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Referanse .

Marine Science Strategy for the Department of Biology at NTNU

1. Introduction

The overall strategy for the Department of Biology (IBI) for the period 2018 – 2025 outlines a general path forward for all the department's main activities: research, education, dissemination, innovation, organisation and management. In addition, the department has two more specific research strategies:

- *IBI's contribution to understanding and predicting the effect of four selected global challenges and*
- *IBI's goals and strategy for the marine science area.*

The strategic vision for the Department of Biology is to ***Understand Life – Preserve the Environment***. The two elements of this dual vision are of equal importance and form the strategic foundation for all research, research training and education at IBI. The research that focuses on ***preserving the environment*** rests on fundamental science aimed at ***understanding organismal life and processes***, at all levels from molecular through physiological to ecological and evolutionary processes. IBI thus aims to promote international excellence in science addressing both fundamental questions and environmental issues.

The vision to "understand life" is at the root of all biological research. In the marine realm, this can be understood as curiosity-driven research into ecological, behavioural, evolutionary, physiological and molecular questions. Marine organisms and ecosystems are used to address topics that are either unique for marine environments or have a more wide-ranging relevance in terms of organisms, area use and environments. At IBI, much of the marine research has a free exploratory profile, which has led to major insights and breakthroughs being published in the most highly regarded international journals.

The department's vision and strategies will contribute to realising both NTNU's vision *Knowledge for a better world* and that of the Faculty of Natural Science (NV), *Natural Science and Technology for a sustainable future.*

In line with NTNU's aim of ***Knowledge for a better world***, the NV Faculty and the Department of Biology have a strong focus on global challenges, in particular with respect to the environment. The Department of Biology has identified four major global challenges as focus areas for our research and education:

- Climate change
- Biodiversity loss
- Environmental pollution

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- Sustainable exploitation and use of natural resources

The present strategy document for marine research complements the research strategy for IBI's contribution to understanding and predicting the effects of selected global challenges, by applying the strategy to marine challenges and highlighting areas of expected future growth and importance in the marine sector.

2. Challenges

The study of marine biological resources and biodiversity, sustainable aquaculture and exploitation of marine resources, climate change effects, ocean acidification, plastic waste and marine pollution are important topics, both nationally and globally. A rapidly increasing world population needs increased food production, and a significant amount of it needs to be produced in the marine environment. Climate change will strongly affect the marine ecosystems and cultivation systems. Increased knowledge related to conservation and sustainable use of the marine environment and organisms in a changing world is important for preserving the biodiversity and for sustainable development.

3. Our contribution within the marine area in 2025

3.1 Desired state for IBIs marine activity by 2025

Based on IBI's strategic vision to *Understand Life – Preserve the Environment,* the department makes use of our broad biological disciplines and the tools provided by these to improve our understanding of marine ecosystems, to contribute to preserving marine biodiversity and environments, and to contribute to sustainable cultivation and use of the marine environments. Our marine research has a threefold focus: (1) to promote high-quality science aimed at exploring marine ecosystems, organisms and processes, (2) to analyse effects of anthropogenic stressors (climate change, pollution, unsustainable harvesting) on marine ecosystems and biodiversity, and (3) to contribute to a scientific foundation for sustainable cultivation, use and management of marine resources. IBI is a key contributor to multidisciplinary activities in marine sciences within NTNUs strategic research area, NTNU Oceans. IBI is leading a Centre for Research-based Innovation, and the Department is also a partner and active contributor in excellent research groups and centres within and outside NTNU.

IBI ensures a high degree of integration among the biological disciplines of marine science. A significant part of the marine research activity is characterised by interdisciplinary research, e.g. in the crossover between marine biology, aquaculture and technological development. The department therefore promotes and supports high-quality marine science across the whole spectrum of biology, both curiosity-driven as well as applied science. The department has a particular focus on marine research areas where IBI has strong national and international standing.

Our marine researchers collaborate closely with leading national and international research groups, educational institutions and with relevant industry and government agencies. Our research capacity and quality are improved by a high degree of external funding from the industry and public authorities, and our basic and applied research enjoy close interaction. Our researchers are successful at obtaining research funding in national and international competitions. We publish our research in highly respected journals, and our publications and data are accessible to the public.

