

ABSTRACT KATALOG



Miljø- og
Fødevareministeriet
Miljøstyrelsen



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KEYNOTES

Life and biogeochemistry in the deepest trenches on Earth

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The deep sea covers more than 60% of the Earth but remains largely unexplored. This is particularly true for the hadal zone that encompasses water depths from 6 km to the deepest trenches that reach almost 11 km of depth. The supply of organic material and thus the biological activity, generally decrease with increasing water depth. However, the 27 hadal trenches that stretch along the geologic subduction zones apparently act as depocenters and recent findings document that they represent biological hotspots with intensified turn-over of organic material. The activity is mainly mediated by unknown communities that flourish at extreme hydrostatic pressure. The exploration of hadal trenches is challenging as recovered biological samples are prone to recovery artefacts and thus investigations to a large extent rely on in situ instrumentation for quantifying processes and distributions of hadal life forms. The talk will present recent discoveries from research cruises to different hadal trench environments in the Pacific and discuss the knowns and the unknowns of hadal research, but also how best to explore this extreme frontier of marine science.

How marine mammals and Greenland Inuit are challenged by long-range pollution

Rune Dietz and dozens of collaborators over the years

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Since 1979, I have worked on marine mammals and contaminant issues, and the present presentation will focus on my work in the Arctic region due to time restrictions. Despite the remoteness of Greenland from the industrialised part of the world, marine top predatory mammals as well as the local Inuit population are affected by global anthropogenic pollution and climate change. Contaminants and effects have been monitored over the last three decades mainly by the Arctic Monitoring and Assessment programme, which have shed light on temporal and geographical trends contaminants in top predators and humans as well as associated effects. Here, examples on trends and effects will be provided on key species. These includes geographical and temporal trends of polar bears as well as changes in food preferences linked to climate change. The vulnerability of toothed whales exemplified by narwhals, killer whales and pilot whales due to their higher exposure compared to carnivores will be presented as well as predictions for future scenarios of toothed whales appearing in the hunters menu. Examples on how contaminant exposure are translated into effects on the population level will be present based on recent worldwide assessments on killer whales. Regional and seasonal Inuit exposure scenarios from selected areas will also be presented. A summary will be provided on how the achieved knowledge has been compiled under the international Arctic AMAP Assessments feeding in to the Arctic Council over the last two decades. Our work has contributed to regulations through national bans, the Stockholm Convention on Persistent Organic Pollutants (Signed in 2001 and effective from May 2004) and the Minamata Convention on Mercury (adopted and signed October 2013) resulting in global reduction of the emission on these detrimental contaminants.

Hav- og vandområder i god tilstand - vandrammedirektivet og havstrategidirektivet som redskaber

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I Danmark har vi altid levet i tæt samspil med havet, fjordene og vandløbene. Ingen steder i landet er vi længere end 52 km væk fra den nærmeste kyst. På land findes tusindvis af kilometer vandløb og store og små søer.

Velfungerende hav- og vandområder er grundlaget for at bevare det mangfoldige liv, og områderne leverer en lang række goder til os mennesker, fx i form af fødevarer, energi og byggematerialer.

De menneskelige aktiviteter på land og på havet påvirker vand- og havområdernes tilstand. Områderne skal derfor udnyttes på bæredygtig vis, hvilket kræver fokus på balancen mellem beskyttelse og benyttelse. Et væsentligt formål med vandrammedirektivet og havstrategidirektivet er at sikre denne balance samtidig med, at målet om god tilstand i hav- og vandområder nås.

I oplægget sættes der fokus på, hvordan Miljø- og Fødevareministeriet arbejder med at implementere de to direktiver nationalt. Der stilles bl.a. skarpt på samspillet mellem de forskellige aktører i forhold til vand- og havstrategiplanlægning, herunder hvilken rolle forskningsverdenen spiller i forhold til implementering af direktiverne.

Maritim fysisk planlægning

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I Danmark står vi overfor at skulle have den første havplan, der dækker de danske farvande, udarbejdet. Havplanen skal sikre en bæredygtig udvikling af energisektoren til søs, søtransport, fiskeri og akvakultur, indvinding af råstoffer på havet, transportinfrastruktur samt tage hensyn til bevarelse, beskyttelse og forbedring af miljøet. Det 4-Årige arbejde med udviklingen af en samlet havplan for det danske havareal skrider frem planmæssigt, og havplanen forventes offentliggjort i 2019 med en 6 måneders høring.

Mere ålegræs, tak! Men hvordan?

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Ålegræs er produktivt, skaber habitat for andre organismer, binder CO₂, fjerner næringsstoffer fra vandsøjlen og beskytter havbunden mod resuspension. Ålegræs bidrager dermed til biodiversitet, kulstofbinding (blue carbon) og mere klart vand. Indirekte medvirker ålegræs endvidere til en mere stabil iltbalance. Mere ålegræs er derfor ønskeligt.

Ålegræs kræver lys, uorganisk kulstof, næringsstoffer, gode iltforhold, moderate temperaturer og gode forankringsmuligheder. Dårlige lysforhold grundet forhøjede næringsstofkoncentrationer samt fysisk eksponering er de væsentligste årsager til begrænset udbredelse af ålegræs i danske farvande. Lav tilgængelighed af næring og uorganisk kulstof kan i særlige situationer begrænse ålegræssets vækst, men forsyningen vil normalt være rigelig til at dække planternes behov. Lokalt og temporalt kan dårlige iltforhold og høje temperaturer forårsage massedød af ålegræs.

Hvis vi skal have mere ålegræs, kan vi hjælpe planterne lokalt ved at skabe bedre forankringsforhold og fysisk beskytte planterne. Vi kan accelerere spredningen af ålegræs igennem såning/spredning af frø eller udplantning af hele skud i områder, hvor modellering forudsiger gode vækstmuligheder. Men vigtigst af alt skal tilførslerne af næring til især fjorde og kystvande fortsat reduceres markant for at få bedre lysforhold og nedsætte risikoen for lokale iltsvind og dermed skabe mulighed for øget udbredelse af ålegræs.

ABSTRACTS FOREDRAG

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Like hitching a ride on a narwhal

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The narwhal (*Monodon monoceros*) is a high Arctic species inhabiting one of the most remote areas on Earth – an area that is also experiencing radical changes due to climate change and an associated increase in anthropogenic activities. Thanks to advances in biotelemetry, it is now possible to collect detailed information on the behaviour of this notoriously skittish whale species. Narwhals caught in nets were instrumented with satellite-linked transmitters and acoustic sound and movement tags (AcousondeTM) over periods of up to 8 days in Scoresby Sound in East Greenland in 2013-2017. The instruments collected detailed information on the movements, diving behaviour (depth and movement in 3D) and acoustic behaviour of the individuals. The acoustic data were analysed for vocalisation events i.e. clicking, buzzing and non-feeding vocalisations as a function of depth, time of day and area. After an initial silent period possibly due to tagging, the narwhals spent 20 - 30 % of their time echolocating. Relative to the percentage of time spent at different depths, the narwhals buzzed proportionately more at depths between 300 m and 600 m. They dive down to these depths presumably to forage on Cephalopods that have also been found in the stomach contents of individuals harvested in the area. Non-feeding vocalisations were predominantly produced in shallow depths near the surface. Particularly one type of sound, burst-pulsed calls, was dominating the non-feeding vocalisations. Burst-pulsed calls were highly stereotypical as well as unique to each individual and could therefore facilitate individual recognition similar to signature whistles described in other odontocetes.

Narwhal fieldwork

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A video presentation of narwhal fieldwork in Greenland. The video will demonstrate the cooperation between local hunters and scientist and the day-to-day life in a field camp in a remote harsh area in the Arctic. The video will show and describe the methods and techniques of satellite tagging cetaceans which have been developed and modified over the years.

SESSION 2: REASEARCH IN RORQUAL BIOLOGY

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Fishermen help scientists reveal far reaching movements of minke whales from coastal North Sea to deep Atlantic habitats

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Fishermen are often in conflict with marine mammal conservation, due to either habitat destruction from trawling, competing for the same prey, or non-target animals end up as bycatch in fishing gear. In case of the Danish pound net fishermen a fruitful partnership with scientists have persisted for more than 20 years. Pound nets are used to trap live fish for human consumption and provide the highest fish quality with little or no discard of dead fish. This sustainable fishery regularly catch live harbour porpoises, and in two cases, 14 years apart, also live minke whales were trapped. In June 2003, a 5 meter long subadult minke whale was caught alive near Skagen harbour at the northern tip of Denmark and in June 2017 the same pound net caught another 4 m long minke whale. The whales swam calmly around in the net until the net was lifted to the surface and the whales were held alongside the fishing boat. An Argos satellite transmitter was attached with three nylon pins to the dorsal fin. Contact remained for almost three months with the first whale while contact remained for 10 months with the second whale. The whales showed similar movements; both whales moved north leaving the North Sea and spending most of the time on the continental slope west of Ireland, around Atlantic offshore seamounts and islands and along the mid-Atlantic ridge. The whales were tracked for 11,500 and 20,000 km, respectively as far south as the Cap Verde Islands, with an average swimming distance of 133 and 66 km per day. The second whale spending longer time in specific places, presumably foraging. Cooperation with fishermen giving such unique opportunities to tag minke whales have provided both the longest track durations of a minke whale, but also insights into unknown seasonal habitat use of the subadult minke whales

The migratory movements of blue whales (*Balaenoptera musculus*) inhabiting Arctic and Sub-Arctic areas of the Northeast Atlantic.

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In the last 20 years the amount of photographic data from blue whales (*Balaenoptera musculus*) from the Northeast Atlantic has increased dramatically, giving us better insight into their migratory patterns. The data presented herein stretches from Svalbard, Norway, in the north south to southern Iceland. The photographic data span the period from 1997-2017 and contain 235 individual blue whales observed in three different countries: Norway (N=62), Greenland (N=4) and Iceland (N=173). Initially the number of blue whale record was 239, but through photo-matching it was shown that four of the “Norwegian whales” was were the same as four individuals seen in Iceland. Tracking movement patterns across the study area over the different months showed that: Blue whales peak in abundance in June-July around Iceland, they then move further north reaching Svalbard and northeastern Greenland in July-August, finally they head south again, likely passing western Iceland in late August-November. The data indicate a distribution shift of the blue whales observed during summer in northern waters. Observations around Svalbard are becoming more common, which suggests that the whales are moving further north and/ -or that their population is increasing, and the species is repatriating the northern reaches of their former range. The data from Iceland suggest that the whales mainly move through western- and northern Icelandic waters during their migration, however further research is needed to fully understand the movement patterns of the blue whales inhabiting the Northeast Atlantic. A better understanding of their movement patterns will be useful for management/conservation planning for these giants of the seas.

