PhD projects at DTU Aqua
March 2021
Preface

This web-publication “PhD projects at DTU Aqua” presents PhD students enrolled at DTU Aqua’s PhD school as of 1 March 2021.

Each PhD project is described by the PhD student. You will additionally find information on research section affiliation and supervisor. Most PhD students at DTU Aqua have co-supervisors as well. However, for the sake of simplicity we have not provided the entire list in this publication.

Our mission is to make sure that our PhD students engage themselves with front line research, whether it is for utilizing new technological approaches in their data collection and processing, for statistical treatment and evaluation of data, or for mathematical modelling. Our ambition is to secure the next generation of innovative and broadly educated applied aquatic scientists that can face the challenges that e.g. climate change and an increased utilization of aquatic resources present to us.

Ken H Andersen
Head of the PhD School at DTU Aqua

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Josephine Grønning

Background
It is estimated that via their photosynthesis, phytoplankton account for more than half of the world’s oxygen production. Phytoplankton is a highly diverse group of organisms, of which many have evolved what is believed to be defence mechanisms. Examples include hard shells, colony formation, and toxin production; all believed to reduce predation mortality. However, the trade-offs are often not documented, neither the benefits nor the costs, and even more rarely quantified. Many presumed defense mechanisms are inducible; that is, they are only harnessed in response to the presence of grazers (or grazer signals, e.g., chemical cues), and that may apply also to both colony formation and shell thickening in diatoms.

Project
My PhD project explores defense mechanisms and trade-offs in diatoms. The overarching aims of my project are to firstly provide a mechanistic description of how (and if) shell- and colony formation in diatoms provides protection. Secondly, to quantify the costs and benefits of these assumed defense mechanisms, and finally examine how the costs are paid, i.e. as a reduction in nutrient affinity (competitive ability), as a change in resource allocation from growth to defense, or as elevated mortalities due to other grazers.

Perspective
This project will provide a good mechanistic understanding of defence mechanisms in diatoms, provide estimates of the trade-offs and of how these trade-offs depend on the presence of different types of grazers. This information will form the basis for more robust trait-based models of plankton, their structure and function, that are currently being developed at the Centre for Ocean Life.

Fredrik Ryderheim

Background
Much like terrestrial plants, phytoplankton have developed a wide range of defense mechanisms. These defense mechanisms have likely evolved due to predation pressure as a form of grazing deterrent, and while several benefits of being defended have been documented, the associated trade-offs are often poorly described or not quantified. To consider defense mechanisms adaptive there must be associated costs; otherwise non-defended species or strains would be outcompeted and all species would be equally defended, which they are not.

Project
My PhD work aims at identifying and quantifying the trade-offs and benefits of physiological defense mechanisms in marine dinoflagellates. It has been suggested that these costs are small or insignificant, but research that is more recent propose that they might only be detectable under nutrient limiting conditions. The experimental designs of my work will revolve around limiting the available nutrients, thus making the organism choose where it expends resources, i.e. growth, or defense. The focus of my initial project will be on the production of toxins in marine dinoflagellates. Many of these toxins work as grazer deterents and can vary among dinoflagellate species, but as of yet there have been no real quantification of the associated trade-offs. I will also look into bioluminescence as a possible aposematic signal used by dinoflagellates to warn grazers of toxicity.

Perspective
The results of my work will improve our understanding of predator-prey interactions in the plankton food web. We expect to add to the knowledge of toxin production as a defense mechanism and establish the potential fitness costs and trade-offs and under what conditions they occur. This will help improve understanding of the mechanism and the evolution of inducible toxin production as a trait.
Sei Suzuki

Background
The ocean hosts a great diversity of single celled microorganisms that are characterized by their flagella: a flexible fine appendix that serves for motility and for capturing and handling food particles such as bacteria and phytoplankton. These unicellular flagellates play a key role in the oceanic food chains and in the biogeochemical cycles of marine ecosystems. Despite of their importance in these marine biological processes, the mechanisms of flagellate feeding and their associated costs in mortality still remain widely unknown.

Project
This study will focus on heterotrophic nanoflagellates: very small flagellates (2-20μm) that exclusively feed on other organisms. At this small scale, aquatic environments become as viscous as a thick syrup and present a challenge for prey capture. First, I aim to understand how nanoflagellates overcome the impeding effects of viscosity by creating currents with their flagella to draw the prey towards them. I will describe these events and study the different types of feeding currents for several species with high-speed video recordings. I will also perform experiments to quantify the rate in which the flagellates graze upon their prey by culturing them together, and I will compare the results with the calculations of computed models of the feeding currents. And secondly, I will investigate potential defense mechanisms: how can the nanoflagellates themselves avoid or reduce the chance of being eaten while they search for food.

Perspective
The overarching aims of this PhD are to describe and to understand prey encounter mechanisms in important marine heterotrophic nanoflagellates. The results of my project will illustrate the evolution of different prey-capture strategies and will establish their potential trade-offs. Studying the feeding mechanisms of these small organisms is important for a better overall understanding of the predator-prey interactions that take place at the small scale.

Louise Catharina Flensborg

Background
Policy makers, managers and the general public are rightly concerned that marine ecosystems and the services which they supply are under threat from a range of human pressures, including overfishing and climate change. Ecological resilience is the ability of a system to remain organized around the same set of processes, structures, and functions. Resilience in a system is a measure of how much disturbance the system can buffer without moving into an alternative regime. Our knowledge of resilience and vulnerability of marine fish communities to changes are scarce. Consequently, there is an urgent need for a better understanding of the underlying process contributing to increase ecological resilience.

Project
In this project, we will use available data on marine fish species abundances and traits to assess, quantify and compare the resilience and stability of marine fish communities across the North Atlantic and North East Pacific following the conceptual framework provided by the cross-scale resilience model. We will investigate how key attributes of ecological resilience (i.e., functional redundancy, response diversity and evenness) vary across marine fish communities, as well as between marine ecosystems in both space and time.

Perspective
This will enhance our current understanding of ecosystem resilience in marine fish communities by quantifying and mapping the extent of ecological resilience in marine fish communities, and by estimating how resilience control fish biomass over time. Furthermore, we hope to help guide future research and conservation effort by providing an assessment, and ranking, of the ability of current marine protected areas to protect fish communities of low resilience.
Kristian Maar

Background
Aquatic suspension feeders span from unicellular organisms to the blue whale and are characterized by various mechanisms of filtration, which enable them to separate and retain particles of food from the water. The ocean is nutritionally dilute and marine suspension feeders must therefore be highly efficient in order to successfully capture enough food to grow and reproduce. The biomechanical adaptations suspension feeders have evolved to solve this problem are as diverse as the community of suspension feeders themselves and is fundamentally constrained by physical properties e.g. the size of the filter feeder and the type and size of particle they capture. The flow generated by active suspension feeders also affects their local environment and is theorized to facilitate the aggregation and sinking of marine snow.

Project
The first part of my project focuses on the fluid dynamics of suspension feeding in sessile barnacles. To determine the flow field generated by barnacle suspension feeding I will use high-speed video and Particle Image Velocimetry (PIV). The second part of my project focuses on the impact of colonization of microscopic suspension feeders on the formation and sinking of marine snow. I will quantify this phenomenon by conducting experiments comparing aggregation and settling of marine snow with and without active suspension feeders.

