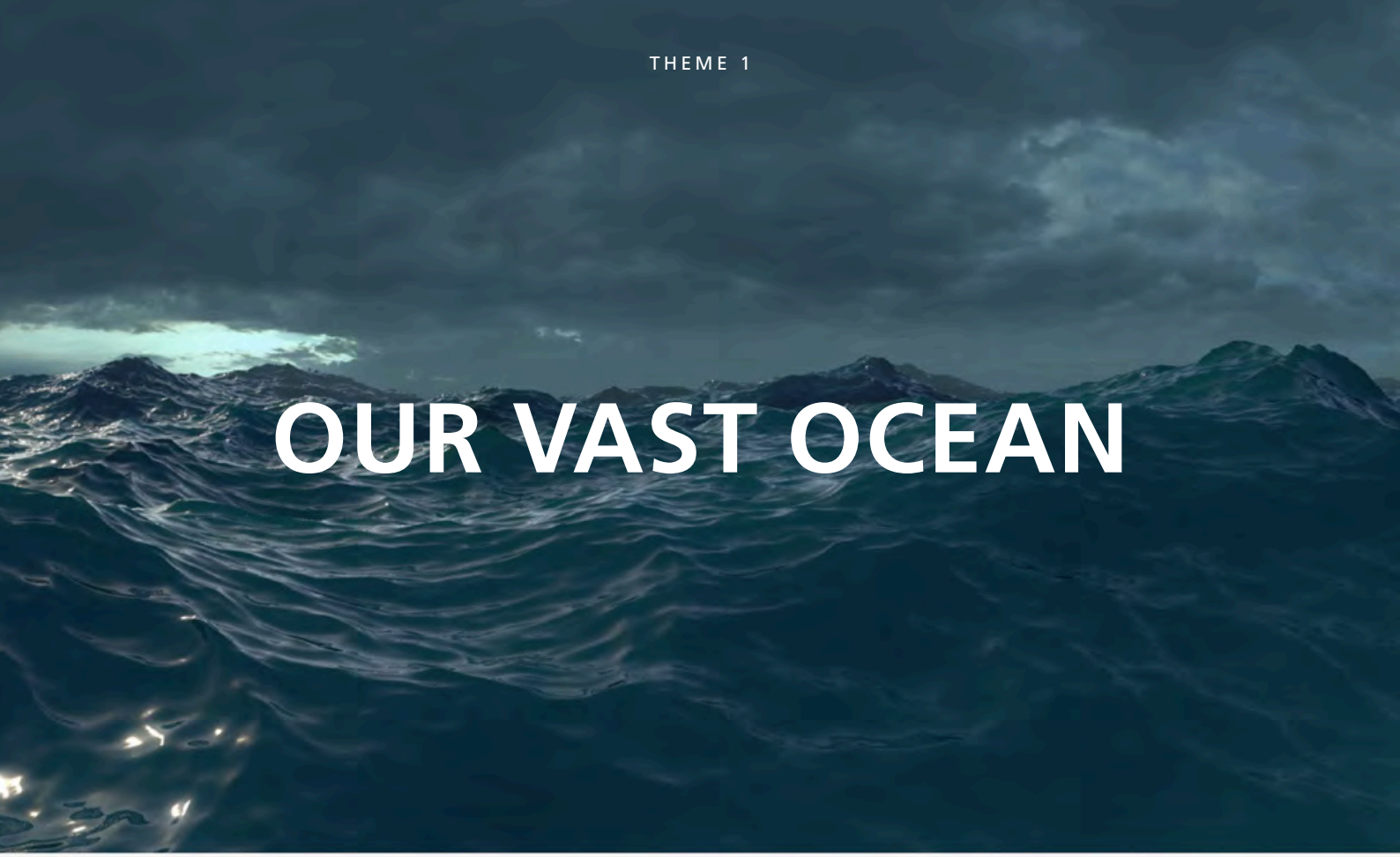
Our Fragile Coasts:
Wadden systems and deltas, but also coralline or rocky coasts globally are the 'front yards' of human settlements; they are highly diverse and experience the largest anthropogenic pressures. The consequences of these human and global pressures worldwide are poorly known, even in our own well-studied backyard, the North Sea, Wadden Sea and Dutch Delta. What is their resilience? Biodiversity? How do their changes impact society? How can we take responsible ownership? What can we learn from global comparisons?

Our Marine Future:
The ocean and coastal seas are changing rapidly. What can we expect in the future? How can we learn from the past? How do marine systems and communities evolve? How can we make sustainable use of the seas? How can we assist in mitigation and adaptation to the effects of climate change?

In the Netherlands, NWO-NIOZ, the national oceanographic institute, in cooperation with Utrecht University, and connecting numerous (inter)national stakeholders, is uniquely positioned to contribute to answering these important questions for society and industry by performing scientifically excellent sea-going research.

Concluding remarks

The above is to be regarded as the NIOZ research rationale or Science Plan 2020-2025, and will be taken as inspiration for future NIOZ marine research projects in general, and including the to be established set of national marine research projects. Importantly, it paves the way for both the 'business as usual' competitive programs and projects, as well as national programs, also in view of maintaining a solid basis for individual - to group-based scientific excellence, a conditio sine qua non for NIOZ.