Source levels of blue whales (*Balaenoptera musculus*) in Iceland measured with a hydrophone array

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Blue whales (*Balaenoptera musculus*) are coming into Skjálfandi Bay by the town Húsavík in Iceland every summer in June. Húsavík is also known as the whale watching capital of Europe and every summer more than 100,000 tourists go whale watching from here. This study was conducted in June 2015. The overall aim of the project was to investigate if blue whales were affected by anthropogenic noise. Four boats (three sailing boats and one fast boat) were used as a platform for recording. Each of the recording platforms were equipped with a hydrophone (Brüel & Kjær 8101 or Reson 4032), connected to an Olympus digital recorder and GPS signal was recorded with frequency-shift keying on one channel. The hydrophones were lowered to a depth of 30 m. Recordings were only made in sea state less than 3. The four boats were leaving Húsavík harbour at 2 or 3 am to get quiet recordings without whale watching vessels. The recorded down sweep calls of blue whales were used to calculate the position of the calling blue whales using the difference of arrival time to each hydrophone. The distance from the calling blue whale was then used to calculate source level of the calls. Source levels varied from 185 – 190 dB re 1 μ Pa rms @ 1m. Ambient background noise was calculated and it varied from 110 to 118 dB re 1 μ Pa²/Hz at low frequencies. The number of blue whale calls were higher (in 10 min bands) when ambient noise level increased. Similar responses from blue whales have been documented in response to airgun sounds off Canada. In conclusion, we document an acoustic response of blue whales in reaction to increased ambient noise levels. This may have importance when mitigating the effects of human-induced noise on blue whales.

Particle motion in vocalizations of the North Atlantic right whale (*Eubalaena glacialis*)

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The vast majority of studies on acoustic communication in cetacean marine mammals have focused on investigating the pressure component of acoustic signals. However, such studies overlook the particle motion component of sound. A number of mammals have been shown to use the particle motion component of sound in communication, and it has been hypothesized that mysticete marine mammals may do so as well. In the current study, we measured levels of particle velocity and acoustic pressure generated by vocalizations from North Atlantic right whales (*Eubalaena glacialis*). We show that *E. glacialis* produce acoustic fields with considerable particle velocity components. Although mysticete hearing capabilities are largely unstudied, it is possible these vibratory particle components may play a role in auditory reception by stimulating bone conduction to the ears. In combination with documented particle velocity components of humpback whale vocalizations, these results from an additional species suggest particle motion may be a possible pathway for mysticete acoustic communication that has been largely unexplored.

Foraging kinematics in Inshore South African Bryde's whales: preliminary results.

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The Inshore South African Bryde's whale (*Balaenoptera edeni*) faces increasing anthropogenic pressure from overfishing, entanglements, and prey distribution shifts, yet nothing is known about their kinematics and daily foraging behaviour.

To understand how and when Bryde's whales find and pursue prey and to identify spatial and temporal overlap with coastal fisheries, we deployed synchronised video and movement sensor tags on seven whales in Plettenberg Bay, South Africa, in April 2018. These tags recorded continuous video and kinematic data (pitch, roll, heading, speed) while onboard the whale.

Whales dived to maximum depths of 101 m, with a highly variable dive duration averaging 4.5 min (range: 53 s - 13.1 min). The average interval between dives was 5:17 min (4.6 s - 221 min). When diving, whales spent 44 % of the time foraging, with a frequency of foraging dive/hour of 2.7 (0.93 - 4.0) and a significant amount of time searching in between lunges (mean interval for foraging dives: 12.3 min, range 4.6 - 112 s). Lunges were performed at an average depth of 60 m characterized by high jerk (acceleration per time) and reaching high speeds (0.9 - 7.9 m/s). During lunging, pitch varied between 67.3° downwards to 96.2° upwards in relation to the horizontal plane. The whales kept their mouths open for an average of 4.9 s during lunges and showed a right-side preference when lunging (61 %), similar to several other rorqual species.

This first attempt at describing the kinematics of Bryde's whale foraging suggests that they may have high energetic costs while foraging and set the stage for comparison of foraging costs among *Balaenopterids*.

SESSION 3: RESEARCH IN HARBOUR PORPOISE BIOLOGY AND CONSERVATION

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Individual growth and intra-seasonal changes in body condition of harbour porpoises (*Phocoena phocoena*)

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Growth and seasonal variations in body mass can potentially affect the survival and reproductive fitness of marine mammals. Due to the difficulties in measuring these parameters in free-living cetaceans, body measurements are usually obtained from stranded or bycaught individuals. This may result in biasing towards certain age or sex-classes, or unhealthy animals, and little longitudinal data exists about body properties of free-ranging cetaceans. This study investigated growth rate and seasonal variations in body size of individual harbour porpoises (*Phocoena phocoena*).

Measurements of girth, blubber thickness, length, and weight were collected for up to 14 years to assess individual growth and seasonal patterns in the body composition of five harbour porpoises kept in a semi-open facility at Fjord&Bælt, Denmark. Moreover, growth rates of calves were determined from birth from an animal in Fjord&Bælt, as well as from four animals born at Dolfinarium Harderwijk, the Netherlands. This unique, long-term longitudinal data showed very rapid growth rates during the first year of life, followed by a more moderate growth until age 3-5 years, after which there were little overall increase in body length or weight, but large seasonal variations in body weight. Our study demonstrates that it is possible to obtain individual age and body condition using a few measurements of length and girth. This opens for the possibility of non-invasive estimates of age and body assessments in the field e.g. using photogrammetry.

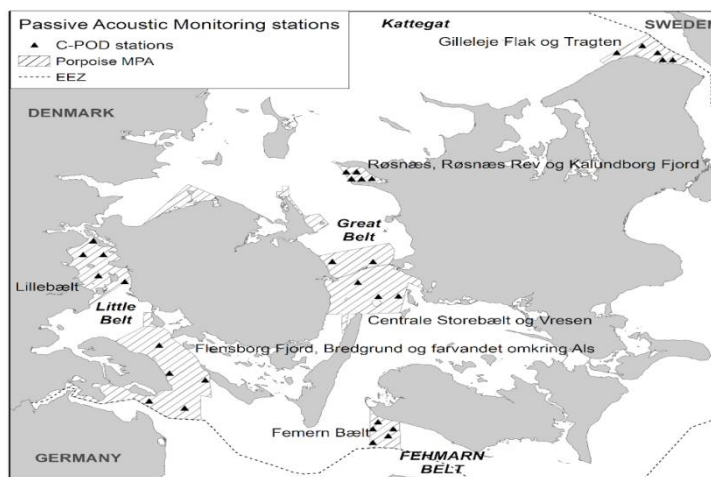
The power of passive acoustic monitoring: the case of harbour porpoises in Danish waters

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The harbour porpoise (*Phocoena phocoena*) is strictly protected in the EU, and monitoring programs must enable the evaluation of trends in density or abundance. Porpoises are often studied by use of passive acoustic monitoring equipment such as C-PODs. C-PODs detect echolocation clicks from porpoises and by assuming that the density of porpoises is correlated to the number of clicks detected, this method can inform on the relative density of porpoises in an area. In Denmark, six Marine Protected Areas (MPAs) designated for porpoises have been monitored using C-PODs from 2012-2016. The aim of this study was to evaluate the statistical power of the monitoring program to detect trends in relative densities. In each MPA, five stations were deployed for two periods of 12-16 month (see figure). Porpoise detections were analyzed as the percentage of minutes with porpoise detections per day (PPM) averaged for each month. Within each site, data were analyzed with mixed-effects ANOVAs. The power analysis showed that the current monitoring scheme will be able to detect 5-20% change in PPM from one period to the next with 80% power and an alpha level of 0.2. Increasing the number of stations or the number of monitoring months did not increase the power significantly. In five out of six MPAs, the mean PPM increased by 19-32% from the first period of deployment to the next. In the last MPA, no significant change was found between the two deployment periods and the power to detect a trend was much lower. This may be caused by lower levels of PPM and higher variation in the data indicating. Based on the current data, we conclude that passive acoustic monitoring using 5 stations within most MPAs provide sufficient power to monitor the status of porpoises.



Do harbour porpoises (*Phocoena phocoena*) in the Baltic Sea prefer certain areas for foraging?

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Protecting foraging areas is essential in the protection of a species. The harbour porpoise population in the Baltic Sea is listed by the IUCN as critically endangered, and in this study we aimed at identifying areas within its distribution range important for foraging. Foraging buzzes, defined as parts of click trains with an inter-click-interval (ICI) of less than 15 ms, were identified in the acoustic dataset from the SAMBAH project, which collected passive acoustic monitoring data from the Baltic Sea. The proportion of buzz ICIs to total ICIs was calculated per station per day per diel phase (dawn, day, dusk and night), and a general additive model was constructed to investigate if foraging areas could be identified within the harbour porpoise distribution range. Two main clusters of animals were evident in the data: one in the southwestern Baltic Proper and one in the Central Baltic Proper, with the sample size in the Central Baltic Proper being small compared to that in the southwestern Baltic Proper. Results show that on the scale of the 304 sampling stations (placed in a grid with 23.5 km between stations) no specific foraging areas could be identified. However, a significant difference could be seen in foraging activity between the two clusters, with a higher proportion of buzz ICIs in the Central Baltic Proper. Buzz ICIs were present in all diel phases, but the proportion of buzzes was significantly higher during night and dawn. Results are interpreted to agree with previous studies suggesting that harbour porpoises need to eat almost constantly, meaning that foraging should occur in the entire distribution range and throughout the day. The higher buzz ratio in the Central Baltic Proper could raise concern that prey quality may be lower in this area, which could potentially force animals to spend more time foraging.

Assessing the impacts of noise on marine populations

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Marine environments are increasingly influenced by anthropogenic disturbances, which can have negative impacts on many animal populations. These impacts are primarily caused by changes in animal behavior in disturbed areas, reducing foraging success and potentially animal fitness. Here we present an agent-based model, DEPONS, that is capable of directly simulating behavioral responses to noise and associated changes in individual survival and reproduction. Population dynamics emerge from the individuals' competition for food and reduced foraging in noisy areas. We use the model to assess the impacts of wind farm construction on the North Sea harbor porpoise population and demonstrate how it can be used to assess the relative population impacts of different wind farm construction scenarios. We demonstrate that construction of a number of wind farms sufficient to meet the EU2020 target for renewable energy is unlikely to negatively influence the porpoise population. However, in scenarios with very high noise levels the population size was temporarily reduced, but the impact depended on the order of the pilings. The model presented here builds on fundamental processes that are general for most species and may therefore be adopted to predict other scenarios of human impacts on marine populations. Such models are expected to have high predictive power in various types of environments, making them ideal tools for marine management.