Perspective
Elucidating the mechanics of suspension feeding provides novel insight into predator-prey relationships and specific solutions to complex fluid dynamic problems. Biomimetic efforts inspired by marine suspension feeders have already yielded technological advancements in industrial filter technology and is currently being discussed as potential solutions to microplastic in the ocean. Understanding the processes of marine snow formation will also increase the predictive power of carbon pump models and contribute to the detailed understanding of sequestration of carbon in the deep ocean.

Mads Boje Rode

Background
Through grazing on phytoplankton and bacteria and by being grazed, flagellates and ciliates transfer primary production to higher trophic levels. Many flagellates and ciliates feed by generating a large flow towards the cell and clearing the water for prey through a filtering mechanism. The foraging of many such microscopic filter feeders is not fully understood.

Project
My work focuses on ciliates that feed using cilia arranged in a so-called membranelle band. The membranelle band is an active filter that simultaneously generates the feeding flow and retains the prey. Using microscopy and high-speed video, we have explored the membranelle function of the ciliate Euplotes vannus, and we have developed a model that rationalizes our observations and provides a mechanistic understanding of the membranelle function. Furthermore, Euplotes vannus and many other suspension-feeding microorganisms forage while attached to surfaces. Through theoretical modelling, we describe the effects on the feeding flow of the proximity of the organism to the surface and the orientation of the flow-generating force. Finally, we work to develop a technique to enable more efficient microscope observations of swimming and feeding behavior by tethering free-swimming microorganisms using ultrasound.

Perspective
Our observations and models provide mechanistic understanding of the feeding of ciliates and other microscopic suspension-feeders, and they enable estimates of key characteristics such as clearance rate and prey size spectrum. These results may serve as input for trait-based, ecological models of plankton that are being developed in the Centre for Ocean Life.
**Magnus Heide Andreasen**

**Background**
Gelatinous zooplankton organisms are a diverse group of soft bodied, transparent organisms that comprise members from diverse phyla in the animal tree of life. They commonly attract large public attention partly due to their bloom and bust population dynamics, partly due to their interference with human activities especially in coastal waters. It has been suggested that their abundances are on a rise due to global change induced stressors. However, the data and experimental basis to support this hypothesis remains inconclusive.

**Project**
The aim of this PhD project is to address the hypothesis that gelatinous zooplankton biomass is increasing due to global change induced stressors from a time series as well as experimental perspective. The project will combine statistical modelling with laboratory-controlled experiments.

**Perspective**
The results are expected to further our understanding about gelatinous zooplankton’s long-term abundance fluctuations, their underlying population dynamics and the response of certain sub-populations to global change induced stressors.

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**Peter Fink-Jensen**

**Background**
Capelin (*Mallotus villosus*) is essential as trophic link between plankton and larger predators in the arctic marine ecosystem around Greenland. Multiple species including fish, birds and marine mammals depend on healthy capelin stocks for successful growth and reproduction. During late spring and most of the summer, large schools of capelin gather at shallow waters in Greenland’s fjords to spawn. However, very little is known about their migration and stock structure through the remainder of their lives.

**Project**
In this project, stock discrimination and the migratory behavior of capelin will be examined on the basis of earstone (otolith) microchemistry using state-of-the-art trace element analysis. The primary contributor to chemical fingerprints in otoliths is ambient water chemistry, while factors such as food intake, temperature and salinity are secondary factors. As otoliths grow incrementally as a fish grows, without physical or chemical post-depositional alteration, their chemical composition can provide chronological records of e.g. fish growth, migration patterns and environmental exposure. I will use this to track the movement of individual capelin between different marine environments and stocks, based on otoliths from more than 1200 spawning capelin from 18 different localities along Greenland’s coast.

**Perspective**
The results of this project will lead to a greater understanding of the movement and behavior of capelin and possible separation into multiple stocks. Such knowledge is crucial for proper scientific advice, which enables local authorities to manage ecosystem services, including fisheries and ecosystem functioning, related to capelin sustainably and optimally. This information is essential for sustainable fisheries of this species – a natural resource that the industry is looking to utilize.
Rocío Rodríguez Torres

**Background**
Marine plastic pollution is currently one of the most concerning environmental problems. In the recent years, research in this topic has increased but there is still a lack of knowledge about the consequences of plastic pollution on marine plankton under realistic environmental conditions. Zooplankton (copepods) is the most abundant group of marine animals on Earth; they play key roles in the transfer of matter in food webs, biogeochemical cycles, and recruitment of benthic invertebrate and fish populations. Since microplastics are frequently in the prey size spectra of zooplankton, ingestion of microplastics by zooplankton is likely the main route by which small plastics enter and are transferred in marine food webs.

**Project**
The general objective of this project is to investigate the interactions between microplastic (plastic < 5mm) and plankton at individual and community levels to evaluate the impact of microplastic pollution on marine food webs. This PhD is part of the Ve-lux project, Danish Center for Research in Marine Plastic Pollution "MarinePlastic" that aims to understand the sources, fate and consequences of plastic pollution in the marine environment to support societal solutions and sustainable policies.

**Perspective**
This project will show the impact of MPs under realistic conditions, using existent microplastic concentrations and real environmental conditions. Based on incubations and video observations we will be able to explain the importance of plankton feeding behavior in the entrance of MPs to the marine food webs. In addition, we will assess the impact of the combination of MPs with other pollutants.

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Regitze Lundgreen

**Background**
Atlantic cod (*Gadus morhua*) is one of the most important commercial fishes and has seen an overall decline in stock size recently. This is especially evident in the Baltic Sea which has been characterized by declining oxygen concentrations and increased temperatures throughout the last decades, resulting in a decrease in the extent of cod nursery areas. However, it is unknown how changing environmental and biological conditions might affect migration patterns in eastern Atlantic cod. In order to ensure efficient management of cod populations in the future, it is necessary to understand the temporal and spatial variation in cod migration patterns.

**Project**
The main aims of the project are to 1) map migration patterns through time, 2) determine which environmental and biological factors affect migration patterns, and 3) identify how individual cod migrate between locations. In order to resolve this, the project will utilize conventional archival tagging data with information on release and recapture of tagged cod from the 1950-1980s covering the Baltic and the North Sea, and more recent data from DSTs (2000-2010s) covering the Øresund to the eastern Baltic Sea. The environment experienced by individual fish will be examined using otolith microchemistry to study individual migrations. By combining these data sources with environmental and biological databases, migration patterns can be studied in great detail using state-space models and geostatistical methods.

**Perspective**
The results of this project will improve our understanding of how environmental drivers affect cod migration patterns which is especially important in light of the changing climate. Furthermore, information on the spatial distribution of cod is invaluable for proper management of stocks.
Kjetil Thorvaldsen

Background
Mesopelagic fishes are ubiquitous to all world oceans and have been estimated to hold an enormous potential biomass. These fishes have a low trophic level, which makes them a potential sustainable source for protein. But the knowledge on these layers of organisms is limited due to inefficient sampling methods. Mesopelagic fish have been observed to be inefficiently sampled with midwater trawls. There are also several challenges with traditional acoustic observation technologies. Problems such as swim-bladder resonance during acoustic surveys, inclusion of gelatinous zooplankton with similar acoustic properties. With new technologies, such as acoustic wideband systems and optics, there is great potential to learn more about these organisms.