OUR VAST OCEAN

Outstanding issues

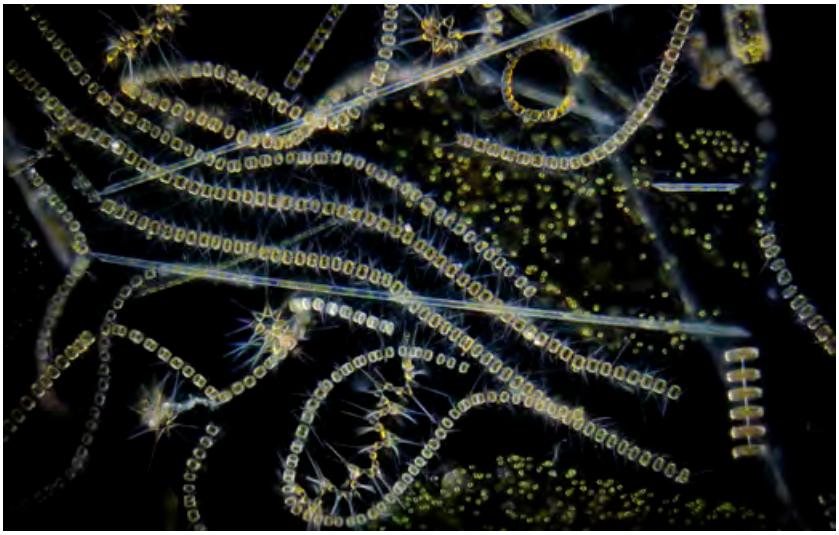
The Ocean represents the biggest biome and reservoir of biodiversity on Earth. Deep oceanic waters, deep-sea sediments and hydrothermally active sites at the sea floor have been suggested to represent the most probable birthplaces of life on earth. The Ocean plays a key role in the climate, storing CO_2 and heat; changes in ocean circulation have, and had, large impacts on global climate in (paleo) history. Note that the only way to study and assess the role of (the slow, > thousands of years) oceanic circulation is to link actuo-observations with paleoceanographic studies. Moreover, over geological time, ocean sediments have accumulated changing signatures of organisms, their ecosystems and environmental conditions.

Today, the ocean environment is changing rapidly as a result of external pressures, which will affect the diverse but little characterized organisms playing an important role in marine food chains and the ocean's carbon cycle. Therefore, it is at the core of the interest of researchers at NIOZ to contribute to the characterization and understanding of the changing ocean environment, its various biotic and abiotic components, and both today and through its geological history. This is carried out by using a combination of information from biological (e.g. biomolecules, genomic data), chemical and physical observations, as well as through modelling efforts. The integration of this data is key for our understanding and shaping of Earth's future. In the following paragraphs, we highlight selected goals, which researchers at NIOZ aim to study from multiple angles during the coming years.

Q1

QUESTION 1:

Characterize the still hidden and **unexplored world of marine life** to learn about the origin and diversification of diverse life forms, their ecosystems, and role in sustaining food webs and the diversity of their biomolecules.



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Among others, we seek to address fundamental questions such as "How did life originate, evolve and diversify through time?", "What drives marine food webs and how do marine ecosystems function?", "How can we use knowledge from these diverse marine life forms for biotechnological applications, and for developing sustainable ways for the recovery of much needed resources?"

A first step to study these questions is to catalogue the organismic diversity of marine life with a focus on the microbial diversity (including viruses, archaea, bacteria, and unicellular eukaryotes) as well as macro-organisms (incl. fungi, sponges, corals, seaweeds) and reconstruct their evolution in light of the geochemical history of Earth. This not only allows us to obtain a deep understanding of the fundamental principles of life and to deepen our insight into its origin and diversification, but also builds the basis for predicting how organisms will respond to future changes. This understanding is the crucial basis that is needed to mitigate and buffer the impact of human induced changes in marine systems, and for designing ways of protecting marine life in the context of global change.

In addition, we aim to determine the functional role of marine life, organisms, in the various different marine waters by investigating their diverse lifestyles and roles in food webs. Among others, this will enable us to determine and identify which compounds are used by the different microbes in the ocean. For instance, a particular focus lies on pinpointing organisms that can obtain energy through the degradation of pollutants, such as complex chemicals derived from the ever-rising amounts of plastics or oil spills, and to subsequently shed light onto how these microbes achieve such important tasks.

Another focus lies on identifying the interactions that microorganisms are involved in, including their impact on macro-organisms. Indeed, survival of most marine life in nutrient-limited oceanic environments, is dependent on symbiotic relationships with other organismic groups. A prominent example is represented by corals, many of which depend on photosynthetic eukaryotic microorganisms (zooxanthellae) for survival. Reef-building corals and other ecosystem engineers are particularly susceptible to increasing ocean temperatures and carbon dioxide levels, which can lead to coral bleaching through the loss of photosynthetic symbionts. We investigate these and similar symbioses to be able to get a systematic understanding of marine life, which is essential for being able to disentangle and predict the various feedback loops – life and death in the oceans – that occur in response to changing environments.

Finally, we aim to define the biological, physical and chemical parameters that shape the adaptability and population dynamics of marine life and populations.

Q2

QUESTION 2:

Unravel the components, nature, and functioning of **marine biogeochemical cycles** to improve our understanding of major nutrient cycles, with a strong focus on the **carbon cycle**.

The oceans are the great climate regulators and hold more than 98% of all bio-available carbon of the planet; minute changes in circulation can have larger effects than any human carbon (CO_2) mitigation effort. But what do we really know and understand of coupled oceanic-atmospheric carbon cycling? To reach this goal we address questions such as “What is the origin of major biogeo-chemical cycles that are driven by thousands of different microbial species and physicochemical reactions?”, “What is the role of these biogeochemical nutrient cycles in global climate change?” and “How can we use this knowledge to contribute to a sustainable Earth?”
Marine biogeochemical cycles are part of, and sustain ecosystems by

contributing to the recycling of nutrients. Furthermore, they influence the composition of the atmosphere and thereby play an important role for the entire biosphere. The carbon and nitrogen cycle are of particular importance in light of global climate change as some of the most potent climate gasses such as CO_2, CH_4 and N_2O are intermediates in these cycles.