Modeling the Energetic Consequences of Disturbance

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For marine species that depend on sound to navigate, forage, and communicate, anthropogenic noise levels in their environment can negatively affect their population dynamics and influence their conservation status. However, predicting the impacts of noise on a population requires an understanding of how disturbances can affect the physiology and behavior of individuals. Here we present the development of a mechanistic, individual-based energetic modeling framework that allows for the simulation of the effects of nonlethal disturbance on populations while maintaining temporal and spatial realism. We apply this framework to evaluate the effect of anthropogenic noise, specifically from small vessels and offshore wind turbine development, on a marine species that has been noted to have exceptionally high metabolic costs, the harbor porpoise, *Phocoena phocoena*. This model serves as a novel approach to evaluate the threat of disturbance both seasonally and spatially to identify not only where but also when a disturbance may most endanger a population, allowing for better informed marine management and spatial planning.

Acoustic development and behaviour of wild porpoise (*Phocoena phocoena*) calves

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We recorded the sounds and behaviour of a wild neonate harbour porpoise (*Phocoena phocoena*) and its mother for four hours distributed over five days. Acoustic signals were recorded using a SoundTrap ST202HF and video observations were made with a drone. Distances from the porpoises to the sound recording device were measured using calibrated data from the drone. The neonate sound recordings were extracted when its distance to the SoundTrap was shorter than 50 meters and the mother was not present. We calculated the inter-click intervals, and the duration, source level and frequency content of the clicks. We found that, similarly to previous studies in captive harbour porpoises, there are some differences between adult and neonate clicks. This methodology has allowed us to link sound and visually observed behaviour in wild porpoises for the first time. Future studies using this method may enable us to estimate the neonate's age based on the development of their clicks and their size, and then, be able to correlate their behaviour with different age stages.

SESSION 4: RESEARCH IN HARBOUR SEAL BEHAVIOUR AND MONITORING

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A novel approach at evaluating wild harbor seal (*Phoca vitulina*) display behaviors

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Acoustic communication is commonly used among aquatic-breeding marine mammal species. During the breeding season, male harbor seals, *Phoca vitulina*, produce underwater vocalizations and perform various surface behaviors (e.g., flipper slapping and bubble blowing), some which emit sound both in air and under water. Due to the difficulties of studying reproductive behaviors, their precise function(s) remains unknown. In this preliminary study, we used a combination of passive acoustic recorders and unmanned aerial vehicles to observe and document breeding behaviors of wild harbor seals for the first time. Simultaneous acoustic and video recordings revealed three adult seals vocalizing under water followed by the release of bubbles; however, not all underwater vocalizations were associated with bubble release. Multiple underwater vocalizations were produced during one dive, indicating that air is recycled between vocalizations. The findings from this study demonstrate that drones are useful tools for studying breeding behaviors of aquatic-mating harbor seals and will perhaps elucidate the functionality of vocalizations and surface behaviors.

Memory for own behaviour in pinnipeds

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Pinnipeds are aquatic predators feeding on a vast range of prey, and their social behaviour differs greatly between species (from extreme polygyny in some sea lions to monogamy in some true seals). It has been hypothesized that the foraging and social complexity of their lifestyle should drive the evolution of their cognitive abilities. To investigate how aware pinnipeds are of their own behaviour, a grey seal (*Halichoerus grypus*), two harbour seals (*Phoca vitulina*) and three South American sea lions (*Otaria flavescens*) were trained to repeat their own behaviour on cue. Three already trained behaviours were used, and the animal was asked to repeat the behaviour twice to ensure the animal recalled its own behaviour and not the cue given for the previous behaviour. All three species could recall their own behaviour significantly better than by chance. The duration for which the grey and harbour seals could recall their behaviour was tested using a staircase paradigm. A delay was implemented between the completion of the behaviour and the cue to repeat it. The delay was increased after correct responses and decreased after incorrect responses. The performance of both species fell towards chance level after 15-18 seconds, with no significant difference between the two species. These results indicate that sea lions and true seals are aware of their own behaviour and that true seals have similar short-term memory abilities, and that pinnipeds have less developed short-term memory abilities compared to other aquatic predators, such as the bottlenose dolphin. The complexity of pinniped foraging and social behaviour does not seem to have driven the evolution of short-term memory abilities in these animals but might have contributed to their ability to recall their own behaviour.

Thermal imagery for detection of marine mammals

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Thermal cameras are useful to detect pinnipeds and cetaceans. Aerial censusing in Denmark utilizes thermal imagery to localize hauled-out seals. The seals appear as warm blobs in thermal imagery which can be counted in near-real-time during a flight and the data stored for later review. As little information beyond temperature and general size can be derived from thermal imagery alone, localities of the thermal targets are used to extract portraits from simultaneous high resolution color imagery. Currently these portraits are viewed manually to determine species but are intended to train a neural network for automatic identification. Image rectification and laser altimetry facilitate precision photogrammetry to measure morphometric properties of the animals from the portraits too. Finally, the portraits of individual seals are archived by species for comparison with future surveys. Thermal cameras also detect porpoises at the surface by identifying heat emitted from their bodies above the waterline and at close range their blow (breath) is detectable too. This can be used for surface monitoring and assist locating porpoises in choppy waters. Thermal cameras function equally well day or night however to verify thermal targets using paired optical cameras requires good light. Some limitations of thermal cameras are their inherent low spatial resolution which may display closely spaced animals as consolidated large blobs of heat containing an uncertain number of individuals and there must be sufficient temperature contrast between the animals and their surrounding medium to function well.

The divergence and spread of Canine Distemper Virus and Phocine Distemper Virus

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Canine Distemper Virus (CDV) is known to cause severe respiratory disease in a wide range of terrestrial carnivores including; raccoons, tigers, monkeys, foxes, wolves and dogs. CDV is most closely related to Phocine Distemper Virus (PDV) which has previously been the cause of mass mortality events of harbour seals (*Phoca Vitulina*) in Northern Europe and along the east coast of the United States. Here we investigate the evolution and divergence of PDV and CDV into two distinct viruses by phylogenetic analyses of 1,698 bp of the H gene from a total of 19 PDV sequences and 106 CDV sequences. The preliminary results of the phylogenetic analysis place the most recent common ancestor (tMRCA) of the CDV sequences somewhere between 1918-1963 and the tMRCA of the PDV sequences between late 1975 to early 1987. Meanwhile the split between PDV and CDV provided highly variable estimates, with TMRCA ~ 75-520 years. In addition the phylogenetic relationships suggest the basal clade of CDV to consist of sequences from America, the Caspian Sea, China and India. Further analyses are underway to further elucidate the split of the two viruses.

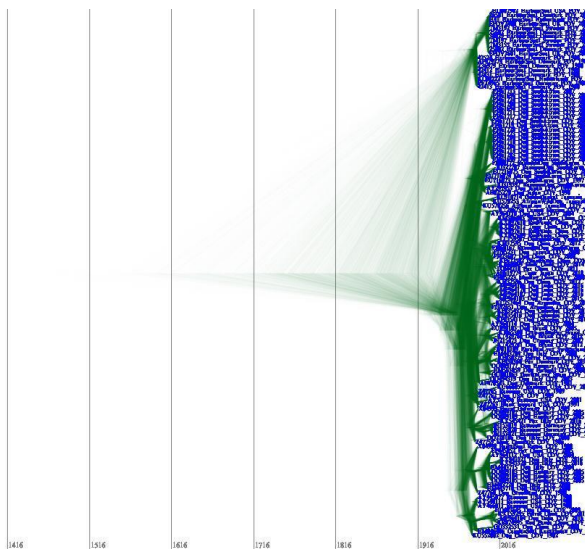


Figure 1. Densitree illustrating the split of PDV and CDV, and the uncertainties of the positioning of the clades and divergence events in the preliminary tree.

SESSION 5: RESEARCH IN MARINE MAMMAL EVOLUTION

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The evolution and diversification of delphinid skull shapes

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The family of oceanic dolphins (Delphinidae) consists of approximately 36 species that occur over a range of aquatic habitats from rivers to the open ocean and in climates ranging from the Arctic to the Tropics. They are the result of an explosive radiation, with a rich diversity of species being established during a short window of time. Within these species, there is a remarkable variation of skull shapes, which has been hypothesized to reflect adaptations to feeding strategy, preferred prey and habitat, as well as sound production. In this study, we investigate the radiation of skull morphology of the 18 delphinid species occurring in the North Atlantic. We used geometric morphometrics to construct species-specific 3D models consisting of 51 anatomical landmarks, based on at least 3 specimens of each species. We then mapped these models on a phylogenetic tree based on full mitogenome data using squared-change parsimony. In the most parsimonious model of skull shape evolution, the last common ancestor had a skull similar to *Lagenorhynchus*, *Lagenodelphis*, *Leucopleurus* or *Tursiops*, thus probably using a combination of raptorial (gripping/snatching prey) and suction feeding. Early morphological diversification occurred in 3 directions: 1) towards more specialized raptorial feeder of small prey with longer, narrower beaks, exemplified by *Stenella* and *Delphinus* species. 2) towards wider skulls with wider, downward-oriented rostra and smaller temporal fossae, exemplified by suction feeders such as *Globicephala*, *Grampus* and *Peponocephala*. 3) Towards shorter and wider skull, wider and shorter rostra, larger temporal fossae and anterior displacement of the orbit, exemplified by *Orcinus*. Under this model, the current delphinid diversity was established early and the only major later development has been a convergence of *Pseudorca* and to a lesser extent *Feresa* towards the characteristics described for *Orcinus*, apparently related to the handling of large prey items.

Interspecific variation of cranial directional asymmetry in select Odontoceti families

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Bilateral directional asymmetry in Odontoceti skulls is described among fossil and extant taxa and is widely associated with environment perception, and intra- and inter-specific communication. This study investigated skull shape variation related to directional asymmetry applying 2-dimensional (2D) geometric morphometrics. We used photographs of skulls in dorsal aspect from 60 specimens of 10 genera belonging to four families of the suborder Odontoceti: Iniidae, Pontoporiidae, Phocoenidae and Delphinidae. 26 anatomical landmarks were selected to allow repeatability and reliability among different taxa. The set of landmarks included uneven points along the central axis of the skull, between the midpoint of the tip of the rostrum and the midpoint of the foramen magnum, and paired, corresponding landmarks at each side of the skull. The softwares TPSUtil and TPSDig were used to compile a database of digital images and digitize coordinates of landmarks, respectively. Statistical analyses of cranial directional asymmetry and measurement of digitizing error were performed using the software MorphoJ. A Procrustes ANOVA demonstrated the presence of significant directional asymmetry with a higher variance than fluctuating asymmetry. Besides that, both fluctuating and directional asymmetry showed much higher variances than the digitalization error. A principal component analysis revealed that the pattern of skull asymmetry and magnitude varies among taxa with a specific morphological variation in the bone structures between the different taxa, besides a general leftward shift of the dorsal midline in combination with increased dimensions of right-side bones. Thus, the geometric morphometric technique used here helped to understand the variation of the asymmetric shape, exhibiting all the morphological variations of cranial structures associated with taxonomic diversity in the Odontoceti, with some genera being much more asymmetric than others. As an example, the family Delphinidae exhibited more accentuated directional asymmetry for left-shift than Iniidae, Pontoporiidae and Phocoenidae.