Project
In this project, different types of state of the art hydro acoustic and video equipment will be used to observe mesopelagic fishes and other components in the mesopelagic layers. The frequency spectrum of single targets will be used to identify different acoustic classes in scattering layers. Small and large scale behavior will be observed to learn more about the components of the layers, the movement of mesopelagic fish, and interactions with other trophic levels.

Perspective
This study will highlight the importance of using wideband acoustics on resolved single targets to identify and learn more about the small fishes at great depths. An effort will be made to find a way to separate between mesopelagic fishes and other scatterers. This project will look at different individual fish behaviors. By using target tracking, this study will explore the spatial behavior of mesopelagic fishes and observe interactions with other trophic levels. Mesopelagic fishes are important in the marine foodweb, and such small scale interactions are the basis to understanding the formation of meso- to large scale patterns.

Christian Mathias Rohde Kjær

Background
Due to recent advances in ocean observations and modelling, today it is possible to make forecasts of the physical variables in the ocean on seasonal to decadal time scales. Using better observational data and more skilful forecasts of the physical environment can improve our understanding of the biological environment, leading to models predicting and forecasting ecological changes. Forecasting ecological changes, from productivity to distribution, can provide valuable information for stakeholders and decision makers and developing these so-called “climate services” for marine ecosystems represents one of the new challenges in marine science. However, current marine ecological forecast products are limited to predictions of phenology or distributions: There are currently no marine fish productivity forecasts.

Project
Traditionally fish recruitment modelling is stock-based, where a single stock-recruitment relationship model is fitted for each stock and rarely incorporates environmental effects. However, the main drivers behind biological processes can change on a yearly basis. Other disciplines have incorporated techniques, such as iterative updating, non-stationarity and multi-model ensemble approaches, which can be adopted by recruitment models. This project attempts to combine the above, possibly resulting in a better understanding of the drivers behind recruitment dynamics. Most importantly, it can also pave the way to operational recruitment forecasting for use in fisheries management applications.

Perspective
The aim of this project is to provide a better understanding of the dynamics and main drivers of fish recruitment. Furthermore, forecast products will be made available for important fish stocks, to provide advice for stakeholders and managers.
Per Anton Vergod Almgren

**Background**
The biological pump is the vertical transport of carbon, bound in organic matter through photosynthesis, from the surface ocean to the deep ocean. Together with the solubility pump (the transfer of atmospheric CO₂ into the ocean), the biological pump play an important role in the global climate system, as it removes CO₂ from the atmosphere and transport it to the deep ocean where it stays for hundreds or thousands of years. A major part of the vertical transport of carbon happens through the sinking of marine snow (particulate organic matter), and the fraction of the marine snow that is not re-mineralized before it reaches the sequestration depth is buried in the deep ocean.

**Project**
Throughout my PhD, I will develop a model that is able to describe the degradation and remineralization, as well as the aggregation, of marine snow particles. This will be put into a global context, using trait-based models of marine ecosystems, to provide input in terms of particulate organic matter. The aim is to use this modelling approach for providing a realistic estimate of the efficiency of the biological pump on both global and regional scales.

**Perspective**
The efficiency of the biological pump in terms of carbon sequestration is difficult to estimate, and current estimates based on e.g. sediment traps, provide a wide range of carbon sequestration rates. Further, the current estimates say little about the mechanistic processes involved in the biological pump. By modelling the processes of particle degradation and sinking, we will both get a more realistic estimate of the efficiency of the biological pump, as well as a framework that may be used for future climate scenarios.

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Anders Dalhoff Bruhn Jensen

**Background**
Terrestrial dissolved organic matter from river upland and permafrost erosion can be found throughout the Arctic Ocean. Terrestrial dissolved organic matter can affect ocean chemistry, carbon cycling and in the end marine ecosystems. With global warming the release of terrestrial dissolved organic matter into the Arctic Ocean will increase simultaneously. It is therefore becoming more and more urgent to understand the fate of this dissolved organic matter.

**Project**
This project will study how to use lignin phenols as a terrestrial plant biomarker and thereby be able to understand and map the fate of terrestrial dissolved organic matter in the ocean, particularly the Arctic Ocean. To separate the lignin phenols I will apply reversed phase High Pressure Liquid Chromatography. Since the lignin phenols hold different spectral fingerprints, absorbance and fluorescence spectroscopy can be used for detection. Finally, chemometric decomposition methods such as Parallel Factor Analysis will be used to analyze the data. Once the method is developed, seawater across the Fram Strait will be sampled and analyzed for lignin. From these results, we can hopefully deepen our understanding of how the terrestrial dissolved organic matter is exported into the Atlantic Ocean. For the future, I hope to establish a lignin method that can be applied in situ.

**Perspective**
From understanding the fate of terrestrial dissolved organic matter in the Arctic Ocean and its export through the Fram Strait, we can hopefully begin to predict how future climate change will affect ocean chemistry and carbon cycling. Will the terrestrial dissolved organic matter be taken up by living organisms, be stored in the deep ocean for millennia or be respired into the atmosphere as carbon dioxide?
**Gunaalan Kuddithamby**

**Background**  
Microplastics (1 μm - 5 mm size) are ubiquitous in the marine environment, making them a major environmental concern. Despite the increased scientific interest in microplastics pollution, many questions on their fate and toxicity remain and their ecological impact is still under debate. Therefore, comprehensive research studies need to fill the gaps in our scientific knowledge on distribution of microplastics in the marine environment. It is essential to understand the distribution of microplastics since they play a crucial role as vectors of different potential contaminants to enter the marine food web. Microplastics can be accidently ingested by zooplankton and egested as part of their fecal pellets.

**Project**  
My PhD project aims on the ecological risk of microplastics pollution on the marine environment and understand the links between oceanographic processes, environmental distribution of microplastics, and their impacts. This project comprises three major interconnected work packages to assess the “risks” of microplastics pollution. Investigate the “abundance” of microplastics and their characterization; the “fate” of microplastics and assess the “impacts” of weathered plastic, plastic leachates and additives by examining ecological and physiological changes in marine copepods at different spheres along a gradient of marine environment from water column to seafloor.

**Perspective**  
The project will assess the abundance, composition and sizes of microplastics in Danish fjords and coastal waters (Kattegat strait) in relation to hydrography. The outcomes of work packages probably lead to develop a model for risk assessment for microplastics in Danish waters.

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**Delove Abraham Asiedu**

**Background**  
Recent reports suggest that marine ecosystems worldwide are increasingly exposed to overexploitation and pollution from heavy metals, petroleum, plastics and persistent organic pollutants. In addition, the UN’s Intergovernmental Panel on Climate Change has reported that the temperature of the ocean is likely to increase by ~1-6°C by the end of this century, with fastest-warming occurring in the Arctic areas. We, however, lack understanding of how key organisms (both native and non-native), from primary producers to higher trophic levels, are impacted by climatic and non-climatic changes and how the individual responses of species influence trophic interactions and community structure. This is particularly urgent for Arctic marine ecosystems because they are highly vulnerable to warming due to ice acting as the vital ecosystem element.

**Project**  
This PhD project will combine field and experimental studies to quantify the zooplankton community composition and production in the Arctic and their sensitivity to the combined effects of climate change (e.g., increasing sea surface temperature, decreasing salinity and turbidity) and pollution. The zooplankton will consist of both native and non-native species, thus including aspects of the potentially different environmental tolerance of these groups. Also, special focus will be on small (< 1 mm) under-studied copepod species that dominate the abundance of Arctic zooplankton at many locations and seasons.