IBI offers marine science study programmes and numerous courses (BSc, MSc and PhD levels), and aspects of marine science are also included in other study programmes. Our education maintains high international standards, and our MSc and PhD candidates are important resources for our research. Our graduates are attractive candidates for employment and find relevant work both within and outside academia. IBI is the preferred place for MSc and PhD students to study marine science.

General developmental goals

IBI will:

- Contribute to an improved understanding of marine ecosystem dynamics, particularly with respect to biodiversity, effects of a changing climate, pollution, and sustainable cultivation, use and management of marine resources.
- Play a national strategic role by building and focusing on marine research areas of national and international strength at IBI.
- Increase cooperation, professional development and internationalisation within the marine research area.
- Be an active contributor in NTNO Oceans and work to make NTNU Oceans a platform for all marine science in biology at NTNU, across all disciplines and within the areas of climate change biology, biodiversity, pollution and sustainable use of natural resources.
- Strengthen the integration and collaboration within the department the by establishing arenas to ensure and promote communication and collaboration on marine research across the research groups.
- Address and develop solutions for the sustainable cultivation, use and management of marine resources in close cooperation with industry and the public sector.

3.2 Priority areas

Our ambition at IBI is to conduct high quality research to increase the understanding of life and to apply this knowledge. We aim to contribute ideas, analyse and predict effects of anthropogenic stressors (climate change, pollution, unsustainable harvesting) on ecosystems and biodiversity. We strive to contribute to a scientific foundation for the sustainable cultivation, use and management of marine resources. The department will prioritise marine research that addresses these global challenges and areas where IBI has strong research groups and/or high potential to become excellent. Our prioritised areas are:

- Marine climate change biology
- Marine biodiversity
- Marine environmental pollution
- Sustainable use of marine resources

Before describing our contribution to these priority areas, we will describe two cross-cutting research areas (enabling technologies) at IBI that provide opportunities for several of our priority areas listed above.

- **The first** cross-cutting research area is the development and use of enabling technologies in marine research through interdisciplinary collaboration between biology and technology within the NTNU Oceans framework, the Autonomous Marine Observations and Systems (AMOS) Centre of Excellence and the NTNU Applied Underwater Robotics Lab (AUR-

Lab). IBI has risen to national and international prominence through its collaborative work in using unmanned instrument-carrying robots such as drones, unmanned surface vehicles (USV), remotely operated vehicles (ROV) and Autonomous Underwater Vehicles (AUV). These technologies are enabling the identification, mapping, monitoring and dynamic studies of marine life at surface, water column and sea floor levels. The department aims to exploit possibilities for developing cutting edge research and to more broadly take advantage of the relevant knowledge, technologies and methods to analyse the effects of anthropogenic stressors. This work will help us reach our ambitions for the four prioritised global challenges.

- **The second** equally important area is the research on molecular mechanisms behind numerous biological processes and responses, e.g. effects of anthropogenic stressors on organisms, and genomics-based identification and development of strains and breeds for marine production. New knowledge has been gained by using an array of methods including cell biology, physiology, biochemistry, molecular genetics, genomics, bioinformatics and systems biology. Researchers at IBI are leading the way in molecular evolution, marine genomics/genome editing and have contributed to develop biotechnology toolboxes for marine algae, fish and microbiota. New and simplified technologies in gene editing enable several possibilities, including 1) functional analyses of genes/proteins and 2) strain improvement for biotechnological applications.

Interdisciplinary cooperation and applying expertise on prediction and modelling in biology, mathematics/statistics, chemistry and physics; technologies for monitoring the dynamics; and the potential for hypothesis testing by adding, deleting and adjusting the principal cellular players open potential avenues for state-of-the-art research and development.

In the following sections, we describe our ambitions and desired state by 2025 for the four prioritised areas within marine activity.

Priority area 1: Marine climate change biology

The oceans are expected to continue warming and acidifying for the foreseeable future, and the biological effects are still largely unknown but potentially dramatic. Marine climate change biology research will continue to be an important and high-profile research topic for many years to come.

By 2025 we expect that:

The department has done extensive research of high quality in marine climate change biology, within and across several research groups. The collaboration within the department is strong and we are attractive collaborators for excellent research groups of national and international caliber. The competitiveness and success in obtaining funding is high, and several of our research groups are leaders within their fields. IBI contributes high-quality research to analyse climate change effects both in Norwegian ecosystems and in marine ecosystems on a global scale.