Small odontocetes from the late Miocene Gram Formation

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Fossil remains from several different cetaceans have been recovered from the ca. 10-million-year-old (Late Miocene) Gram Formation in Denmark. These are mainly mysticete specimens, but also include material from at least two ziphiids, teeth from a raptorial physteroid, and several single isolated elements from small odontocetes. The small odontocete specimens include three bullae, three periotics, three teeth and 41 vertebrae representing 15 different collection events.

This study aims to determine how many types of cetaceans these isolated elements represent and if they can be referred to known cetacean taxa.

There is only one type of bulla and one type of periotic. The bullae, periotics, seven lumbar and 10 caudal vertebrae are morphologically very similar to those of the slightly older *Kentriodon hoepfneri* from Gross Pampau, Northern Germany [1]. However, the earbones are also morphologically close to those of extinct pontoporiids like *Protophocaena* from Belgium and the Netherlands [2] sensu [3]. Both earbones and the mentioned vertebrae also match the morphology of *Brachydelphis* and *Atocetus* from Peru [4]. Pontoporiids are also known from the slightly younger Marbæk Formation exposed near Esbjerg [5] making it likely that the Gram material is a pontoporiid and that *K. hoepfneri* is either related to, or nested within Pontoporiidae.

Nine vertebrae are, markedly smaller and morphologically different. Currently no diagnostic features that can refer them to any known taxon have been identified. They do, however, fit in size with the vertebrae described as *Graamocetus*.

In conclusion, the Gram fauna includes at least two types of small odontocetes. One is a pontoporiid or a stem-taxon related to Pontoporiidae, perhaps including *K. hoepfneri*. The other is a smaller type with unknown taxonomic affinity, perhaps including *Graamocetus*.

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SESSION 6: KYSTZONEN (GEO/BIO)

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Kombinerede oversvømmelser fra hav og vandløb

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Kystdirektoratet har netop udpeget de områder i Danmark, hvor risikoen for oversvømmelser er størst. Udpegningen er del af implementering af EU's oversvømmelsesdirektivs 2. planperiode (2016-2021), der har som hovedformål at reducere risikoen for oversvømmelser. Udpegningen og den anvendte metode præsenteres overordnet. I direktivets første planperiode (2010-2015) udtrykte berørte kommuner ønske om fokus på sammenfald mellem oversvømmelse fra hav og vandløb. Her er en vigtig del af arbejdet at bestemme sandsynligheden for kombinerede hændelser i de områder, hvor begge kilder kan forårsage oversvømmelser. I arbejdet med oversvømmelsesdirektivet og det EU-støttede Interreg projekt FAIR er der udvalgt fire områder (Randers Fjord, Vejle, Ribe og Odense Fjord) som udgangspunkt for at udvikle en metode til at bestemme sandsynligheden for sammenfald mellem høj vandstand i hav og i vandløb. Heraf kan potentielt oversvømmelsestruede områder identificeres og risikoen beregnes gennem Kystdirektoratets oversvømmelsesmodelleringer.

Til sammenfaldsstatistikker benyttes copula funktioner, som muliggør behandlingen af data fra flere oversvømmelseskilder. Udregningsprocessen inkluderer mange vurderinger og valg, som påvirker den endelige statistik, bl.a. en vurdering af graden af afhængighed. Sammenfaldende statistikker er et vigtigt skridt på vejen til bedre at forstå naturens hydrologiske processer og den menneskelige påvirkning af kystnære systemer. Statistikkerne er udarbejdet med fokus på vandstand i hav og vandløb på baggrund af målinger, og resultaterne er endnu ikke undersøgt omkring årsagerne til de sammenfaldende hændelser; herunder om klimaændringer har markant indflydelse på sammenfaldenes hyppighed. Arbejdet med kombinerede hændelser spænder videre og bredere end Kystdirektoratets ekspertiseområde, hvorfor et godt samarbejde med bl.a. kommunerne og DMI er essentielt til at opnå forståelse for hele systemet og kunne planlægge for det fremadrettet.

Improved estimates of Arctic dissolved organic carbon fluxes in the East Greenland Current.

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The Arctic Ocean receives a disproportionally large discharge of river waters that are also high in organic matter content, and thus carbon. The fate of this organic matter, whether mineralized by photochemical and microbial degradation, flocculated and buried or exported to the Atlantic Ocean, is still unclear. Current estimates of organic carbon export to the Atlantic are based on sparse and sporadic dissolved organic carbon (DOC) measurements and scaled to gross estimates of water fluxes. What is lacking is improved estimates based on higher temporal and spatial coverage of measurements at important Arctic export gateways. The Fram Strait, with the inflow of Atlantic water with the West Spitsbergen Current and outflow with the East Greenland Current (EGC) is a main channel for exchange with the North Atlantic. Here the EGC carries a strong signal of DOC and freshwater. Likely due to the dominance of terrestrial DOM in the Arctic, there is a close relationship between the optical properties of Coloured DOM (CDOM) and DOC. Systematic measurements across the Fram Strait since 2009 have allowed us to develop a robust relationship between CDOM and DOC, which appears to be constant across the time series. This presents the opportunity to use profiling instruments (fluorometers) to obtain higher resolution measurements of the distribution of DOM. Together with hydrographic measurements (CTD and ADCP profiles), volume fluxes of freshwater and DOM transport in the Fram Strait can be derived. Here we present improved estimates of Arctic DOC fluxes in the EGC that indicate annually flux on the order of 40-64 Tg C yr⁻¹ that is correlated to the freshwater flux in the EGC. This time series offers a unique opportunity to monitor how organic carbon fluxes from the Arctic change annually.

Juvenile ål foretrækker en havbund med masser af sten og skjul: indspark til forbedret kystnær beskyttelse og restaurering

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Den Europæiske ål (*Anguilla anguilla*) har i mange år været kritisk truet i hele dens udbredelsesområde. Én af årsagerne kan være, at der bliver færre opvækstområder med egnede habitater. Ålen er afhængig af specifikke habitater, der strækker sig over et meget stort geografisk område, tilpasset de enkelte livsstadier. Tidligere studier viser, at en stor del af åleynglen, der kommer til de europæiske og dermed danske kyster, i høj grad forbliver i fjorde og kystnære områder i stedet for at trække op i ferskvand. Derfor er det vigtigt, at der også findes egnede levesteder til ålene ved kysterne. I ferskvand er et områdes bærekapacitet i høj grad bestemt af antallet af skjulesteder (f.eks. trærodde). I nærværende studie viser vi at noget tilsvarende sikkert finder sted i saltvand, idet resultaterne viser at åleyngel foretrækker en stenet havbund med masser af skjul imellem stenene. Resultaterne fra studiet, kan danne grundlag for en bedre beskyttelse og restaurering af kystnære områder, hvilket forhåbentlig kan bidrage til at ophjælpe den truede europæiske ål.

Sand er ikke bare sand

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Substratsammensætning og strømpåvirkning er af afgørende betydning for dyrelivet knyttet den bløde bundtype. Selv relativt små forskelle i korstørrelse og sorteringsgrad, sætter sit præg på levevilkårene, og dermed på hvilke organismer der kan etablere sig i den pågældende bundtype. Et studie på sandbanken Disken i det nordlige Øresund har forsøgt, at klargøre betydningen af de derværende forskelle i sanddynamikken for makroinfaunaen. I forhold hertil lader en mellemkategori af sandpartikler at være optimal set i forhold til de bunddyr fisk lever af.

Danish estuaries as coastal filters: identification of hotspots.

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Coastal zones are directly exposed to human activities that, among other effects, increase inputs of nutrient and organic matter. Although continuous human alterations might disrupt the subtle ecological balance, coastal ecosystems are to some degree resilient and can absorb changes in these inputs, acting as a filter between land and ocean. In such transition zones, the salinity gradient is critical for a number of biogeochemical processes in the water column and fluxes across the sediment-water interface. Danish estuaries are characterized by receiving freshwater inputs from many scattered streams, yielding relatively high residence times in the near-source environment. Monitoring data from different coastal locations in Denmark indicate that substantial amounts of nitrogen and phosphorus are removed at low salinities, indicating an important sink of nutrients in the vicinities of freshwater sources. Thus, this study aims to identify potential hotspots for the removal of nutrients and organic matter in two coastal zones, Hove Å and Nivå. Spatial variability at the two sites were explored using high frequency sampling of multiple water quality parameters to characterize changes over the salinity gradient with a fine resolution. Distinct salinity gradients characterized the two study sites, with a broader salinity range (0-25) observed in Nivå than in Hove Å (2.5-15). Non-linear relationships with salinity were clearly identified for different parameters (pH, dissolved oxygen, phytoplankton) in Hove Å, indicating intense biological processing in the salinity range 5-10. At Nivå, most of the changes were observed at salinities of 5-15, with more linear relationships between water quality variables and salinity, indicating that simple mixing as the dominant process. Our results suggest that the significance of the coastal filter function may vary broadly among locations, likely reflecting differences in the freshwater inputs and spatial extent of the transition zone.

Asiatiske klippekrabber erobrer Stillehavsøsters-reven i det danske Vadehav - Hvad gør de her?

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Siden omkring 2011 har to asiatiske krabbearter (*Hemigrapsus sanguineus* og *H. takanoi*) bredt sig i Vadehavet, hvor den almindelige strandkrabbe ellers har været enerådende. Deres succes ser ud til at være faciliteret af tilstedeværelse af Stillehavsøsters-rev. Et spørgsmål er, hvordan krabberne, der allerede flere steder forekommer i store tætheder, vil påvirke den lokale flora og fauna? Her giver vi en beskrivelse af de to arter og størrelses- og kønsfordelingen i Vadehavet. For at fastslå fødegrundlaget for de to krabbearter, har vi analyseret krabberne og flere af deres potentielle fødeemner og konkurrenter for de to stabile isotoper ^{15}N og ^{13}C , der kan belyse arters placering i fødenet. Heraf fremgår, at der er små forskelle på det trofiske niveau mellem arterne afhængig af køn og størrelse. Generelt øges det trofiske niveau med krabbestørrelse. Vores forsøg viser, at klippekrabber især *H. sanguineus* hunner spiser lidt mere algeføde end strandkrabber. Forsøgene viser endvidere, at juvenile blåmuslinger er et vigtigt fødeemne for klippekrabber af alle størrelser. Sammenlignende fourageringsforsøg med de to klippekrabbearter og strandkrabben tyder på et stort overlap i fødevalg, dog med køns- og størrelses-forskelle i muslingestørrelses præference. Præliminære estimer tyder på, at klippekrabberne gennem deres konsumtion potentielt kan få indflydelse på rekruttering af blåmuslinger i Vadehavet.