**Perspective**  
The project will provide novel knowledge on the mechanistic impacts of stressor combinations on native, non-native and small under-studied zooplankton species at different ontogenetic stages of development. This will contribute to the general understanding of how individual tolerances accumulate to community-level stressor responses, which is essential knowledge to be able to predict the effects of environmental change in the vulnerable Arctic ecosystem.
**Aurelia Pereira Gabellini**

**Background**
Interactions between ocean currents and life history traits can regulate fundamental processes in marine ecosystems including spatial segregation, speciation and metapopulation structures. These processes can act across several temporal and spatial scales altering the response of ecosystems to multiple pressures including climate change. It is therefore relevant to develop methods to assess the marine connectivity across distant biogeographic regions to support the identification of management strategies for the sustainable exploitation of ocean resources.

**Project**
My PhD project aims to better understand dispersion and connectivity patterns across biogeographic regions in the Atlantic Ocean, by combining trait-based modeling description of marine organisms to high resolution ocean circulation models. General circulation models for the Atlantic Ocean will be coupled to a Lagrangian particle tracking algorithm simulating dispersion of numerical particles with properties defined by specific traits. The analyses will include a wide range of movement strategies from passive transport to more directed movements (e.g. migrations). The resulting connectivity matrices will be investigated to assess the importance of specific traits and the importance of transport across specific regions. The model will be used to assess past and present conditions as well as to provide scenarios of future connectivity patterns in the Atlantic Ocean.

**Perspective**
This thesis is part of Mission Atlantic project which aim is to map and assess the present and future status of Atlantic marine ecosystems. The results are expected to contribute to further our knowledge about connectivity in the Atlantic Ocean and possible consequences in the recruitment of some selected groups due to climate change.

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**Camilla Christensen**

**Background**
Archived specimens held in museums and other natural history collections can provide a population genetic baseline, against which to assess potential negative consequences of recent changes in the environment. Thereby, offering an opportunity to track demographic and evolutionary consequences of climate change and other human-induced pressures. The recent advances in molecular genomics has made it possible to investigate genetic changes in many individuals sampled more than a century ago. However, few retrospective genomic analyses has comprised sharks.

**Project**
This PhD project is part of an international collaborative project, GenoJaws, involving the University of Queensland, Technical University of Denmark and Flinders University. The ambition of the project is to gain knowledge about population genetic parameters of the vulnerable sand tiger shark (*Carcharias taurus*) on a spatial and temporal scale. Performing genomic analysis on contemporary and historical samples will allow us to test for changes in abundance, effective population size, distribution and connectivity and ultimately make us capable of evaluating adaptive responses to environmental change and exploitation.

**Perspective**
By tracking changes in genetic composition on a temporal scale, it is possible to find evidence of both distributional shifts and responses to selection. Ultimately, analysis of such records, taken over several years, can help us understand micro evolutionary processes. In addition, retrospective analysis can help making informed decisions for the protection and management of the current populations of sand tiger sharks.
Elisa Benini

Background
Self sustainable aquaculture and conservation efforts are needed to restore the critically endangered European eel, *Anguilla anguilla* stock. Its life cycle has not been closed in captivity yet although laboratory studies have identified optimal environmental conditions for improved early offspring performances. However, there is still paucity in knowledge about nutrition and mechanisms regulating digestion of European eel larvae.

Project
The objectives of my PhD project is to investigate aspects of digestive physiology and nutrition of *A. anguilla* as a step forward in closing its life cycle in aquaculture. A multidisciplinary approach will be used to assess and describe different aspects of the digestive capacity of eel larvae. The first step will focus on the biochemical composition of larvae to define which components are essential for growth and survival. The second study will assess the impact of exogenous feeding on the ontogeny of the digestive tract during early development. The third study will focus on larval nutritional requirements and digestion capacity.

Perspective
The knowledge gained during this project will help us to enhance larval survival and growth under controlled conditions. Based on my research outputs regarding larval digestive physiology and nutrition, we will be able to grow larvae until the juvenile stage.

Homère Alves Monteiro

Background
The flat oyster *Ostrea edulis* represents a valued food source since the Romans, and a luxury good nowadays. It has been overfished and heavily impacted by disease outbreaks. In contrast with the pacific oyster *Crassostrea gigas*, where the whole genome sequencing enabled novel and more powerful genetic population studies of the species, the flat oyster has not got the same consideration yet. In Denmark, the current distribution is confined to the Limfjorden. In Norway, records have been reported as far north as the Nordland region, which likely represents the northernmost distribution limit of the species. In Sweden, flat oysters are observable in the north of the Swedish Skagerrak coast and show sustainable populations in relatively good health in contrast with other European flat oyster’s locations.

Project
We aim to gain insights into the European flat oyster natural genomic diversity, with a particular focus on the Scandinavian populations, and to develop genetic knowledge of the species as a practical tool to inform aquaculture production and restoration projects. To achieve these goals we will perform an analysis of genome-wide markers at an unparalleled level of geographical and genomic detail. Expected results are knowledge on 1) Genetic diversity of the Scandinavian natural flat oyster, with comparison among populations from the species’ entire distribution range, and 2) Genetic practical tools applicable to aquaculture and restoration programs.

Perspective
This large sampling campaign and subsequent genetic diversity analysis will permit an assessment of the putative population structure, local adaptation, and effects from translocations of *O. edulis* in Scandinavia. As well as providing genetic input resulting in a set of recommendations/guidelines for the flat oyster aquaculture and restoration.
Background
Environmental DNA (eDNA) describes all DNA molecules found in an environmental sample, e.g. water, soil or air, that originated from organisms present in that environment. Consequently, analysis of eDNA can be used for monitoring of species or species assemblages. This would likely save time, costs, and workload for such procedures. So far, eDNA implementations for large scale monitoring projects conducted by management institutions, such as fisheries institutes, are limited. This includes both single species monitoring, of e.g. invasive species, and monitoring of species assemblages, e.g. for bycatch estimations. One of the reasons for this might be the need for quantitative estimates for such applications. In order to use eDNA for quantitative estimates, eDNA behavior needs to be better understood, and the molecular methods applied need to be calibrated and validated.

Project
My PhD project aims at facilitating practical implementations of eDNA based methods for monitoring of single species and species assemblages in management and industry. To archive this, on the one hand I will develop methods for eDNA-based quantitative assessment of species assemblages that could be used for by-catch estimations in fisheries. On the other, I will assess and advance methods for monitoring single species, e.g. invasive species that would enable fast monitoring of their spread in ecosystems.

Perspective
Results gained from this PhD project will improve the understanding of eDNA ecology and behavior, and improve the molecular methods applied on eDNA for different monitoring goals. If successful, the methods developed throughout the PhD will come at hand to applied areas such as management, and industry, which need frequent species monitoring.

Paulina Urban

Title: Analysis of environmental DNA, “eDNA” from marine organisms
Supervisor: Einar Eg Nielsen
Section: Marine Living Resources

Background
Managing the reproductive cycle of lumpfish (Cyclopterus lumpus) is essential for a closed life cycle under captivity, ensuring a year-round production of the right-sized juveniles for the biological control of sea lice in salmon. Moreover, high quality of the deposited eggs is required for robust larvae, which plays an important role in closing the life cycle. However, in lumpfish, little is known about its gonadal development, egg quality, and their relations to photothermal manipulations. In this context, monitoring of gonadal development and the accompanying sex steroid profiles is useful for managing the reproductive cycle of fish. Also, photoperiod and temperature (photothermal) manipulations have proven to be useful in the management of spawning and gamete quality.