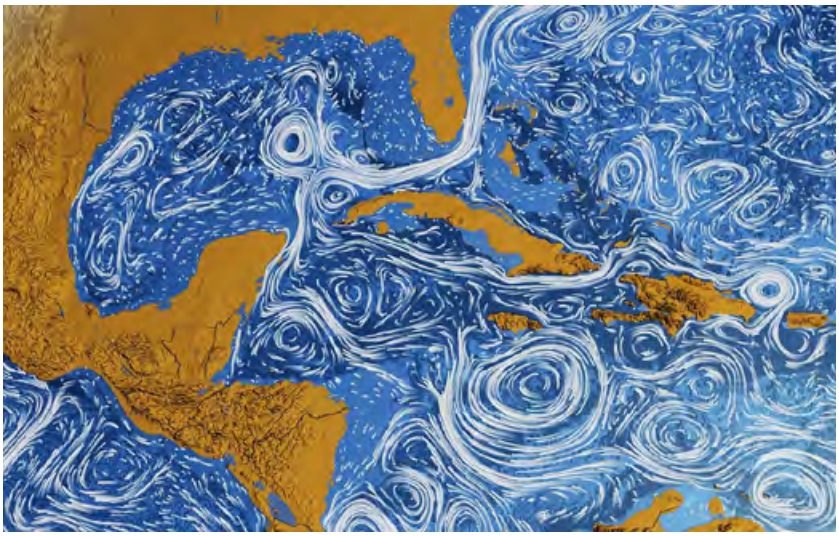
Terrestrial ecosystems are predominantly powered by sunlight, i.e. by photosynthetic organisms, most importantly plants, which can harvest sunlight and convert it to chemical energy: this is the basis for the functioning of food webs on land. Similarly, a large fraction of marine ecosystems is sustained through autotrophic production of biomass by photosynthetic algae & seaweeds and microorganisms. Yet, most regions of the ocean are in eternal darkness, but sinking particles can deliver biomass to deeper water masses contributing a large fraction of energy that can sustain ecosystems in the deep sea. Nevertheless, another fraction of biomass seems to be derived from chemo-autotrophic organisms that are able to contribute to biomass production in the absence of sunlight by harnessing energy from chemical (inorganic) compounds. Currently, the varying contribution of these different processes to sustaining deep-sea ecosystems is debated. By studying the key players of biogeochemical cycles in marine waters as well as the dynamics (including vertical and horizontal exchange processes) that mediate the physical and chemical cycling of nutrients, we seek to further our understanding of the processes shaping marine nutrient cycles.

Furthermore, the characterization of pelagic food webs and function, including biotic and abiotic connectivity and the elucidation of the relationships and interplay of biological and chemical components, provides the basis for deciphering the role and resilience of major nutrient cycles such as the carbon and nitrogen cycles in the ocean and their impact on global change.

QUESTION 3:

Q3

Define connected physical and chemical processes that characterize the ocean through time and space to inform the **role of the ocean for our global climate** and help finding solutions to human-induced changes.

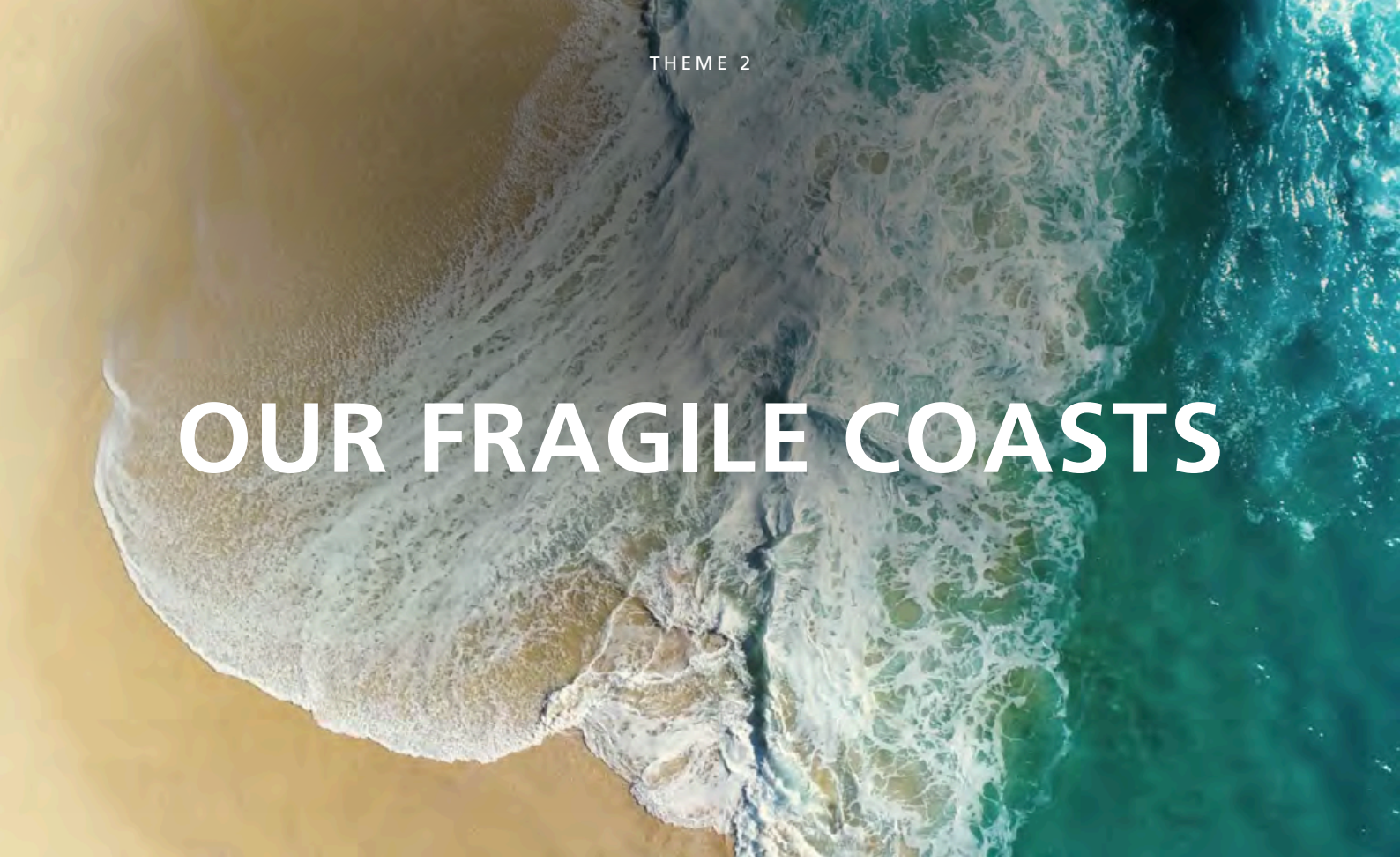


This aspect of our work seeks to inform questions such as: "What are the controls on large scale circulation patterns and mixing regimes, how do these change in space and time, and what are the consequences for our climate?", "What is the influence of atmosphere-ocean interactions on ocean primary productivity?" and "How can we develop and apply proxies that allow us to reconstruct Earth's conditions from geological record?"