SESSION 7: FISK OG FISKERI

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Oceanografisk strømningsregime og rekruttering af fisk: Skift i Nordsø-cirkulation falder sammen med usædvanlige stærke rekrutteringer af havtobis

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Sammenhænge mellem produktionen af fisk og miljøvariable er efterspurgt og eftersøgningen efter kandidatvariable der kan forudsige antallet af fisk i havene er i fuld gang. Selv om der er blevet foreslået adskillige sammenhænge mellem miljøvariabler og rekruttering af fisk, så har de sjældent en funktion i en forvaltningsmæssig kontekst i dag. Årsagerne til dette kan være mange, men fejlagtige korrelationer, brugen af indikatorer for klimasystemer på højere niveau og forkert opfattelse af årsagssammenhænge kan nævnes i denne forbindelse. Her præsenterer vi et studie, som eksemplificerer hvordan modellerede oceanografiske data kombineret med en simpel probabilistisk risikovurdering, kan bruges til at forudsige rekruttering af fisk. Vi bruger havtobis (*Ammodytes marinus*) i Nordsøen som et eksempel og fokusere på de cirkulationsmønstre, som de helt nyklækkede fiskelarver på Dogger Banke er dikteret af. Vi fandt at de mest ekstreme tobisrekrutteringer har fundet sted i år med en bestemt type strømningsregime i februar, hvilket kan være forbundet med sjældne lejlighedsvis skift i Nordsø-cirkulationen. Ved brug af risikokvotienter viser vi potentialet for at anvende flowregimer i probabilistiske kortsigtede prognoser for usædvanligt stærke årsklasser. Endelig foreslår vi en hypotese for rekruttering af havtobis, der kan udvides til andre arter og derved bidrage til fremtidige undersøgelser af sammenspillet mellem miljø og fiskerekruttering, rekrutteringshypoteser og rekrutteringsprognoser.

Fra simple t-tags til avancerede satellitmærker – udvikling i mærkning af torsk

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Tusinder af torsk er gennem tiden blevet mærket for at kortlægge vandringmønstre mellem gyde- og fourageringsområder. Traditionelt er fiskene mærket med simple t-tags – en metode der giver information om mærke- og genfangststed samt længdetilvækst. I Grønland alene er der siden 1920'erne mærket over 125 000 torsk, som har bidraget med værdifuld viden om bestandsadskillelse, gydeområder, vandringshastigheder, bestandsspecifik vækst mv. I takt med at de store linjer i torskens adfærd og opholdssteder er blevet kortlagt, er det blevet muligt, at undersøge torskens adfærd mere specifikt med dataloggende mærker. Med henblik på at opnå detaljeret viden om torskens dybde- og temperaturpræference, har vi monteret pop-up satellit mærker på torsk. Pop-up mærkerne har været benyttet til blandet andet laks, tun og grønlandshajer flere steder i verden, men erfaringerne med torsk er særdeles få.

I det aktuelle projekt monterede vi pop-up satellitmærker på seks kønsmodne torsk i starten af juni 2018, med det formål at vurdere torskens tilgængelighed for fiskeriet. Mærkerne var programmeret til at registrere data, med logning hvert 3. sekund, i ca. fire måneder. Mærkerne indsamler data om på hvilken dybde og ved hvilken temperatur torsken har ophold sig samt lysdata, der kan omsættes til en position. Vi præsenterer vores erfaringer fra fangst af torsken og montering af mærker til påvirkning på fisken og indsamling af de udløste mærker. Endvidere viser vi foreløbige resultater om torskenes præferencer og adfærdsmønstre herunder opholdssted uden for gydeperioden, dagsrytme og ændringer i temperatur- og dybdepræference gennem perioden. Afslutningsvis lægger vi op til en diskussion om anvendelighed og erfaringer med brugen af pop-up satellitmærker.

Otolith and body-shape characteristics provide insights into the recruitment dynamics of sand gobies (*Pomatoschistus minutus*) along a restored Fyn coastline

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Habitat restoration is a vital step in the conservation of coastlines and their biota, although this requires a parallel understanding of how particular habitats contribute to processes such as recruitment that are essential for population recovery. Sand gobies are an abundant demersal fish along the Baltic coast, and an ideal species with which to examine how coastal fishes might respond to shoreline restoration. While its life history is broadly understood, we have a very limited sense of sand goby recruitment dynamics, and how early life history processes may help shape subsequent population strength.

Otoliths can provide a wealth of information on the timing and rate of key early development processes, while shifts in body shape may also signal the timing of critical development events. Here I describe preliminary analyses of otolith characteristics, early growth, and variation in body shape in sand gobies from Gyldensteen, north-west Fyn.

Otolith data were obtained from fish $\geq 6,8$ mm SL although sagittae were only located in 27% of fish less than 8 mm SL. Sagittae shifted from an oval to circular or cubic shape at around 9,6 mm SL, coincident with completion of larval fin development. Otolith size varied substantially within individuals, with 27% of fish having otoliths differing by $\geq 5\%$ in length, up to a maximum difference of 45%. Sagitta growth with body length suggested two transitions — at between 2,5 mm (hatch size) and 7 mm, and secondly from around 24 mm SL.

Relationships between body length or weight and age indicated rapid early growth, decreasing from an average 8% per day in body length and 34% per day in body weight at 10 to 15 days in age. Equally, change in external morphology was rapid and followed linear trajectories with body length without obvious inflections.

These patterns suggest a species driven by rapid establishment within coastal environments over their recruitment season, with some loss of ‘developmental control’ as a trade-off.

DNA og Discard – genetiske metoder og forbud mod udsmid af fisk

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EUs landingsforpligtelse er i øjeblikket ved at blive indfaset i det danske fiskeri, hvilket gør at udsmid af fisk, ikke længere vil være tilladt. Så med få undtagelser skal alle fangede fisk bringes i land. Det betyder potentielt en lang række forandringer i hvordan der fiskes og hvordan fiskeriet forvaltes. I den sammenhæng er der en række områder, hvor moderne DNA teknikker med fordel kan tænkes ind i rådgivning og forvaltning. Specifikt drejer det sig om: 1) Genetisk identifikation af bifangst 2) Genetisk analyse af blandede fiskeprodukter der forarbejdes ombord 3) Anvendelse af miljø-DNA (eDNA) til at reducere eller undgå bifangst. For alle tre områder bliver de mest relevante metoder forklaret inklusiv eksempler på deres anvendelse. Vi tager også et kig på udviklingen af transportable og automatiserede DNA analyser, som er på vej revolutionere anvendelsen af genetiske metoder i felten.

Effekter af sæl-relateret leverorm på Østersøtorskens sundhedstilstand

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Den østlige Østersøtorske, *Gadus morhua*, var indtil starten af 80'erne en sund bestand, som bidrog med en betydelig andel til et profitabelt fiskeri. Fra midt 80'erne faldt antallet af individer i bestanden markant, og var lavt i de efterfølgende årtier, hvorfor det blev besluttet af reducere fiskeritrykket i forsøg på at hjælpe bestanden på fode igen. Dette tiltag havde den ønskede virkning, og siden midten af 00'erne har bestanden vist tegn på genopretning, med et stigende antal individer. Dog har det efterfølgende vist sig, at fiskene er historisk tynde (afspejlet ved en lav kondition) og generelt i dårlig sundhedstilstand.

Fiskenes dårlige tilstand skyldes efter al sandsynlighed en kombination af flere faktorer, såsom fødebegrænsning og forringede iltforhold. Derudover er antallet af gråsæler *Halichoerus grypus* steget markant i den østlige Østersø gennem de seneste årtier, og denne sæl er slutvært for parasitten *Contracaecum osculatum*, også kendt som torskens leverorm. Torsken fungerer som mellemvært for parasitten, og parasitten sidder – som navnet antyder – i torskens lever. Intensiteten af infektioner med leverorm i den østlige Østersøtorske er steget i takt med at antallet af gråsæler er steget, og der findes nu i gennemsnit 32 leverorm i torskenes lever i den centrale del af Østersøen. Enkelte leverer huser op til 130 leverorm.

Leveren er et livsvigtigt organ der er involveret i essentielle stofskiftfunktioner relateret til energiproduktion og vækst. Derudover er den fedtholdige lever torskens energidepot. Mange orm i en lever kunne derfor potentielt nedsætte organets funktionsevne, og hvis dette er tilfældet, vil torsken derfor ikke være i stand til at producere den nødvendige energi der kræves for at søge føde, vokse og reproducere. I dette studie undersøger vi, hvorvidt infektion med leverorm påvirker torskens sundhedstilstand. Mere specifikt I) kvantificerer vi effekten af leverorm på fiskens stofskifte, II) undersøger hvordan energiindholdet samt prote

Sediment transport and dispersal during mussel fishery

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Mussel fishery in Denmark is heavily regulated and controlled in Natura2000 areas under the Danish mussel policy. Restrictions such as gear size and weight, quotas and limit in the amount of area impacted have been established in order to protect key ecosystem components such as macroalgae and benthic organisms. For eelgrass, no tolerance is accepted, fishery is restricted below 5m depth in the eelgrass zone, and a buffer zone of 300m is established around the eelgrass where no fishery is allowed to take place. In order to assess the potential indirect effects of dredging operations such as: i) reduction of light availability to the eelgrass beds due to sediment resuspension during and after dredging ii) smothering and burial of eelgrass seedling and beds from transport and sedimentation coming from sediment plumes, two sets of experiments were conducted in the Limfjorden in two different broads and with different fishery intensity. A range of water quality parameters was measured such as: light intensity, suspended particulate matter concentration, sedimentation, turbidity, oxygen and chlorophyll concentrations were measured under natural condition versus various fishing intensity at different distance from the fished areas.

Field data showed that the resuspended material signal from mussel seed fishery activity is highly dependent on the current direction and the fishing practice. Collected data was used to calibrate a sediment transport module in the Flexsem model developed for the Limfjorden. The model describes the transport of different size fractions of sediment particles under different fishing scenarios and will be used as a new tool for managing fisheries and help to decide on an appropriate buffer zone to protect the existing eelgrass beds from indirect impacts from mussel seed fisheries.