Project
My PhD project focuses on describing the gonadal development and determine indicators of egg quality in lumpfish under different photothermal conditions. The morphological changes during oogenesis and spermatogenesis, and the accompanying profiles of sex steroids, will be described. The response of the gonadal development to varying photothermal regimes will also be studied. Egg and embryonic stages from broodstock in different photothermal regimes will be categorized based on their lipid and fatty acid compositions, and expression levels of the maternal mRNAs as potential egg quality indicators. Ultrasound technology will also be tested in sex identification and monitoring of the gonadal development.

Perspective
Understanding the lumpfish reproductive cycle, the indicators of egg quality, and their relations to photothermal manipulations, is useful in the development of protocols for juvenile production. Furthermore, knowledge generated from the ultrasound technology contributes to inclusion of non-invasive methods in broodstock management hence improved welfare in farmed lumpfish.

Frank Thomas Mlingi

Title: Photoperiod and temperature effects on lumpfish (Cyclopterus lumpus) sexual maturation and egg quality
Supervisor: Jonna Tomkiewicz
Section: Marine Living Resources

Background
Managing the reproductive cycle of lumpfish (Cyclopterus lumpus) is essential for a closed life cycle under captivity, ensuring a year-round production of the right-sized juveniles for the biological control of sea lice in salmon. Moreover, high quality of the deposited eggs is required for robust larvae, which plays an important role in closing the life cycle. However, in lumpfish, little is known about its gonadal development, egg quality, and their relations to photothermal manipulations. In this context, monitoring of gonadal development and the accompanying sex steroid profiles is useful for managing the reproductive cycle of fish. Also, photoperiod and temperature (photothermal) manipulations have proven to be useful in the management of spawning and gamete quality.

Project
My PhD project focuses on describing the gonadal development and determine indicators of egg quality in lumpfish under different photothermal conditions. The morphological changes during oogenesis and spermatogenesis, and the accompanying profiles of sex steroids, will be described. The response of the gonadal development to varying photothermal regimes will also be studied. Egg and embryonic stages from broodstock in different photothermal regimes will be categorized based on their lipid and fatty acid compositions, and expression levels of the maternal mRNAs as potential egg quality indicators. Ultrasound technology will also be tested in sex identification and monitoring of the gonadal development.

Perspective
Understanding the lumpfish reproductive cycle, the indicators of egg quality, and their relations to photothermal manipulations, is useful in the development of protocols for juvenile production. Furthermore, knowledge generated from the ultrasound technology contributes to inclusion of non-invasive methods in broodstock management hence improved welfare in farmed lumpfish.

This is an alliance PhD with Norwegian University of Science and Technology.
Kasun Anuruddha Bandara

Background
Eels, although being a targeted high value fish in aquaculture, their production is based on wild capture of juveniles. As the natural stock of European eel has declined sharply and is ranked as critically endangered on the IUCN red-list, there is an urge developing hatchery technology for a sustainable aquaculture and assisting management and conservation plans. Recent research conducted at the prototype hatchery, EEL-HATCH located at DTU Aqua in Hirtshals, has led to a stable production of larvae entering the feeding stage. Establishing feeding in larval culture entails increased bacterial load in the water leading to detrimental effects on the larvae. Therefore, research addressing microbial management and immune system ontogeny is essential to progress hatchery technology for European eel.

Project
The aim of this PhD project is to fill gaps in knowledge about impacts of microbial interactions on offspring survival and developmental success in culture of European eel larvae. The experimental research and laboratory analyses are organized into several tasks. We study the effect of stocking density at different developmental phases (embryonic, yolk-sac and feeding stages) on microbiome composition and on embryonic and larval health. Additionally, we explore how gut-priming/immuno-stimulation, dietary composition, and feeding regime drive the microbiome in culture water and larvae, and we identify if and how the shift in microbiome affects larval development. Finally, the data on microbial communities of larvae and the environment, generated from the above studies will be used as input to conclude on community assembly and succession of the microbiome in European eel larvae.

Perspective
This project will expand our knowledge on the importance of microbial management in enhancing offspring survival and developmental success in marine fish larval culture, using European eel as a model.

This is a joint degree with Norwegian University of Science and Technology.

Katrina Bromhall

Background
Fishing with mobile bottom-contacting fishing gear is described as the largest anthropogenic pressure to the seabed. Therefore, this fishery has been subject to debate, particularly when it occurs near, or on, habitats protected under European legislation such as the Habitats Directive and the Marine Strategy Framework Directive. In response, the use of alternative or modified, less damaging fishing gears has been suggested to offer some alleviation; conserving both environmental function and economic sustainability of the fishery. Yet, strong quantitative evidence to support these predictions is lacking.

Project
The PhD project intends to provide quantitative evidence on the benthic impact of three common demersal fishing gears used in Danish waters. Experimental fishing used in Before-After-Control-Impact studies can reliably determine the one-off mortality of a pulse-fishing event. The advantage of using a BACI, rather than a comparative analysis of historical fishing pressure gradients, is the ability to control for differences in environmental conditions; selection of sites with the same physical characteristics, as well as for differences in time. Therefore, the case studies will assess the effects of different gears in different sandy habitats using experimental fishing (BACI design) and, for the first time, quantify the ecosystem impacts of gears described to be of low environmental impact.

Perspective
The insight gained is highly relevant and needed for fisheries management, by providing empirical evidence of the broader ecosystem effects of these fishing gears. The output from my PhD has the potential to provide alternative management strategies, such as better gear-differentiated closures, and to support the use of more environmentally friendly fishing practices.
Background
This PhD project is part of the Horizon 2020 WaSeaBi project, which aims to bring the state-of-the-art in solving the barriers to sound exploitation of the aquatic resources with focus on the optimal utilization of seafood side-stream through development of storage solutions, sorting technologies and decision tools to secure an efficient, sustainable supply system for by-catches and side-stream from aquaculture, fisheries and the aquatic processing industries.

Project
The focus of the PhD project is to illustrate how the companies in the WaSeaBi project can optimize their decision-making processes to improve the sustainability and economic utilization of the aquatic side-streams by using decision making tools. This will mainly be explored through the development and application of a new decision support tool to the already existing Analytic Hierarchy Process (AHP) methodology, that accounts for different decision-making biases and the decision makers’ dominant logic, which are rarely studied or accounted for in this methodology. By using the psychological technique of cognitive mapping to map out a decision makers decision paths on sustainable development it will be identified which biases and components of dominant logic are causing barriers to the sound exploitation of the aquatic resources and side-streams.

Perspective
The insights gained from this PhD project will be used to formulate the support tool’s methodology and create a new AHP support tool that to greater degree can account for biases and dominant logic components in its calculations, in order to support decision makers in making unbiased decisions about sustainable optimization of aquatic resources and side-streams.

Søren Espersen Schrøder

Title: Decision tools and management in the fish sector
Supervisor: J. Rasmus Nielsen
Section: Ecosystem based Marine Management

Background
The mesopelagic layer of the ocean is located in the pelagic water masses between 200m and 1000m depth. This layer is inhabited by a diverse community, from which Lanternfishes or Myctophids are important constituents. Recent hydro-acoustic survey estimates of these fish species indicated a biomass of 10 billion metric tonnes: an order of magnitude larger than previous estimates. There is increased interest from commercial fisheries to exploit these species for the use for fishmeal, fish oil and nutraceuticals, but the question is whether such potential exploitation is sustainable or not.