IBI scientists have specialist expertise in direct (thermal) and indirect acidification (e.g. eutrophication, ocean, changes in biodiversity and pollution patterns) effects on behaviour, physiology and evolution. Researchers are collaborating to increase our understanding of how a changing climate affects marine organisms. Their approaches include natural habitat studies and utilisation of unique continuous cultures of several key organisms. By using enabling technology, we

are able to obtain bio-geo-physio-chemical measurements with high resolution for time and space measurements that elucidate previously undetectable dynamic processes.

Our expertise in modelling dynamic processes has resulted in important new knowledge of the consequences of expected climate changes on the dynamics in space and time of keystone species in marine ecosystems, and how this should guide our exploitation of commercially important species.

Development goals

IBI will:

- Increase collaboration between research groups within and outside the department to integrate marine climate change effects.
- Enhance cooperation and integrated studies regarding climate change, pollution and key natural environmental variables' effect on marine life.
- Maintain and strengthen basic research in modelling dynamic processes and applying this research to keystone species in marine ecosystems.
- Further develop and increase the use of underwater platforms with sensors to identify, map and monitor marine biodiversity and eco-physiology in the context of climate change, to generate knowledge and enhance marine resource management and decision-making.
- Ensure state-of-the-art experimental facilities and analytical methods, including production of important marine model species.
- Address climate change and other big societal challenges like food production, bioenergy, and health by collaborating and using existing expertise on primary producers and photosynthesis to study mechanisms behind biological carbon capture.

Priority area 2: Marine biodiversity

An important area of research in marine ecology has been the development of sustainable harvest strategies with a particular focus on multi-species interactions. By 2025 we expect that IBI's cutting-edge expertise in stochastic modelling of terrestrial ecological systems is successfully being applied to biodiversity issues. The modelling is generating unique insights into issues of management and conservation of harvested fish stocks, with direct relevance and significant importance for major Norwegian fisheries, for conservation of commercial fish species and for viability analyses of marine (and other) populations. Based on knowledge from the Centre for Biodiversity Dynamics (CBD) Centre of Excellence, scientists at IBI have made state-of-the-art contributions to understanding the population and life-history dynamics of marine organisms, including how these are affected by harvesting and management practices. With national and international collaborators, we have been able to analyse and model how single-species changes affect ecosystem processes, and the potential for exploiting commercially important fish stocks in a changing climate.

IBI has also contributed to new methods of using several types of underwater robots with improved sensors to enhance the understanding of stressors (cues) for marine life in time and space through its partnership with the AMOS Centre of Excellence. This research provides crucial information for nature management and decision-making.

Development goal

IBI will:

- Use existing knowledge and principles for conservation and sustainable exploitation of harvest species to derive multi-species management that includes an ecosystem perspective.
- Utilise and develop relevant concepts within NTNU's AUV technology as a toolbox to investigate and gain important information about marine diversity from an international perspective, and to better understand marine ecosystems, nature management and decision-making.

Priority area 3: Marine environmental pollution

Our research within environmental toxicology has very strong national and international standing. IBI has the largest research group in Norway within this field and works on a broad range of organisms and pollutants. The activity in marine environmental toxicology ranges from molecular and genotoxic effects, through physiological and behavioural effects on marine organisms (from marine bacteria, algae, via invertebrates and fish to seabirds and marine mammals) to effects on populations.

By 2025 strong and broad collaboration in environmental pollution research dominates; and close collaboration exists among research groups within IBI, between departments, and with topnotch national and international research groups, relevant industry and the public sector. Activity focuses on studies integrating multiple stressors, such as pollution along with temperature changes, ocean acidification, ocean dead zones, disease prevalence, aquaculture, domestic effluents, shipping and deep see mining. These stressors range from molecular, individual and population effects on marine organisms to effects on marine and coastal ecosystems, including Arctic organisms and ecosystems. An important part of the research is to understand to what extent (and why) arctic marine organisms and ecosystems are more sensitive than temperate organisms and ecosystems.