SESSION 8: MARINE VIRKEMIDLER

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Tang som virkemiddel – kvælstof og klima

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Dyrkning og høst af tang er et af de 7 marine virkemidler, som kan bringes i spil i de kommende vandplaner. Når tang vokser, optager og binder det næringsstoffer fra havmiljøet. Når tangen høstes, fjerner man næringsstoffer fra havet og den høstede tang kan samtidig anvendes til fødevarer, foder og biomolekyler.

I Danmark har interessen for produktion af tang været stigende de seneste 10 år, og virksomheder og forskningsinstitutioner samarbejder tæt omkring optimering af dyrkningsteknologi. Produktionen af sukkertang i Danmark er dog pt. lavere end i andre Nordatlantiske områder. Baseret på dansk forskning fra Limfjorden og Horsens Fjord 2013-2016, ses at dyrkning og høst af sukkertang under danske forhold kan fjerne op til 39 kg N ha⁻¹ år⁻¹, og samtidig binde op til 0.6 ton C ha⁻¹ år⁻¹.

Skånsom høst af søsalat udgør endnu en mulighed for at fjerne kvælstof fra næringsbelastede marine områder: Masseforekomster af søsalat i danske fjordområder skaber både iltsvind og tab af rekreativ værdi. Testforsøg viser, at man ved høst af søsalat vil kunne fjerne op til 90 kg N ha⁻¹ år⁻¹, og samtidig forebygge emissioner af både metan og lattergas.

Begge tangvirkemidler er mindre effektive til at fjerne N end f. eks. muslingeopdræt, som er opgjort til at kunne fjerne 600-900 kg N ha⁻¹ år⁻¹. Der er dog andre væsentlige fordele ved tang som marint virkemiddel: 1) positive klimaeffekter via tilbageholdelse af C, modvirken af forsuring og forebyggelse af emissioner af metan og lattergas; 2) opdræt af tang kan implementeres i forskellige typer af havområder, både næringsfattige og næringsrige, eksponerede og beskyttede; 3) opdræt og høst af tang øger lokal biodiversitet. Samtidig forventes teknologiudviklingen over de kommende år at øge udbyttet og sænke omkostninger i produktionen af tang.

Potentialet og omkostningseffektiviteten af marine virkemidler er senest beskrevet i et katalog fra 2016, men Miljøstyrelsen og DCE opdaterer kataloget i 2019.

Sandcapping – a method to restore marine ecosystems?

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Decades of high nutrient loading and high phytoplankton production have increased the turbidity and organic matter sedimentation in estuaries. High turbidity has diminished the area of seabed in Danish waters with sufficient light intensity to support growth of eelgrass (*Zostera marina*). Furthermore, lowered anchoring capacity of eelgrass in areas with historically high deposition of organic matter has contributed to loss of eelgrass. Former eelgrass areas have therefore turned into bare bottom muddy areas with frequent resuspension events maintaining the systems in a turbid state. When harbour authorities dredge navigation channels at the outer boundary of Danish estuaries they typically remove ~100.000 m³ of sandy sediment by ship to sites far afield. If this material instead is used to consolidate adjacent muddy areas by sand-capping, it results in a win-win situation. The approach was tested in the summer of 2018 where two muddy locations in Odense fjord were capped with a 10 cm layer of sand (1 ha and 1.5 ha). The organic content at the sites was 8-9% and 3-5% LOI before sandcapping. The sites have been followed closely since sandcapping. The sand remains stable on the mud without accumulation of mud on top. Erosion thresholds increased from current velocities of about 10-12 cm s⁻¹ for mud to 40 cm s⁻¹ for sand-capped mud, resulting in a less intense resuspension. Erosion rates are also lowered from 5 g suspended solids m⁻² min⁻¹ in muddy areas to about 0.2 g suspended solids m⁻² min⁻¹ in sand capped areas, leading to improved light conditions. The positive effects of the sandcapping in combination with the increased anchoring capacity of eelgrass, provides a potential for recovery of lost eelgrass habitats.

Using a Commercial harbor for fish nursery restoration in a Northern context : a pilot project in Helsingør

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For the last six years, the French company Ecocean and Perpignan University have been involved in several research projects aiming at developing and optimizing an artificial fish nursery called the Biohut®, meant to enrich human infrastructures such as ports. Traditionally perceived as nature-depleted zones as it is an ecosystem providing little opportunities for life to develop, ecological functions of such areas can be enhanced thanks to ecological engineering like the Biohut®.

By providing food and shelter to the young fish and crustaceans, this micro-habitat enables them to survive and grow through their most vulnerable life stage, up to a size where they are ready to join adult population. These projects have brought two main conclusions in the Mediterranean context 1) Micro-habitat does attract a rich biodiversity 2) Eco-engineering can greatly improve the potential of underwater artificial infrastructure to provide opportunities for young fish and crustaceans to grow and feed.

The structures are scientifically validated in the Mediterranean Sea, and are used as a remediation tool in 22 harbors along the shore.

Through a project pilot with the Øresund aquarium, Helsingør harbor hosts 4 Biohut® since 2017 (2 in the marina and 2 in the commercial port) that have been monitored during one year. It is the first Northern marine location with these artificial fish nurseries Through the year of monitoring performed by the Øresund and Copenhagen University, 10 species of fish have been monitored in the 4 Biohut®, including species impacted by fisheries.

Even if the functions are not already scientifically validated in the Danish context, the preliminary results are very encouraging about similar function and utility for Denmark as for the Mediterranean Sea.

Aarhus Havnebad - fortællingen om badevandskvalitet

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Etableringen af havnebadet i Aarhus krævede at der kunne opnås bade-vandskvalitet. Havnebadet består af forskellige træbeklædte pontoner, der er koblet sammen på en måde så de samlet udgør en ramme omkring flere bassiner. Bassinerne står i forbindelse til havnen gennem en åben bund, der er sikret med trådnæt, så man ikke kan komme til at svømme ind under pontonerne.

Aarhus Å har sit udløb inderst i Aarhus Havn, og påvirker i høj grad vandkvaliteten i havnen, som især under regn indeholder høje koncentrationer af bakterier.

I samarbejde mellem Aarhus Kommune udviklede COWI et koncept til løsning af denne udfordring. Konceptets kerne er en spunsvæg omkring havnebadet, som afskærmer de badende fra det bakterieholdige åvand. Vandkvaliteten opnås med to mekanismer.

1) Tidevandsventiler:

Installation af ventiler i spunsen sørger for at vandstanden i havne-badet følger vandstanden i havnen. Ventilerne tilfører vand til havne-badet fra 5,5 m dybde. Dette vand er ikke påvirket af det forurenede åvand, idet åvandet er lettere end havvand og derfor vil strømme ud gennem havnen i overfladen. Udstrømning foregår gennem ventiler tæt på vandoverfladen. Derved opnås en cirkulation i havnebadet.

2) Filteranlæg

Der er etableret et biofilteranlæg på havbunden under havnebadet. Anlægget renses vandet i havnebadet indenfor spunsvæggen.

Alternative rensningsmetoder med muslinger blev undersøgt gennem felt-forsøg og beregninger. Metoden viste sig mindre velegnet og blev fravalgt. Målinger henover sommeren 2018 har vist høje bakteriekoncentrationer og alger i havnebassinet, hvor havnebadet er opført, men badevandskvaliteten i selve havnebadet har været udmærket og havnebadet har ikke haft lukke-dage som følge af problemer vandkvaliteten. Spunsen har den sidegevinst, at den afviser bølgerne og reducerer fortøjningskræfter i de glidebeslag som fastholder havnebadet.

MUSLINGEFILTRATION SOM RENSEMEKANISME I AARHUS HAVN

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Orbicon har i samarbejde med COWI og Aarhus Kommune gennemført et udviklingsprojekt i Aarhus Havn med henblik på at undersøge, om muslinger kan anvendes til at rense havnevandet for mikroalger og sundhedsskadelige bakterier. Muslingernes effekt på havnevandet blev i projektet undersøgt, ved at udlægge flydende forsøgsrammer hvorunder der hang net og liner med muslinger på 4-7 cm. Muslingernes evne til at rense vandet for mikroalger og bakterier blev målt som reduktion af koncentrationer i vandet indenfor forsøgsramme med muslinger versus udenfor forsøgsramme, hvor havnevandet ikke var påvirket af muslingernes filtration.

SESSION 9: NY TEKNOLOGI I MARIN FORSKNING OG OVERVÅGNING

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Species-specific eDNA-based monitoring of non-indigenous species in Danish marine waters compared with conventional monitoring

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Invasive aquatic species pose a great threat to marine ecosystems and have both economic and environmental impact. Conventional monitoring and sampling of marine species can be difficult, costly and time consuming. Monitoring of environmental DNA (eDNA) obtained from filtered water samples, could potentially be a powerful supplement the conventional monitoring of non-indigenous species in Danish marine waters. In a collaborative research project between both Danish and Norse research institutions, we made a first attempt of monitoring non-indigenous species in 16 Danish harbors using both a species-specific eDNA method and conventional monitoring. Species-specific assays comprising primers and probes for quantitative polymerase chain reaction setups were designed and tested for 20 non-indigenous species that occurs in Danish Seas and the north Atlantic Ocean. With initial laboratory tests of the primers and probes, specificity of each assay was first validated before tests were performed on water samples. Water samples were collected and filtered on site in early summer and late autumn, and afterwards analyzed for the level of eDNA from the non-indigenous species. The intensity of the eDNA monitoring was then compared with conventional monitoring and past knowledge of the occurrence of the 20 marine non-indigenous species. The eDNA method with two sampling events across the year, reflected seasonal changes in the distribution of non-indigenous species better than the single conventional monitoring event.

The use of an ESP (Environmental Sample Processor) for automatic analysis of environmental DNA (eDNA) in Kattegat

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DNA is constantly expelled into the environment from all living organisms. This so-called environmental DNA can be extracted from a water sample and subsequently analyzed for species-specific DNA in order to obtain knowledge about the aquatic species diversity within an area. As compared to traditional methods, like net fishing, eDNA analysis is not invasive and has been shown to be a sensitive and potential cost-efficient alternative. However, for offshore locations, temporal collections (over several month) of eDNA may be still be too difficult and expensive to achieve, thus preventing more comprehensive monitoring of many areas and species. Moreover, traditional analysis of eDNA is a laborious task leading to a time-lack from initial water sampling to analysis, which may hinder the applicability for e.g. fisheries managers.