Project
This project evaluates the sustainability of potential exploitation of selected stocks of two key mesopelagic fish species, Maurolicus muelleri and Benthosema glaciale, in the North-East Atlantic, both in terms of ecological and economic sustainability. Length-based statistical methods for data-limited stock assessments are used to estimate demographic parameters related to growth, mortality, stock size and production of the stocks according to Maximum Sustainable Yield. The economic sustainability of a mesopelagic fishery and different management strategies will be evaluated with among other the DISPLACE individual vessel based bio-economic model for large scale pelagic fisheries. This project is part of the H2020 MEESO project, which aims at filling knowledge gaps related to mesopelagic species, to assess their role in the ecosystem and the sustainability of potential mesopelagic exploitation.

Perspective
Alongside with the global human population growth, the demand for food, including marine products, continues to increase. The sustainable exploitation of new marine resources such as mesopelagic species could complement and potentially partially relieve the fishing pressure on existing marine resources while meeting the increasing demands of aquaculture and human nutrition. It is important already in an early stage to make assessments of the long-term ecological and economic sustainability of potential exploitation, and to develop suitable management measures before large scale fishery starts.

Berthe Vastenhoud

Title: Fish stock assessment and fisheries dynamic modelling—Investigating the sustainability of potential mesopelagic resource exploitation
Supervisor: J. Rasmus Nielsen
Section: Ecosystem based Marine Management
**Background**

Commercial fishing with trawls compared to similar industries is a field where the uptake of technology has been low. This means that there are currently both economically and biologically costly fishing activities, where part or the entire fishing process is taking place in blind. The technologies that change this are today available and may be transferred from other sectors and adapted to fisheries. Establishing the future fishing gears that aim to ensure the best possible economic and biological sustainability as well as comply with ambitious management goals such as the EU landing obligation (Common Fisheries Policy, CFP), requires the fishermen to control the catch process and actively respond to what they observe. It is therefore a crucial first step to establish a real-time monitoring of the catch process. There is an expectation that future fishing gear will contain significantly more technology as well as solutions that can actively affect the selectivity of gears without necessarily interrupting the capture process.

**Project**

The PhD project will be focused on developing and establishing decision-making tools primarily in trawl fisheries. The goal of this approach is to make fisheries more targeted and intelligent in its catch process and to ensure the best possible economic and biological sustainability in the trawl fisheries.

**Perspective**

Establishment of the real-time monitoring tool allowing fishermen to control the fishing operation will allow to actively react and adjust the capturing procedure and thus will lead to more targeted fisheries and bycatch reduction. Overall, the implementation of such tool will contribute to success of the CFP.

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**Maria Sokolova**

**Title:** Improving selectivity and catch efficiency in demersal trawl fisheries using real-time camera monitoring and real-time decision making tool both prior to and during the fishing operation

**Supervisor:** Ludvig Ahm Krag

**Section:** Fisheries Technology

**Background**

Towed bottom fishing gears can cause widespread disturbance to the seabed of shallow shelf seas. The physical impacts can have environmental and ecological consequences that affect primary production and threaten the biological sustainability and economic viability of fisheries, whereas the energy requirements will have global consequences associated with emissions of CO₂ and NOₓ gases. In Denmark, demersal trawls are widely used and to ensure the long-term sustainability of these fisheries and to reduce their environmental impact there is a need to develop and design fishing gears that have a reduced impact on the seabed and that are more fuel-efficient.

**Project**

This project will focus on developing methods for the assessment of the physical impact and drag of demersal trawls and the evaluation of low impact gears that are being developed by the fishing gear manufacturing industry. A specially designed sledge that tows individual gear components will be used to investigate the depth to which these components penetrate the seabed, the hydrodynamic turbulence they create and the associated quantity of sediment they mobilise into the water column. Small-scale modelling trials in a flume tank will be used to get a better understanding of the hydrodynamics of the trawl gear components and to extend the results of the sledge trials. Additionally, there will be full-scale trials to assess and compare the physical impact and fishing gear performance of a conventional otterboard with a remotely controllable otterboard that is being developed by a commercial trawl door company.

**Perspective**

This project will ensure that towed gear fisheries will be biologically sustainable, environmentally friendly and economically viable. It will allow policy makers and fishery managers to implement the EU Common Fisheries Policy (CFP) and contribute to the Danish Government’s sustainability target or reducing CO₂ emissions by 70% by 2030.

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**Morteza Eighani**

**Title:** The development of low impact and fuel efficient fishing gears

**Supervisor:** Barry O’Neill

**Section:** Fisheries Technology

**Background**

Towed bottom fishing gears can cause widespread disturbance to the seabed of shallow shelf seas. The physical impacts can have environmental and ecological consequences that affect primary production and threaten the biological sustainability and economic viability of fisheries, whereas the energy requirements will have global consequences associated with emissions of CO₂ and NOₓ gases. In Denmark, demersal trawls are widely used and to ensure the long-term sustainability of these fisheries and to reduce their environmental impact there is a need to develop and design fishing gears that have a reduced impact on the seabed and that are more fuel-efficient.

**Project**

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**Perspective**

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**Tim Wilms**

**Background**
Structural complexities of coastal reefs are of major importance in providing suitable niches for many species of fish. For instance, marine boulders provide a stable surface enabling safe anchorage and growth of macroalgal species, while forming complex cavernous reef structures. Such heterogeneous environments attract numerous fish species by increasing the overall food supply and offering refuge from larger predatory species. In Denmark, large-scale extraction of marine boulders has occurred for over a century until it was banned in 2010 as part of the EU Natura 2000 program. Since then, a number of restoration projects have been initiated in an attempt to recover this important habitat type and its functions.

**Project**
This research project aims to document the ecosystem effects of restoring various coastal reefs in Southern Denmark. The reefs were constructed in late 2017 and surveyed pre- and after restoration by the use of underwater video stations. Of specific interest is the overall restoration effect on the fish community, as well as localized effects from reef designs varying in height and boulder density. Environmental DNA (eDNA) analysis of seawater samples will furthermore allow for a comparative assessment between this newly emerging survey tool and the conventional method of underwater recordings.

**Perspective**
Habitat restoration constitutes a vital step in the recovery of exploited stone reefs, as the extraction of marine boulders permanently alters the seabed structure and ecosystem recovery is unlikely to occur without human intervention. Yet, methods of restoring temperate reef structures are still poorly understood. This PhD study will produce pertinent information for future assessments of reef-associated fish communities and will shed light on cost-effective methodologies for artificial stone reef construction.

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**Aris Thomasberger**

**Background**
Eelgrass is a key element and indicator species for water quality in the European Union Water Framework Directive. To ensure that the Danish shellfish fishery complies with EU environmental directives, eelgrass is fully protected within Natura 2000 areas under the Danish Mussel Policy and environmental impact assessments have to be carried out before fishing activity can commence. Consequently, detailed knowledge on eelgrass distribution is of high importance.