Our ocean is an extremely complex system and is always in motion. The global ocean circulation, particularly in the Atlantic Ocean, is a major player in modulating the global climate through changes in heat transport. Yet, the interplay between physical processes at different scales, from turbulence to the gyre circulation, is poorly understood. Old paradigms, like that of the ocean conveyor, need to be replaced with new understanding of connectivity through mesoscale processes. Understanding these natural variations, as well as the interplay and feedback mechanisms between global change induced climate variations and oceanic transport and overturning mechanisms, is thus a major research focus at NIOZ.

Primary productivity in the ocean, and thus its capacity to bind carbon dioxide from the atmosphere, is strongly dependent on the transport of nutrients. Riverine input and surface runoff are huge sources of nutrients and allow coastal systems and shelf seas to bloom. But in the deep ocean other important processes provide nutrients. Upwelling and internal waves can provide these from the deep ocean to nutrient limited regions. Furthermore, Aeolian deposition of dust, which has been blown off from the continents and sometimes travelled thousands of kilometers before it settled into the sea, may be a key player that controls ocean-atmosphere carbon dioxide exchange. At NIOZ we aim to understand how these mechanisms work, how important they are in modulating ocean productivity and climate, and to define ways how these could be used to mitigate undesired changes.

Because the ocean is of utmost importance in modulating climate, providing food and services of societal relevance, NIOZ also aims at deciphering variations of climate and other environmental parameters in the past. Depending on conditions such as temperature or nutrient availability, different types of microorganisms thrive in the ocean. When these organisms die, their remains sink to the ocean floor and get buried in sediments. Parts of them may be preserved for millions of years – molecular fossils. Similarly, environmental conditions may also leave a physico-chemical imprint in minerals. Analyzing communities from the past in sediment cores, or analyzing mineral phases on the atomic level, thus allow to reconstruct how the environment was at the time when these organisms lived and/or minerals were deposited. Knowledge of such past variations are the key for understanding the Earth system at present and for predicting its future.



OUR FRAGILE COASTS

Outstanding issues

Wadden systems, either or not as part of deltas, are located at the physical intersection between terrestrial and marine environments. The Netherlands, for example, is in post-glacial times shaped through the interplays of wind, land and sea, rivers, and brackish deltas, the Wadden Sea and North Sea systems, and human activities.

Coastal zones face questions regarding climate and anthropogenic influences, sea level rise and resilience to these changes, and how these changes in turn impact the humans inhabiting these areas both in the Netherlands, in other parts of the Kingdom (e.g., the Caribbean), and globally.

NIOZ performs scientific research that improves our understanding of the ecology of marine and estuarine systems and that answers the questions about how humans affect these environments. Seen in this light, coasts and deltas represent an active front line and are highly sensitive in the face of changing conditions, heavy exploitation, and marine policies.

Researchers at NIOZ build insight and understanding of these fragile ecosystems, with research across a range of connected fields from physics to behavioral ecology.

Q4

QUESTION 4:
How does the interaction between habitats and species communities affect the **stability of coastal ecosystems**?

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Coastal systems including estuaries and deltas form the link between terrestrial and marine habitats and are highly dynamic marine systems. In the physical realm, tidal changes constantly shape and destroy geological and ecological structures, while in the biological realm species utilize but also build and influence such structures, often in specific life-stages.

The productivity of resources or prey species depends on the abiotic conditions present in the system. To understand the dynamics of species (such as the commercially interesting flatfish species or e.g., the widely appreciated birdlife), we need to understand how the individual organisms are impacted by their changing abiotic and biotic environment and vice versa.

While surrounding conditions influence how organisms can use their environment, some species are able to shape their habitat themselves (ecosystem engineers). Species such as benthic microalgae, mussels, corals, sponges, and salt marsh grasses can enforce positive feedbacks where their presence in the habitat provides structure, and ensure the stabilization of habitat and persistence under changing physical pressures.

Such engineering activities facilitate the persistence and coexistence of other species that rely on the biogenic structures. Research focuses on how these feedbacks can arise and remain, and how changing conditions impact the ability of organisms to fulfil these functions for the ecosystem.

Q5

QUESTION 5:
How do organisms respond and adapt to a **changing coastal environment**?

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The Wadden Sea is a UNESCO heritage site, the Eastern Scheldt a National park. In spite of many levels of formal protection and management, all Dutch coastal systems, including Caribbean coasts, are intensely exploited and impacted by fishing, sand nourishments, protective engineering structures, pollution, dredging, aquaculture and energy production. All these forms of exploitation interact, their potpourri affecting the natural ecosystem processes.

NIOZ builds on a long tradition to understand the resilience of individual organisms, as well as of populations, communities, and ecosystems. Salt marshes and macrofauna, such as oysters, shape the landscape by trapping sediment and changing the topography, or by making the sediment sandier or muddier, and they adapt to changes in sea level and sediment supply. Benthic production capacity supports exploitation of harvested species (fish, shrimps, and mussels, for example), but is also the basis for survival and reproduction of higher trophic levels, such as the migrating shorebirds that biotically connect chains of coastal ecosystems including the Wadden Sea and Delta.

We study how environmental changes affect the energy flows and ecological processes within the context of trophic interactions, ranging from biogeochemical to species interactions, and ultimately evolution. This research includes both spatial (ranging in scale from millimeters to hundreds of kilometers), and temporal dynamics (ranging from tidal through seasonal to centennial periods). We develop and use multidisciplinary state-of-the-art techniques and equipment, such as spatial surveys, temporary and permanent measurement stations, and numerical modelling. With our research we aim at a deeper understanding of species interactions and habitat requirements in coastal systems across different levels of ecological organization. That is: to understand environmental effects on individuals (behavior), populations (abundances and adaptations), species (coexistence and diversity), and communities (structure). We explicitly link the patterns at large scales (species communities) with adaptations at small scales (individual organisms), identifying and studying the feedbacks driving their ecological interactions. We explore the possibilities, as well as limitations,

of organisms to adapt to environmental change with its effects on population dynamics and community structures. Using empirical data, both from experiments and from long-term data, we study this interplay in detail, over large spatial and temporal scales. The empirical insights work in tight connection with theoretical approaches, predicting and understanding resilience, state shifts, and evolutionary dynamics, which allows a comprehensive understanding of ecological interactions in a changing coastal system.