Here we present the results from the first study using an Environmental Sample Processor (ESP) to collect and analyze eDNA from fish in a natural environment. In short, the ESP is an instrument that can be deployed at sea to perform automatic water collection, real-time eDNA extraction and analysis. The instrument can during a normal deployment sample for up to 3 month. Data is uploaded via the internet allowing real time remote analysis of the results.

In this study, we tested the potential for using the ESP to collect and analyze eDNA from fish in Kattegat over a one month period. Specifically, we developed real-time qPCR detection systems allowing us to detect eDNA from four species of migrating fish: Atlantic bluefin tuna (*Thunnus thynnus*), Atlantic mackerel (*Scomber scombrus*), garfish (*Belone belone*) and Atlantic bonito (*Sarda sarda*). Moreover, we tested the potential for using so-called meta-barcoding of archived ESP samples to analyze species-diversity from a broader group of species.

Automated real-time monitoring of commercial fish species using environmental DNA and an Environmental Sample Processor

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Marine fish surveys are essential fishery management for proper conservation. However, the current survey methods, usually trawls, are destructive, time-consuming and financially expensive due to the associated boat costs. Environmental DNA (eDNA) and robotic ocean observation systems have made much progress in the past decade. Combined these two emerging fields provide new opportunities for automated in situ monitoring of user defined aquatic target species, which may benefit current monitoring and management efforts. In this study, we evaluate the 2. Generation Environmental Sample Processor (2G ESP) with an added module capable of performing in situ DNA extraction and quantitative PCR (qPCR) to autonomously detect and quantify eDNA from 4 marine species in a 4.5 million liter mesocosmos at the North Sea Oceanarium, Hirtshals, Denmark. During the deployment the 2G ESP collected 56 discrete water samples, hereof 26 of which was analysed in situ and 30 which was chemically preserved and stored onboard the instrument for traditional laboratory based analysis post-deployment. Our results demonstrate that the 2G ESP was able to consistently detect and quantify target molecules from the most abundant species (Atlantic mackerel) in the tank with analytical results becoming internet accessible few hours after initiation of sample collection. Detection of the less abundant species was challenged by both biological and technical aspects coupled to the nature of eDNA and 2G ESP instrumentation. We conclude that the ESP has the potential to expand the application of eDNA and marine ecological surveys to become a core tool for environmental monitoring opening up for automated eDNA and fine scale offshore time-series, which historically have been economical impossible.

Et hav af ferskvand - Tanganyikasøen: Afrikas dybeste og ældste sø i den antropocæne tidsalder.

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Tanganyikasøen er en af verdens største og ældste søer og er blandt andet kendt for sine mange endemiske cichlider. Søen er også en vigtig kilde til proteiner i form af fisk, for op mod 10 millioner mennesker, som lever i søens opland. De seneste 150 år har fiskeproduktionen i søen været faldende i takt med, at vandtemperaturen har været stigende. Dette har givet næring til hypotesen om at fiskeproduktionen er fødebegrænset og at primærproduktionen har været faldende, grundet stigende vandtemperatur, som har medført en oligotrofiering af de øvre vandmasser i søen. Med støtte fra DANIDA har det været muligt at søsætte en avanceret målebøje i søen, i håb om at kunne modellere primærproduktionen og følge søens interne dynamikker i de øverste 100 meter vandsøjle. Dette er en rejse ud i ukendt farvand, med uforudsete udfordringer, som kan give vigtig viden om Tanganyikasøen nu og i fremtiden og samtidig give et vigtigt erfaringsgrundlag for overvågning med målebøjer i et lavproduktivt og til tider hårdt akvatisk miljø.

Forsknings- og overvågningsplatforme i Grønlandsk farvand

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Forskningskibet Sanna udfører forskning- og overvågningsopgaver i havet omkring Grønland, især i fjordene. Sanna erstattede i 2012 fartøjet RV Adolf Jensen der overordnet var designet til at operere med fiskegrej (tejner, trawl, garn og langliner) og bidrog siden 1967 hovedsagligt til overvågning af skaldyr og fisk. Med Sanna kan der varetages opgaver vedrørende overvågning af de kommercielt vigtige arter samt udfører oceanografiske og pelagiske undersøgelser, benthos undersøgelser og udsætning af moorings. I 2017 blev en multibeam (SeaBat T50-R) og fiskeakustik (EK-80) indsat, som gør det muligt at kortlægge havbunden og overvåge pelagiske fiskearter som f.eks. lodde.

Det udenskærs forskningsskib RV Paamiut havde i 2017 sit sidste togt. Skibet fra 1971 blev i 1992 overtaget af Grønlands Naturinstitut og har hovedsagligt udført overvågning af rejer, hellefisk og torsk i de udenskærs havområder i Vest- og Øst Grønland. I 2021 indsættes et nybygget forskningsskib designet til at udfører overvågning af bund og pelagiske arter af rejer og fisk, oceanografiske og pelagiske undersøgelser, benthos undersøgelser og kortlægning af havbunden samt udsætning af moorings.

Derudover råder Grønlands Naturinstitut over seks småbåde, som bruges til lokale undersøgelser i nærområdet.

Foredraget vil føre tilskueren igennem årscyklussen for havundersøgelser foretaget af Grønlands Naturinstituts afdelinger fra monitoring af Hellefiskebestande i Nordgrønland til fysiske, kemiske og biologiske undersøgelser af vandsøjlen i Godthåbsfjorden samt kortlægning af havbunden og pelagiske fiskeundersøgelser med den nyeste teknologi inden for akustik.

SeaBat T50 – a multibeam sonar with features specifically developed for science

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Teledyne RESON's SeaBat T50 shallow water multibeam sonar is considered the benchmark in the industry.

The sonar produces the cleanest bathymetry data yet seen – but also comprises of several advanced features making the sonar more than just another multibeam.

Normalized Backscatter - is designed for seabed classification and allows for simultaneous acquisition of high quality bathymetry and high quality backscatter.

Multi Detect - makes it possible to map features in the water column – features otherwise invisible to the sonar.

Compressed Water Column Data - significantly reduces the data volume while maintaining the required important information.

This presentation will explain and provide examples of these advanced features, used as tools by hydrographers and scientists around the globe.

Perspektiver for udvikling og anvendelse af billige hydrografiske instrumenter

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Priserne på hydrografiske måleinstrumenter er en begrænsende faktor for den mængde af data, der indsamles fra havene. Det er derfor sandsynligt at en kraftig reduktion i prisen på hydrografiske instrumenter vil lede til en stigning i mængden af indsamlede data. Den øgede tilgængelighed til data vil ikke blot være til gavn for havforskningen men også for ingeniørprojekter og forvaltning af have og kyster.

I de seneste år har teknologiske fremskridt inden for sensorer, mikroprocessorer og fremstillingsteknikker åbnet op for nye muligheder for at udvikle og fremstille hydrografiske instrumenter til priser, der er mange gange mindre end priserne på konventionelle instrumenter. Den store mængde information der er tilgængelig vedrørende anvendelsen af disse teknologier gør det nu muligt for forskere uden ekspertise indenfor elektroteknologi at give sig i kast med denne udvikling.

Denne præsentation beskriver processer og teknologier til udvikling af billige hydrografiske instrumenter. Vi giver en række eksempler på projekter hvori der er udviklet instrumenter til måling af blandt andet strømning, bølger, bundniveau og turbiditet. Vi beskriver desuden, hvordan vi har udført felteksperimenter med meget begrænsede ressourcer ved hjælp af disse prisbillige instrumenter.

Der lægges op til en diskussion om, hvordan sådanne prisbillige instrumenter kan komme forskere, ingeniører og forvaltere til gavn og om hvilke udfordringer man eventuelt vil møde.

Water depths and coastal dynamics from space

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The coastal zone is highly dynamic and there is high demand for up-to-date base-maps of the entire zone. In this presentation we will demonstrate how state-of-art bio-optical modelling is used to derive accurate and high-resolution water depths from satellite. This is followed by a demonstration of how machine learning and high-resolution satellite data can be used to identify and quantify coastline dynamics.

As modellers are moving more and more towards higher spatial resolution in their models, the need for having accurate information about the bathymetry is increasing. Existing bathymetries are typically both quite coarse and of older origin. For open and deeper waters this is no problem but for the dynamic shallow areas it introduces significant uncertainties. At DHI GRAS we have recently completed a new national 10m bathymetry model based on satellite data. In the presentation we will demonstrate how this improves the currently widely used 50m model from the Danish Hydrographic Office. The new model has better spatial coverage, it is up-to-date and it has significant impact on both hydrodynamic and ecological modelling activities and is already being used by the Danish Environmental Protection Agency, local authorities, coastal planners and large engineering companies.

Being able to accurately delineate the active coastline is also important for many purposes. If you can quantify accurate erosion/accretion rates it will for instance allow for more accurate modelling of sediment movements. Also, knowledge about the natural dynamics will allow for better planning of coastal protection facilities and general spatial planning both onshore and nearshore.

The tools and methods we have developed are globally applicable and the potential for large-scale uptake is therefore considerable. Also, both examples are good examples on how new technology and data sources are rapidly changing coastal monitoring processes – it is becoming much more dynamic and data driven.

New possibilities for nation-scale environmental monitoring – Danish case on mapping of underwater vegetation

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Recent advances in satellite technology offer a range of new possibilities for more efficient and data driven approaches to environmental monitoring activities. The new data and methods mean that systematic and cost-effective solutions are now being considered, and to some degree used, in national monitoring programs all over Europe. In Denmark, the Environmental Protection Agency is actively pursuing these options as well, however, the activities are still in pilot phases, and not fully implemented in operational or large-scale mode.

DHI GRAS was in 2018 awarded a grant from the Velux Foundation with the aim of conducting the first ever national scale mapping of submerged underwater vegetation in the Danish coastal waters – moving beyond the pilot stages. During the activity, DHI GRAS will incorporate existing knowledge (monitoring data, model results, existing GIS layers etc.) and build a machine learning submerged vegetation classifier approach. Based on the inclusion of large amounts of satellite data and advanced computer modelling a complete national submerged vegetation map will be created.

Access to calibration/validation data is crucial for the model performance and quality of the output, and the satellite approach should therefore not be seen as an alternative to the existing monitoring activities, but rather as a valuable addition to the ongoing activities. The different technologies are complementary and should be used that way to optimize both the monitoring resources and the knowledge we have of the ecological status of the littoral zone at large-scale.

First initial results from a number of Danish water bodies will be presented during the presentation. When the activity completes in the last half of 2019, the output data will be made freely available to any interested stakeholder with the hope that the data will form the first complete baseline of the abundance of aquatic submerged vegetation in Denmark and be part of the future monitoring activities.