**Project**
The project will carry out extensive studies with drones in water bodies of different characteristics to explore the possibility of implementing drone technology in future mapping of subaquatic vegetation. I will focus on the development of new methods for eelgrass mapping in environmentally complicated areas with deep and/or turbid waters. Different sensor/platform combinations and new approaches to image classification processes will be tested to explore strengths and limitations of drone based mapping. The project is funded by the EMFF and will be carried out in close collaboration with other sections of DTU Aqua, the DTU Space Drone Center and SDU’s drone group at the Department of Biology.

**Perspective**
The project is expected to develop new technological methods and tools that in the future can ensure an economically and professionally sound mapping of subaquatic vegetation in Danish coastal waters. Of special interest will be Natura 2000 areas where fishing with bottom trawling takes place, thus is subject to the Danish Mussel Policy. The developed methods are expected to be directly applicable in the annual impact assessments for mussel and oyster fisheries as a more accurate and cost-effective alternative to the current point specific video surveys. In addition to Natura 2000 areas, the methods developed will also be applicable within other management practice, e.g., the future third generation water plans.
Background
Recreational fishing is an important leisure activity for millions of people on a global scale. The associated economic, sociocultural and ecological effects are immense. Recreational fishing is a multi-billion dollar industry that also holds great sociocultural values for the users, such as social cohesion and environmental education. Additionally, recreational fisheries represent the main use of many freshwater as well as some marine fish stocks. The traditional methods to investigate aspects of recreational fisheries, such as ecological effects and human dimensions, are often time consuming and cost heavy. With the emergence of so-called angler applications (angler apps), the use of smartphones for fisheries management and research poses a promising avenue for collecting data from recreational fisheries directly and efficiently.

Project
The aim of this project is to investigate the strengths and weaknesses of citizen science as a method to collect recreational fisheries data. With special emphasis on smartphone applications for anglers. In 2016 DTU Aqua launched a citizen science platform, Fangstjournalen, where anglers via a smartphone app, can register their trips and catches. Evaluating Fangstjournalen, in regards to the general main challenges associated with angler apps, will be a priority.

Perspective
Angler apps hold the potential to be a cost-effective tool for recreational fisheries management and research that can supplement and even replace the traditional survey methods. However, it implies a better understanding of how best to recruit, retain and potentially reactivate the citizens, i.e. the anglers, on the platform and not least to determine the accuracy of the collected citizen science data.
Renata Goncalves

Background
The European lobster, *Homarus gammarus* L., is a commercially important and highly-priced decapod species in northern Atlantic area. A general decline in catch per unit effort has been observed, with occasional stock collapses. The release of hatchery-reared post larvae in the wild has been used as a fisheries management tool to counteract this decline. The success of stock enhancement depends on the production of high-quality juveniles with higher chances of survival after release into natural habitats. A major bottleneck of lobster culture concerns the low survival rates given their highly cannibalistic nature, particularly if the feed is sub-optimal. A promising solution is moving away from live/frozen food and embracing a dry formulated diet. This type of diets can offer several advantages, in particular, a more consistent nutritional quality. However, the development of formulated dry feeds for lobsters has received little research effort compared to the improvement of water quality and rearing technologies. Thus, commercially dry feeds specifically designed for European lobsters are not yet available. Some attempts to grow lobsters on dry feeds have been tried with fish and shrimp pelleted diets, but they are likely to have sub-optimal protein, carbohydrate and lipid composition.

Project
The focus of this PhD project is to explore the nutritional requirements and metabolism of European lobster larvae and post-larvae. The specific goals are 1) to define macronutrient requirements of post larvae, 2) understand nutrient metabolism of larvae, and 3) evaluate performance of post larvae fed optimized experimental feeds under temperature stress.

Perspective
Generated knowledge from this project will provide valuable insight for the formulation of nutritionally balanced dry feeds specifically designed for the species at each developmental stage. Ultimately, a species-specific formulated diet will contribute to an improvement of growth and survival rates in lobster production units.

Tilo Pfalzgraff

Background
The continuous growth of the aquaculture sector puts pressure on finite marine ingredients such as fishmeal and fish oil. These ingredients are bottlenecks in the feed production for aquaculture, necessitating the full or partial substitution of these ingredients with land-based alternatives. Currently, vegetable oils are already used to provide large parts of the lipid fraction in fish feed. High inclusion rates of terrestrial lipids however, may result in decreased production efficiency and exert a limitation on the physiological and metabolic performance in salmonids.

Project
My PhD project therefore focuses on the causes behind the performance related decline due to the substitution of fish oil by vegetable oils. Diets containing different fatty acid compositions will be tested to assess the nutrient digestibility as well as metabolic changes of the fish. Dietary fatty acids are used as an energy substrate, but also serve structural functions. Specifically, fatty acids constitute the bulk of cellular membranes, and modifications in composition lead to changes in membrane permeability. It is hypothesized that dietary remodeling of membranes leads to increased energy cost towards maintaining ionic homeostasis. It is a part of the project to figure out if this results in an overall cost of living and a reduced opportunity for activity and feeding. A second objective is to evaluate to what extent stress affects growth performance and nutrient digestibility in fish. This is achieved by examining the consequences of elevated cortisol levels, arising from different stress situations, on the lipid digestibility and metabolism in rainbow trout.

Perspective
The results of my PhD project will help understand the correlation between stress and the use of dietary vegetable oil on production related performance in salmonids, ideally leading to recommendations for feed formulations and a more sustainable aquaculture production of the respective species.
**Freja Karlsen**

**Background**
Aquaculture constitutes a significant contributor to the global fish and shellfish supply. However, owing to a steadily growing population, the production volumes and competition for resources have increased significantly, which in turn has led to high production costs. These consequences have necessitated the development of a more sustainable aquaculture feed production. Several industrial processes generate immense quantities of protein-rich residues, which are either sold as low-value products or discarded as waste. Due to their high content of recoverable proteins and low production costs, these by-products provide a more sustainable alternative to presently applied aquaculture feed.

**Project**
My PhD project is concerned with the utilization of brewer’s spent grain (BSG) - a proteinaceous by-product from beer-brewing—in aquaculture feed. Due to the high protein content, BSG constitutes a potential unexploited source for fish feed and therefore the ultimate aim of this project will be to develop a fish feed that contains BSG as the sole protein source. However, when unrefined, BSG is expected to have a low nutritional value, owing to a high content lignin and fibre, which are antinutritional factors (ANFs) for fish. To enable the employment of BSG in fish feed, ANFs removal and protein optimization are required. In order to accomplish this, two different strategies have been elaborated for the refinement of BSG. In the first strategy, proteins are extracted from BSG leading to formation of a protein concentrate, whereas the second strategy focuses on conversion of BSG to a high-value product applying a combination of different chemical and biological treatments.

**Perspective**
The work of this project will generate knowledge about the valorization of industrial by-products containing high levels of proteins and ANFs. Ultimately, these efforts might lead to development of an industrially applicable product for commercial fish farming; thereby contributing to increased sustainability of aquaculture feed production.

**Kylian Manon Eggink**

**Background**
The increase in human population and a larger middle class are drivers of the growth of the aquaculture sector. To be able to keep up with this growth, resources need to be used efficiently and in a sustainable way. Current feed ingredients such as fishmeal and soybean meal are associated with overfishing and deforestation, respectively. Therefore, current research is investigating alternative protein and lipid sources. One of the most promising sources are insects. Insects provide high-quality proteins and lipids with low requirements of water and land use.