Q6

QUESTION 6:

How are coastal marine ecosystems **connected**?

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Coastal areas are linked all over the world, by the seasonal visitation of the shorebirds which migrate between Western Africa and the Arctic. Similarly, many fish species connect different marine regions and even freshwater and marine habitats. Changes in coastal systems, due to natural processes and anthropogenic impacts, require our understanding of food web structure and dynamics, and how such systems are connected biologically and abiotically.

NIOZ research pays attention to the connection between intertidal, shallow regions and deeper marine regions through the utilization of these habitats for nursery areas versus spawning areas in fish, for example. More examples can be found in the exploration of shallow and deep oceanic physical processes and dynamics relevant for coastal and deep-sea futures, as well as the sustainable exploitation of the deep. Movement is crucial to almost any ecological and evolutionary process. Studying the key processes affecting movement at different spatial and temporal scales, will generate understanding of how organisms react to environmental change, such as habitat fragmentation, climate change, biological invasions etc. Movement and migration of animals and plants act as important transport routes of nutrients, energy and information, both within and between ecosystems. Long-distance movements and migrations even connect ecosystems on a global scale. As such, moving organisms can carry over ecological effects obtained in one (part of the) system to another.

OUR MARINE FUTURE

Outstanding issues

In consequence of climate change and ever-increasing human pressure, estuaries, seas and oceans are rapidly changing, often at a rate with which humans can hardly keep up.

The importance of these environments for human societies makes it urgent that the insights obtained in the functioning of marine systems are efficiently translated into predictions, approaches, scenarios and methods that can help managers and policy makers to ensure optimal and sustainable future use and management of marine ecosystems.

To this end, NIOZ research output advances a range of scientific approaches and methods in a wide number of fields.

Q7

QUESTION 7:
How to assist **mitigation and adaptation** towards climate change and ensure safety, health, and well-being in urban deltas and coasts?

Deltas and coasts are attractive areas to live in and therefore densely populated. However, they are threatened by a variety of human impacts, sea level rise and climate change at high rates of change. Dealing with these threats requires a solid understanding of the complex interactions between physical, biological and chemical processes and human interventions which often affect critical processes like e.g., rates of subsidence and loss of ecosystem services. NIOZ research targets to improve the management strategies by following a four-step approach to addressing and mitigating these challenges:

Observing ecosystem responses – Based on observations from the field and long-term data sets of remote sensing, ecosystem responses to changes and (human) interventions are assessed; a particular integrative class of observers is formed by the shorebirds that connect various Wadden and other marine systems in the course of their annual cycles and connect the marine realm with the fastest changing biota on Earth, the high arctic tundra. The capacity to instrument these birds with microtags enables them to tell us interpretable stories of change.

Understanding drivers – Based on a sound experimental methodology and fundamental insights, we develop better understanding of the complex interactions among physical, biological and chemical processes, and human interventions, and how they determine key marine processes such as ecosystem establishment and restoration, and the persistence of ecosystem services.

Predicting impacts – Using our arsenal of techniques ranging from evidence-based in situ measurements, via fundamental knowledge combined with well-constrained experiments, to computational modelling techniques, we aim to predict how marine ecosystems will develop under pressure. Examples include human mitigation measures, continued pressure from expanding economic activities, continuing sea level rise, as well as assessing and predicting impacts of loss of ecosystem services in deltas;

Optimizing solutions – We aim to contribute to designing a range of techniques to mitigate both ongoing human impacts, improve nature

restoration and compensation (e.g. building with nature), provide insights in the growth and applications of marine biomass, and develop modern approaches for food production to ensure human health, safety and well-being, in marine ecosystems.

Q8

QUESTION 8:

How to forecast and project **impacts of human activities** on marine systems?

Human activity is now affecting the seas and oceans and their ecosystems on an unprecedented scale. Fundamental NIOZ science will contribute to improving our knowledge of system-resilience and effects, improved environmental management, better understanding impacts of (regional to global) environmental change, and contribute to the development of mitigation pathways. Amongst others, these human impacts include:

Blue growth – The EU Blue Growth Agenda targets sustainable use of the marine environment such as aquaculture, fishing, mineral mining, oil and gas extraction and construction of windfarms. Planning for a sustainable future, rather than reacting to problems, requires fundamental knowledge of the functioning of marine systems and the potential (cumulative) impacts of present and future human activities;

Sea-level rise and nature-based coastal defense – Regional sea level change poses challenges to coastal safety; we explore the possibilities of ecosystem engineers and 'building with nature' options in which natural processes are used to improve coastal protection. Part of this to explore the windows of opportunity of e.g., salt marsh growth and how sea level change affects them.

Oceans as a buffer for CO_2 – Probing the dynamic biogeochemical cycles, including relationships with vertical and horizontal exchange processes, changing pelagic food webs, benthic-pelagic coupling, and ecological consequences, through combining gathering field data and modelling. In this context, notably the role of the carbon cycle is central in our research, since it co-determines, and mitigates, the rates of change of atmospheric CO_2.

PEOPLE

Perspectives for marine researchers

NWO institutes like NIOZ are, and should remain attractive and inspiring places for students, junior and more senior researchers. One of our continuing roles is indeed to operate as a *breeding ground* for talent that may subsequently move on to other research institutions, academia, industry or other societal organizations, nationally and internationally.

One of our continuing roles is to operate as a breeding ground for talent.

With NWO, NIOZ is an institute that gives high priority to a sustainable environment. We contribute to such an environment by aiming for e.g., a paperless office, avoiding unnecessary use of plastic, making its buildings as climate neutral as possible and encouraging employees to use public transport.

As mentioned, a dedicated NIOZ education officer is our contact with our academic partners and monitors and aligns national BSc and MSc courses in various aspects of marine sciences, and brings them together on the NIOZ website. Furthermore, this person coordinates and co-organizes the annual national Marine Masters Summer Course that NIOZ provides and facilitates BSc and MSc research internships at NIOZ.