Development goals:

IBI will:

- Increase activities and collaboration involving research on the effects of multiple stressors (both natural and anthropogenic stressors) on marine organisms and ecosystems, including planktonic organisms, invertebrates, fish, seabirds and marine mammals.
- Develop models for investigating mechanisms of action of toxic substances that are specific for evolutionary adaptations to marine ecosystems.
- Strengthen research on effects from coastal pollution caused by human activities on model marine organisms, biotopes/ecosystems and aquaculture systems.
- Utilise and develop relevant concepts within NTNU's AUV technology as a toolbox for investigating levels and effects of pollutants in marine organisms.
- Apply cross-scientific approaches to investigate routes of exposure and biomagnification of toxic substances in marine food webs (e.g. through collaboration with chemists).
- Focus on comparative studies of arctic versus temperate ecological keystone species.
- Utilise research infrastructures in Svalbard (UNIS and Ny-Ålesund) to investigate impacts of long-range and local pollution on keystone species in Arctic marine ecosystems.
- Make marine environmental toxicology more attractive to students and young researchers, giving them more initiative to develop small bottom-up projects.

Priority area 4: Sustainable exploitation of marine biological resources

IBI is contributing to sustainable environmental utilisation of the ocean space. The research focuses on developing more "environmentally friendly" aquaculture systems, aquaculture ecology (environmental interactions between nature and culture), utilisation of new feed resources, fish development and fish welfare. IBI accomplishes these objectives through basic and applied research and through close interdisciplinary collaboration with excellent research groups and the industry. Furthermore, the use of new sensor technology for monitoring of ecological mechanisms in the marine system is generating strong activity. These technological solutions are being successfully applied in monitoring environmental interactions in the aquaculture sector. The research and collaboration within these fields has resulted in important knowledge, methods and innovations, and both the industry and the regulatory authorities support the activity. IBI's research is acknowledged as excellent, and the department is leading a Centre for Research-based Innovation (SFI) focused on environmental interactions for marine-based aquaculture.

In the ecological realm, IBI has unique expertise in theoretical analyses of stochastic population, community and ecosystem processes that has garnered the department high international regard. The analyses have produced knowledge and methods for sustainable harvesting and management. The research has led to a greater understanding of spatial processes and geographical differentiation of harvesting, which is of great practical importance in a time when several species are changing their distribution area, and spatially differentiated quotas become more important.

Increasing evidence now exists that harvesting affects the characteristics of species subject to exploitation, generating feedback between harvest tactics and the potential future yield from the fish stocks. Researchers at IBI have been heavily involved in analysing eco-evolutionary processes in a wide variety of systems, and harvest strategies have been developed that reduce the potential for harvest-induced evolutionary changes in commercially important fish stocks.

Development goals

IBI will:

- Develop an SFI application within "environmental interactions for marine-based aquaculture".
- Strengthen advanced marine experimental and analytical capacity for research activities on key species including safe use of gene editing approaches.
- Develop research groups that model and analyse how trophic interactions and marine ecosystem processes change in time and space.
- Integrate eco-evolutionary processes into the development of harvest strategies for marine fish stocks.

4. Securing high-quality research infrastructure for the future

High quality infrastructure is essential for meeting tomorrow's challenges in marine basic and environmental marine science, and within sustainable use of marine resources. IBI aims to provide excellent infrastructure and support functions for marine science of a high international quality in order to make optimal use of the scientific potential of our staff and to ensure working environments that promote excellence and creativity. The biggest challenge is that the capacity and quality at the Trondhjem biologiske stasjon (TBS) and NTNU SeaLab are not sufficient to support NTNU's land-based marine research ambitions in the future. SeaLab is also a rented space, and the contract ends in 2026.

In order to promote marine biological science in Trondheim, and in particular to secure a future prominent role of NTNU as a major actor in international marine science, we expect that NTNU by 2025 will have established, or will soon establish, a modern, high capacity research unit for experimental marine research and education. This new centre includes and expands all marine biological science that is currently conducted at TBS, NTNU SeaLab, and ideally also at SINTEF and other marine research environments in Trondheim. The new research centre, with its state-of-the-art research facilities at a high international level and with sufficient capacity for growth, is an important part of the Ocean Space Centre in 2025.

Development goals

IBI will:

- Take initiative and be a driving force in the progress and planning for a new centre for marine research, education and development. Different locations need to be evaluated in relation to future capacity needs, strategic priorities and possibilities.
- Strive for high quality experimental and analytical facilities and for maintaining production lines of key model organisms, also in the period before the new centre is established.
- Enhance international collaboration and use of marine experimental facilities.