**Project**
The main focus of this PhD project is to identify possible fish feed ingredients obtained from insects, in this project specifically black soldier fly larvae. Black soldier fly can be reared on biological waste streams, converting low-value organic waste into high-quality macronutrients. In the project, the influence of the rearing substrate on the nutritional composition of the larvae will be investigated. Additionally, the optimal inclusion levels of black soldier fly meal will be determined in feed for rainbow trout and Nile tilapia, to test its effect on carnivorous and omnivorous species.

**Perspective**
Knowledge generated by this project will provide valuable information on the use of insect-based ingredients in aquafeed, its effect on performance and physiology. Ultimately, the project will contribute to making the aquaculture sector more sustainable by the use of waste streams for rearing insects.
Julie Hansen

Background
The use of recirculating aquaculture systems (RAS) in production of Atlantic salmon is continuously increasing, partly due to the technological advancement in increasing the sustainability of production. Filtration and treatment of the water is done with a limited exchange of water, which is putting less pressure on valuable resources. However, the limited water exchange pose a challenge, as the concentrations of e.g. organic matter can be high, which provides a foundation for bacteria, including sulfate reducing bacteria (SRB). SRB can affect water quality and imperil fish health, as they produce hydrogen sulfide (H₂S) as a by-product metabolizing organic matter anaerobically. Seawater consists of much higher levels of sulfate compared to freshwater, and the potential for production of H₂S is higher. Atlantic salmon smolt is produced under saline conditions, and are at risk of being exposed to dangerous concentrations, as H₂S is toxic even at very low concentrations.

Project
This project aims to understand the physiological mechanisms and behavioral response related to acute and chronic H₂S exposure. The project will examine the underlying mechanisms of how Atlantic salmon copes with H₂S, which physiological systems are the most sensitive, identify sub-lethal and lethal levels, and whether the fish to some extent are able to adapt to non-critical H₂S levels. We will determine the effects of H₂S exposure through a combination of metabolic studies, behavioral assays, and bioenergetics and welfare indicators.

Perspective
The results from this project will provide an understanding of the impact of H₂S on the physiology Atlantic salmon and lay the foundation of a practice to best manage the toxicant in aquaculture. The information gained during this research will be used to aid land based aquaculture, by providing an array of values that are considered safe. By mitigating the effects of H₂S, fish health and welfare can be improved and mass mortalities avoided.

Xiaoyu Huang

Background
Feed is the main input of nutrients in form of nitrogen (N), phosphorus (P) and organic matter into a recirculating aquaculture system (RAS). Ingredient composition in fish feed, and consequently the input of available nutrients and organic matter, changes continuously due to ingredient availability and market price, technological developments in feed processing, and tightened environmental regulations. There is, however, very limited information on the effects of changing feed composition on RAS water quality, treatment efficiency and accompanying effects on fish performance. Effects on chemical composition might somewhat be expected but any effects on microbial water quality remain unknown and unpredictable at present.

Project
In this project, the impacts of feed composition will be investigated in four aspects: (1) feed ingredients, (2) dietary C/N input, (3) dietary P input, and (4) particulate feed waste. Feeding trials will be conducted in RAS with rainbow trout at DTU Aqua, Hirtshals. Water analysis will reveal the changes in micro-particle conditions, chemical contents, and microbial quantities and activities. Based on the results, possible mitigation methods will be discussed to manage RAS water quality.

Perspective
The purpose of this PhD project is to systematically study the interactions between feed composition, nutrient balances and RAS water quality, with special focus on the effects and dynamics of microbial water quality. The generated knowledge will contribute to future diet evaluation, improve system compatibility between feed and RAS, and secure stable water quality and fish production in RAS.
Wanhe Qi

Background
Recirculating aquaculture systems (RAS) have a high degree of water reuse, reduce environmental impacts and provide controlled rearing conditions for fish production. All RAS rely on a central biological treatment process – biofiltration. This microbial process involves nitrifying bacteria that converts toxic ammonium (excreted from the fish) to harmless nitrate. It is crucial to get more information about how water disinfection strategies affect biofilter performance. Currently, such assessment is difficult to perform, and there is limited knowledge and tools available to understand and quantify the mechanisms, activity and importance of surface attached bacteria known as biofilm.

Project
The PhD project is supported by a joint Danish-Norwegian research project “RASHealth” (nofima.no/en/project/rashealth), where assessment of disinfection strategies on water quality and biofilm activity is central. The aim of my PhD project is to develop simple, fast and practical assays to quantify biofilm activity that can be used as a tool to assess biofilter performance, disinfection efficacy and predict disinfection demand in RAS.

Perspective
The outcome from my research will provide tools to test biofilm activity under controlled lab-scale experimental conditions and pilot-scale practical situations. This will provide guidelines for improved disinfection strategies in RAS and generate theoretical and applied knowledge on biofilm formation and tolerance during disinfection practice. Ultimately, these efforts will support ongoing research and development of biofilter designs and RAS operation.

Sofie Hansen

Background
The Mediterranean aquaculture industry is compromised by nodavirus infections causing considerable disease and mortality in European sea bass (Dicentrarchus labrax) and recently also gilthead sea bream (Sparus aurata), the two main cultured marine fish species in the region. This project is part of a large collaborative EC H2020-supported research and innovation action focusing on improved competitiveness and sustainability of Mediterranean aquaculture production. Currently, one of the major bottlenecks for the development of aquaculture of sea bass and sea bream is Viral Encephalopathy and Retinopathy (VER) also known as Viral Nervous Necrosis (VNN), an infectious disease caused by betanodavirus, a member of the family Nodaviridae.

Project
This project will focus on optimizing a vaccine prototype against nodavirus infection in sea bass based on recombinant VLPs (virus like particles). A nodavirus infection model will be establish in sea bass at the facilities at DTU and this model will be used for testing different vaccination strategies, including dose, delivery and adjuvant aspects and to characterize the vaccine induced immune response, protective mechanisms and safety aspects as well as. Protection across viral genotype/serotype will also be assessed under experimental conditions. Finally, the vaccine will be tested under field conditions in Mediterranean fish farms.

Perspective
A safe and efficient vaccine against nodavirus will directly improve the survival rates of sea bass in Mediterranean fish farms thus improving the sustainability and competitiveness of Mediterranean fish farming.
**Background**
Since late 2017, a novel subtype of *Piscine orthoreovirus* (subtype 3, PRV-3) has been associated with disease and increased mortality in Danish rainbow trout (*Oncorhynchus mykiss*) farming. A surveillance study conducted in 2018 revealed that the majority of Danish rainbow trout farms are infected with PRV-3, although only some farms experience disease in relation to the infection. However, the farms that do experience disease and increased mortality are subject to major economic losses. Additionally, PRV has recently been hypothesised to be involved in discoloration in the fillet.

**Project**
The aim for this project is to develop and implement two high throughput diagnostic tools: 1) Fluidigm assay for detection of PRV-3 virus along with other pathogens and host immune gene expression in samples from fish, which will enhance the predictive value of disease outbreaks. 2) Luminex assay for detection of antibodies directed against PRV-3, which will enable mitigation of disease by introducing immune-competent fish into PRV-3 infected facilities.

**Perspective**
Overall the tools developed within this project will advance the diagnostic capacity of the Unit of Fish and Shellfish Diseases at DTU Aqua. Furthermore, this project will generate relevant knowledge to explain host-pathogen interactions once environmental changes occur, and will help the industry in mitigating the impact of this disease in RAS.