NIOZ also facilitates training of students and young professionals in research-analytical, to maritime technological education by providing on-site internships for the respective educational programs, including know-how and access to sea-going, and onshore state-of-the-art analytical and

NIOZ facilitates training of students and young professionals in research-analytical, to maritime technological education.

experimental infrastructure. In terms of PhD programs, together with NWOI, and with the pertinent universities, we will continue to augment the number and quality of relevant courses. In addition, with NIOZ HRM, the dedicated NIOZ PhD information and monitoring program will be updated and upgraded.

Many tenured staff of NIOZ (~20 Principal Investigators) hold an appointment at a university as well, where they also teach and inspire the next generation of marine researchers.

NIOZ will further strengthen its relationships with other research institutions and will facilitate exchanges, guest researchers and shared appointments when and where feasible.

Good research not only requires good researchers but also well-trained, responsible, inspired, cooperative and efficient supporting staff. As part of NWO-I, NIOZ aims to remain attractive as an employer, and as national catalyst of marine science in general, and the community at large. This can be achieved not in the least by providing a cooperative, diverse, safe, comfortable, and friendly working environment, with ample opportunities to continue to develop in all career phases.

NIOZ provides a cooperative, diverse, safe, comfortable and friendly working environment.

NIOZ also prioritizes the fostering of a culture of gender awareness and addresses unconscious biases in decision-making processes, to ensure that (gender) diversity is increased in all ranks among faculty appointments and in leadership positions. This is also manifested through the co-signing by NIOZ of the infra-NWO institutes-declaration to the same effect.

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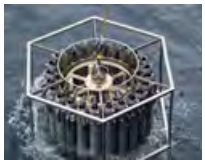
INFRASTRUCTURE

© J. Sinner

Accessible marine scientific infrastructure

As an NWO institute, and as amply noted above, NIOZ makes available its knowledge and state-of-the-art analytical and sea going facilities at-large for the entire scientific community working in or with marine sciences in general in various ways, nationally and internationally. We commit to constantly updating and upgrading our analytical, technical and logistical capabilities where and when needed and feasible. We do this while coordinating with our various national and sometimes international research partners so that large scale equipment and capabilities are most effectively distributed (operationally and financially).



We commit to constantly updating and upgrading our analytical, technical and logistical capabilities.

Within NIOZ, field- and sea-going analytical and research equipment infrastructure is operated through National Marine research Facilities (NMF), while the bulk of the shore-based analytical and experimental facilities is housed within the most pertaining departments (see further below). Extremely important in the coming years is the notion that our current research fleet is aged, and well beyond its practical and economic lifetime. The urgent need for replacement has been noted throughout the past decade by every single national and international review panel.

Together with NWO, the taskforce **fleet replacement** is now taking all appropriate technical and strategic steps to guarantee the viability of the Dutch marine science community in order to secure ocean and sea-going expeditions for the Netherlands in the future. Current planning includes

Within NIOZ, field- and sea-going analytical and research equipment infrastructure is operated through NMF.

having the new ships in operation by 2022. The new ships will be geared towards low to zero emission in due course, and will serve the marine and maritime (technical) communities alike, also with the aim to further building bridges between them.

© C-JOB

NIOZ NMF 2020-2025

Marine research facilities and services for the Dutch marine scientific community

NIOZ continues to focus on the development of marine technology for the improvement of our research capabilities.

Sea-going marine research infrastructure plays a central role within the NIOZ organization. It is a necessary precondition for our prominent (inter) national research. In this respect, not just the 'hard' equipment and facilities are important but also the technical support and a professional environment where brainpower is concentrated and people meet. Our marine infrastructure brings together researchers from different disciplines, countries and cultures.

Within NIOZ, the National Marine research Facilities (NMF) department maintains a range of facilities and services, including research vessels and equipment, for the sea-going marine science and maritime community in the Netherlands. We provide researchers working in the Netherlands with ships, state-of-the-art sea-going equipment, data management and qualified personnel to operate these facilities.

NIOZ continues to focus on the development of (notably autonomous) marine technology for the improvement of our research capabilities. The reason for this also being that research infrastructure encourages innovation at technology companies that are involved in its development. The development and exploitation of our research infrastructure also contributes meaningfully to the training of specialized personnel. Consequently, research infrastructure ensures cross-fertilization with positive scientific and societal results.

Connecting marine agendas, science and society

In this Strategy and Science Plan 2020-2025, it is often noted that NIOZ aims (to continue and intensify) to connect national and international researchers from the various disciplines associated with marine sciences, from across the entire knowledge chain, bringing them and societal partners together. Through the to-be-established national research programs, NIOZ, with Utrecht University (UU), invites partners from other research institutions, industry, the government and other societal organizations to contribute with their own knowledge agendas, and questions to the programming, realization, and co-funding of marine research.

Strategic and scientific alliances have been formed between NIOZ and the various national marine/ maritime research institutions

Setting the stage, NIOZ recently established and revitalized existing MoUs with many national universities (UU, RUG, UvA, VUA, Radboud University). This included e.g., conditions associated with enrollment of NIOZ PhDs in the graduate schools and programs of these universities, installation of chairs in marine sciences of NIOZ PIs, and cooperation in teaching and research. As mentioned, because of NIOZ high quality research and leading national role, Utrecht University was prompted to support the institute through long-term substantial financial contribution aimed at intensifying UU-NIOZ collaboration, and strengthening national fundamental marine science research in general. Following a formal agreement between UU, NWO and NIOZ, a first five-year program started 2016, involving formal affiliation of NIOZ scientific productivity with UU, but also involving other

universities where opportune and feasible. We will formulate a new, next five-year research and implementation plan with our UU focused on establishing national research programs, open to other partners for 2020-2025.

Strategic and scientific alliances have also been formed in recent years between NIOZ and the various national applied marine/maritime research institutions, including e.g., the maritime technology Institute MARIN, and Wageningen Marine Research, (or WMR; formerly WUR-IMARES), Deltares and TNO. The latter also within the so-called MUST consortium (Netherlands Marine consortiUm of Science and Technology) for Global Ocean Innovation, to further expand and promote our valorization programs and collaboration. In addition, NIOZ 2.0 includes a dedicated external industrial liaison - 'business development' function; by now, NIOZ has become a well-known, and appreciated partner in the national economic priority areas ('topsector') domain for valorization, most notably with the subsectors 'delta-technology' and 'maritime' of the sector 'water'. We aim to conceive and link national programs with UU to the various research agendas of these stakeholders, thus connecting and leading large consortia of academic and societal partners.

NIOZ has aligned itself with recently established institutions focusing on climate mitigation and adaptation

Furthermore, NIOZ has aligned itself with recently established institutions focusing on climate mitigation and adaptation: (1) the Erasmus University Rotterdam-University of Groningen based 'Global Center of Adaptation' GCA, and (2) the Utrecht University initiative 'Netherlands Consortium on Climate Change Adaptation' CCCA, and wishes to make significant contributions to the goals of these centers, in concert with all partners and stakeholders, from academia, TO2, industry and NGOs. In addition, NIOZ has meanwhile become a well-established partner in various governmental policy-making (inter)departmental steering committees (e.g., IDON North Sea spatial planning, and 'Living Oceans' committees, both Ministry of Infrastructure & Water Management and Ministry of Agriculture, Nature, and Food Quality, among others), coordinating with, and connecting to all conceivable stakeholders. This function needs to be further strengthened in the coming period, also in the frame of the envisaged national research programs.

In summary, NIOZ will have an open attitude and aims to actively connect all actors, expertise and agendas operating in the marine realm, internally and externally, locally, regionally, nationally and internationally. Together with UU, a principal first goal is to establish national research programs, attractive and open to the entire community; with both in-kind support, as well as various degrees of co-funding.

The two NIOZ locations

Indeed, NIOZ Yerseke (YE) is strategically located in one of the epicenters of actual and near future effects of climate change in the Netherlands: the Southwestern Delta. Specifically, its department of Estuarine and Delta Systems research is currently, and will continue to be, engaged in gathering

momentum towards the formation of a (virtual) Southwestern Delta center of expertise, with regional partners like Province, WUR/WMR, UU, Hogeschool Zeeland (HZ), University College Roosevelt (UCR), local companies and industries, and the Belgium (Flemish) colleagues at VLIZ, and at the universities of Ghent and Antwerp. An initiative fitting well with strategic planning of cooperating institutions and ministries, as well as with the Blue Route of the Dutch National Research Agenda NWA, and combined NIOZ-UU interest. In this context, NIOZ YE will continue to develop and expand its experimental labs and other facilities, in- and outdoors, in the period 2020-2025 for further stimulation of (inter)regional cooperation; its 'Nexus role'. Our larger facility on the Wadden Island of Texel, including Sea Port Texel, is equally strategically located at one of the strongest, and most dynamic tidal inlets in Northwestern Europe, on the edge of the Wadden and North Sea. Recent positive decisions regarding co-financing the dike-elevation project of the NIOZ Wadden Sea dike by NWO, safeguarding infrastructure for the future, also allow for further investments in NIOZ Texel (TX) research facilities, in- and outdoors (e.g., including mariculture) in 2020-2025. Notably the NIOZ department of Coastal Systems research on Texel has strong ties with stakeholders and other societal parties associated with in the Wadden Sea system as a whole, including many local and regional links, many of which with the growing mariculture activities.

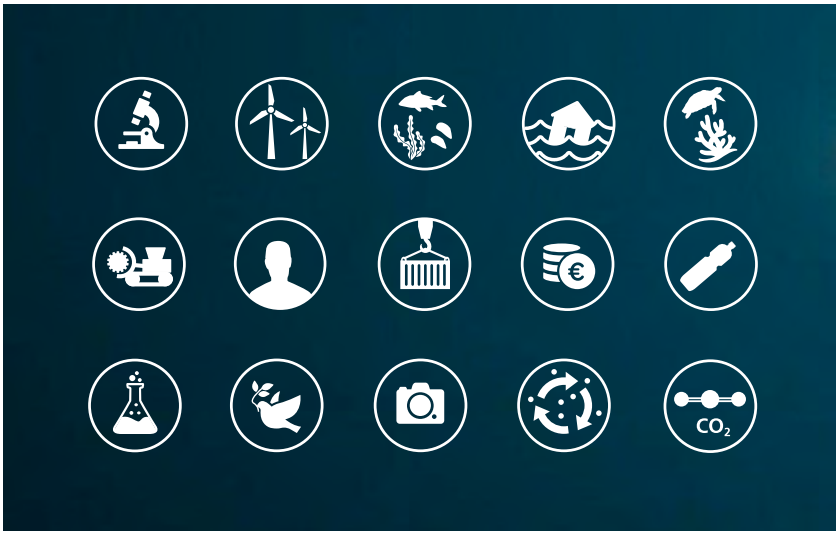
NIOZ on an international level

On an international level, new or revitalized MoUs, including intensified cooperation with e.g., aspects like personnel exchange, facility sharing, combining and coordinating cooperative projects, H2020 initiatives, etc., have also been signed in recent years with international partner institutions like VLIZ (Belgium), AWI Bremerhaven (Germany), HZG Geesthacht (Germany), MARUM (Bremen University, Germany), MTA (Turkey), Oldenburg University (Germany), and IMR (Norway), several Indonesian institutes, and, most recently, with JAMSTEC, Japan. We aim to further develop international collaboration, in the near future notably with our northern German partners (AWI, MARUM, GEOMAR, and HZG).

The NIOZ departments of Ocean Systems research and of Marine Microbiology and Biogeochemistry concentrate more on our international, sea and ocean-going efforts, working in concert with larger international networks like e.g., the European Marine Board, POGO, MARS, SCAR, IOC, besides industry (WOC), global NGOs, and governmental parties. In recent years, NIOZ has become the (single) national representative in these organizations (for NWO), in essence a Nexus role for the entire marine science community of the Netherlands. Meanwhile, we have significantly increased our influence, input and visibility in these international bodies, and we aim to promote and increase international cooperation and associated visibility further, notably with activities associated with the UN-IOC 'Decade of the Ocean 2021-2030', and the sustainable development goals (SDGs). In addition, NIOZ PIs are, and will be extensively involved in developing global agenda's and reports, like e.g. for the IPCC, POGO, and the European Marine Board.

Nexus, Outreach and Open Science

Besides on a scientific level, our research and associated outreach has significant societal impact as well, contributing to addressing outstanding societal, foremost environmental issues affecting the socio-economic situation. NIOZ facilitates societal impact through open and transparent, independent knowledge sharing towards fundamental and applied science, and between public and private parties (companies, government bodies and societal organizations) and outreach. NIOZ aims to further augment these processes, facilitating knowledge sharing, also by further increasing the collaboration with users. In effect, NIOZ sees an added role in utilizing knowledge developed from research (valorization) to create societal impact. A combination of excellent knowledge, entrepreneurial education and accelerator programs encourage the establishment of start-ups, which can convert this knowledge into marketable innovations. Where possible, NIOZ aims to contribute to professionalizing the ecosystem of start-ups and the knowledge economy, also through its Holding BV.

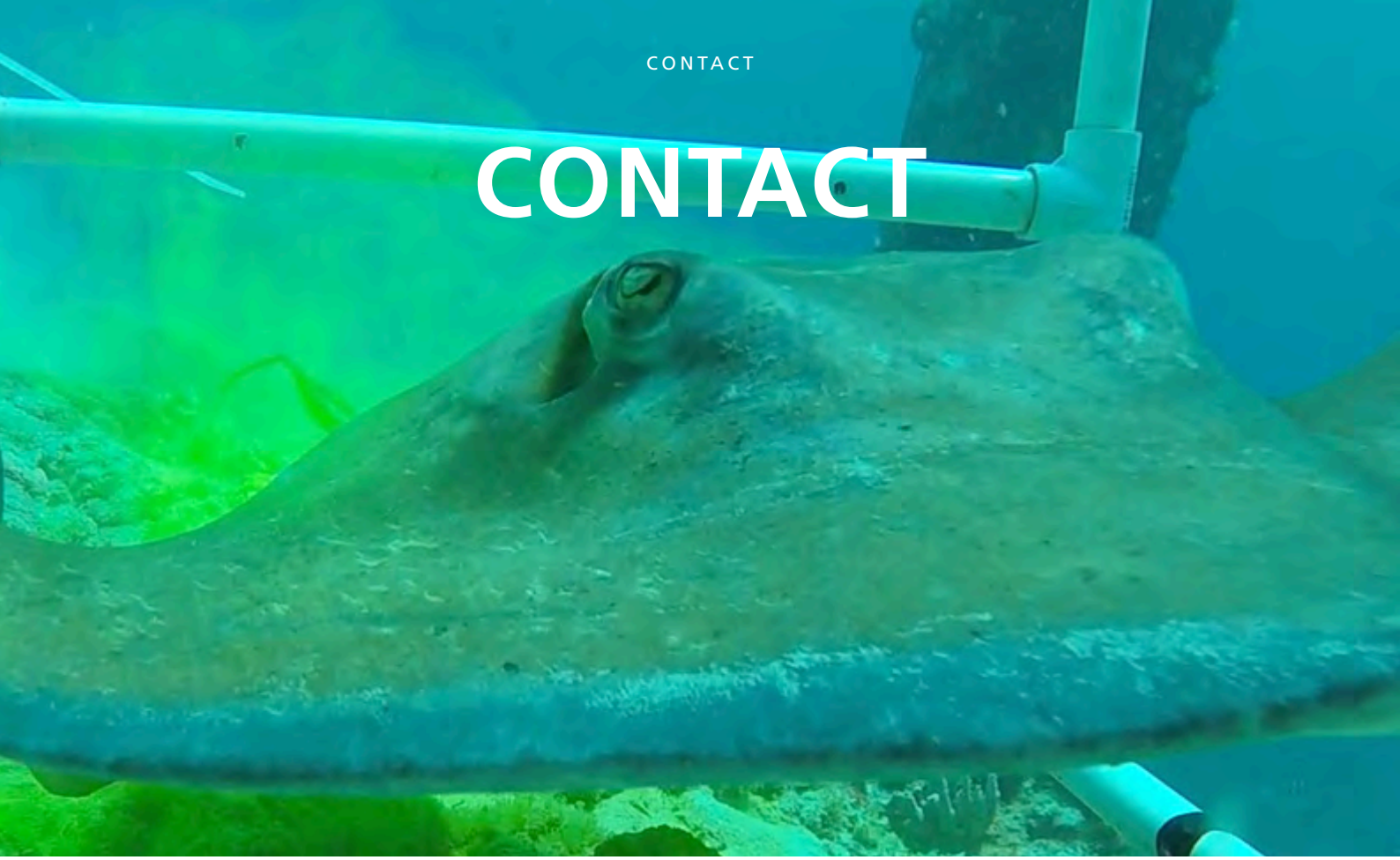


NIOZ is, and will be further developing an institutional policy for Research Data Management (RDM) and implementation via our Data Archiving System (DAS), which can be considered a role model for other institutions. Based on the Findable, Accessible, Interoperable and Reusable (FAIR) principles, the NIOZ Research Data Policy is a significant advance towards open science and open data. Given the complexity and wide range of scientific data generated across NIOZ, the department-specific data-management plans are very appropriate. NIOZ leadership will closely monitor the implementation of the RDM plan with the potential for additional staff where needed for this important task, and will facilitate institutional level training on RDM for early-career scientists to make this strategy future proof.

Final remarks: new Nexus avenues

Considering all the above, our efforts 2020-2025 will be geared towards contributing to outstanding scientific and societal questions regarding changing marine environments and ecosystem architectures during the Anthropocene – a time of rapid global environmental change and ever-increasing human impact.

One of our aims is to utilize our knowledge for developing pathways of mitigation and adaptation, including our own frontier-applied research, also towards sustainable Blue Growth. Not surprisingly, most, if not all of our stakeholders share this broad view on future research directions. Individually, most universities and institutions have meanwhile installed strategies that include at least one or more of these broad notions. NIOZ should take the opportunity to emphasize her role by bringing all the 'marine' lines of activities and strategies together in a national, and perhaps even international setting – creating national research programs supported and connected by all players. In this fashion setting our own 'nationale wetenschapsagenda' (national research agenda). This goal should be central in the activities of our ~50 research scientists and the four scientific departments, individually, but also as combined 'engines of multiple cooperative efforts', internally and externally.



CONTACT

Thanks for reading our plan!

We are curious to read what you think. If you have any suggestions or questions, just drop us a note and we'll get back to you and/or connect you to the NIOZ colleague who can help: communication@nioz.nl.

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