Marin monitoring ved brug af droner: Ålegræs- og presfaktor-kortlægning ved billedanalyse

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I de seneste år har der været øget fokus på presfaktorer, der påvirker de danske ålegræspopulationer, samt på udvikling af metoder til beskyttelse og restaurering af ålegræsbede. Der er derfor behov for metoder til kortlægning af dækningsgrad, biomasse og miljøtilstand i ålegræsbede, samt en kvantificering af presfaktorerne. Ålegræsdækning monitoreres traditionelt ved dykker- eller ROV-transektopmåling med lav tidslig og rumlig opløselighed, med kun lidt information om de presfaktorer, der påvirker ålegræspopulationernes vækstforhold.

Vi præsenterer her en ny metode til at studere/kvantificere de nævnte processer ved brug af billedmateriale med høj opløselighed, indsamlet med en prisbillig drone, samt avanceret billedanalyse. Ved brug af dronen var det muligt at kortlægge store ålegræsbede i Odense Fjord, samt bestemme makroalgeforekomsten i og ved bedene. Kortlægningen blev udført i flere højder og dækkede derfor både organisme- og landskabsniveau. Ved brug af specialiseret software var det muligt at afgrænse både ålegræs og blæretang på billederne, og ved brug af en objektbaseret billedanalyse blev en semiautomatisk klassifikation udført. Kortmaterialet med ålegræssets arealdækning i 2015 og 2017 blev efterfølgende anvendt til at bestemme en vest-øst orienteret stress-gradient, der havde indflydelse på ålegræssets vækstmønstre. Billedanalysen kunne i kombination med feltobservationer af arealspecifik ålegræs- og makroalgebiomasse benyttes til estimering af den totale biomasse, samt N- og P-indhold. Vi konkluderer at metoden er yderst anvendelig og kan benyttes til at udvælge passende områder til restaurering af ålegræsbede og til detaljeret tidslig monitoring af processerne, der påvirker eksisterende ålegræspopulationer.

Sporing og opmåling af havpattedyr vha. droner

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Droner giver os mulighed for at indsamle billeder og video af havpattedyr såsom marsvin og sæler. Når dronen flyver, gemmer den kontinuert information omkring dronens præcise placering, herunder højde og kameraets orientering i en logfil. Ved at kombinere information fra logfilen med observationer i tilhørende videoer, er det muligt at bestemme dyrenes præcise position og størrelse. Til dette formål har vi udviklet et program, som lader brugeren markere punkter og måle længder i en videooptagelse. Outputtet fra programmet er en fil med bl.a. tidsstempler og GPS-koordinater over de enkelte observationer. Disse informationer kan benyttes til at analysere havpattedyrs adfærd i form af bevægelse og interaktion. Oplægget beskriver, hvordan programmet virker og hvilke usikkerheder, der må forventes i resultaterne fra programmet.

Estimation of diffuse light attenuation for Danish waters from measurements of inherent optical properties

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Light is essential for primary production and, therefore, its attenuation controls the vertical distribution of plants and phytoplankton over the water column. Additionally, diffuse light attenuation (k_d) is mainly governed by the attenuation by the water itself and the concentrations of inherent optical properties (IOPs) of e.g., phytoplankton, inorganic particles and colored dissolved molecules, what makes it an important parameter for eutrophication monitoring. Given that Denmark has recurrent eutrophication episodes and few light hours during winter, this study aims at developing a model valid for the shallow Danish waters to estimate the k_d of photosynthetic active radiation (PAR, 400-700 nm), $k_d(\text{PAR})$, from a spectral AC instrument (AC-S). The possibility of retrieving $k_d(\text{PAR})$ in the absence of light will allow for environmental monitoring outside the daylight hours making it more efficient, and will provide insights into the factors controlling light attenuation. We used a monitoring dataset where $k_d(\text{PAR})$ was estimated using two distinct approaches: (1) using a spectrally resolved calculation over the PAR range; and (2) using values integrated for the PAR wavelength range. Results show that modelled $k_d(\text{PAR})$ profiles follow the overall shape exhibited by in situ radiometric profiles. Moreover, the modelled $k_d(\text{PAR})$ is strongly correlated to the reference $k_d(\text{PAR})$ values, however, with some values deviating from 1:1 regression line. We attribute such an overestimation to the fact that the upwelling light is not accounted in the model and there might be an influence from bottom reflection and solar-induced fluorescence from phytoplankton. Finally, with respect to the two methods applied, results from the spectrally resolved approach presented better performance. This is mainly because the spectrally resolved calculations take into account the stronger absorption, mostly in the blue and red bands, that is not accounted when computing k_d from PAR data.

Måling af finkornet sediment – eksempel fra Rødsand Lagune

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Måling af suspenderet sediment i kystnære områder anvendes ofte i miljøvurderinger. Sådanne målinger foretages normalt med instrumenter af typen optical backscatter (OBS). OBS instrumenter måler turbiditet i enheden NTU. Har man brug for suspenderet sedimentkoncentration (TSMC) kræves en omsætning mellem NTU og TSMC. Denne omsætning er afhængig af sedimentets karakteristika, herunder dets form, farve og størrelse. Her præsenteres sensitivitetsanalyser af især afhængigheden af sedimentets kornstørrelsesfordeling.

Rødsand lagune ligger op ad Femern Bælt på Lollands sydkyst. Området er beskyttet mod Femern Bælt af en oddedannelse og to delvist oversvømmede sandbarrierer. Vandskiftet med Femern Bælt foregår gennem tre åbninger mod syd og vandstanden i lagunen er således overordnet styret af vandstanden i Femern Bælt. Rødsand lagune har ligeledes en åbning mod nord, Guldborgsund, som også er med til at styre vandskiftet.

Området er præget af lavvandede områder mod vest hvor bunden består af fint sand med mindre forekomster af silt og ler og lidt dybere områder mod øst hvor bundmaterialet er udpræget finkornet.

I løbet af projektet blev der optaget bundprøver fra flere lokaliteter i og omkring området for at lave en generisk omsætning for sedimentet. Disse analyser blev lavet i laboratoriet. Det viste sig at det for en given sedimenttype er muligt at lave en entydig sammenhæng. Ændrer man sedimentets karakteristika ændrer man også på sammenhængen. Dette betyder at det i områder med varierende sedimentsammensætning ikke er muligt blot at bruge en enkelt omsætningsformular.

I sommeren 2015 blev opstillet fire målestationer i området med henblik på at kvantificere sedimentdynamikken i området. På stationerne måltes turbiditet med OBS udstyr samt på nogle af stationerne strømprofiler, bølger og in situ kornstørrelse. Gennem sommeren blev der udtaget vandprøver.

Studiet beskriver løsninger på ovennævnte problem og kvantificerer usikkerheden på målingerne i det marine miljø.

SESSION 10: ARKTIS: KOBLING MELLEM GRØNLANDS INDLANDSIS OG HAVET OMKRING

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Hearing by wild whales

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Essentially all hearing studies on whales are performed on captive animals. Two methods are employed: behavioral and neurophysiological. Colleagues and I decided to attempt to measure the hearing of wild whales. We started with the Icelandic white-beaked dolphin. These dolphins use clicks with energy over 200 kHz. But, are these high frequencies audible to the dolphins? We captured two dolphins, placed them in a pool on board ship, played underwater sound and measured their hearing (using a non-invasive brain recording method). The one dolphin had good hearing at 130 kHz, but very poor hearing at 200 kHz. So, the very high frequencies must be artifacts of sound production and not usable by the dolphin for echolocating prey. Our success with measuring the hearing of wild dolphins inspired the International Association of Oil and Gas Producers to fund a very costly project to capture and measure the hearing of a baleen whale, which has never been done. The oil industry wanted to know the sensitivity and hearing range of such whales since they use explosive-like sounds to search for undersea oil and gas fields. Such sounds could potentially damage the hearing of whales. We set out to capture a young minke whale and study its hearing using the same method we used with the dolphins. An international team of experts was assembled and a fishing vessel, with a km long purse seine net and crew, was hired. Naturally we had permission from the Icelandic authorities as before. The plan was to encircle a minke whale, confine it in the net and guide it to a float with a stretcher alongside the vessel. With the whale stable in the stretcher we would play sounds and measure its hearing. After many attempts to net a minke we had to give up. The whale was just too fast for us. The hearing abilities of baleen whales are still unknown. The talk will be illustrated with graphics and several video clips, og kan holdes på dansk hvis ønsket.

Open water investigations at Villum Research Station in northeast Greenland (81°N): Sea ice breakup and marine melt of a retreating tidewater outlet glacier

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In August 2015 we investigated the marine conditions around Villum Research Station. This was the first open-water oceanographic investigations in the area.

Rising temperatures in the Arctic cause accelerated mass loss from the Greenland Ice Sheet and reduced sea ice cover. Tidewater outlet glaciers represent direct connections between glaciers and the ocean where melt rates at the ice-ocean interface are influenced by ocean temperature and circulation. However, few measurements exist near outlet glaciers from the northern coast towards the Arctic Ocean that has remained nearly permanently ice covered. Here we present hydrographic measurements along the terminus of a large retreating tidewater outlet glacier of Flade Isblink Ice Cap. Melting and retreat of the glacier was found to be critically dependent on the retreat of sea ice adjacent to the terminus and the duration of open water.

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Underwater Hearing in Arctic and Antarctic Birds

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Hearing is of special importance in the aquatic environment, where sound can be reliably transmitted over much larger ranges than light. Marine mammals therefore have very fine-tuned hearing abilities. At the same time this makes them vulnerable to human-induced sounds from shipping, sonars, and air guns.

Apart from whales and seals, the degree of hearing adaptations to the aquatic environment has only been studied in a few species of secondarily adapted aquatic vertebrates. Aquatic turtles and crocodiles have tuned their hearing to work well in both air and under water.

Many species of marine birds find their food under water. Penguins, auks and cormorants are actively chasing prey while diving, but marine bird underwater hearing has only been studied in the great cormorant (*Phalacrocorax carbo*) and the black duck (*Anas rubripes*). Both have acute hearing abilities underwater in the 2-3 kHz range. It is conceivable that other groups of marine birds such as penguins and auks, would likewise also have acute hearing abilities.

We played underwater sounds to diving Gentoo penguins (*Pygoscelis papua*) and Common murrelets (*Uria lomvia*) in a quiet pool. Both species showed a graded reaction to sound intensities above 110 dB re 1 μ Pa. This indicates that penguins and auks may use underwater cues while diving and therefore may be affected by anthropogenic noise in similar ways as marine mammals.

Diatom-based reconstruction of ocean surface conditions in the SW Greenland during the last two millennia

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Sea surface temperatures (SSTs) in the North Atlantic are important climate factor as they modulate the Arctic winter sea ice extent, surface water circulation and the intensity of the Deep Water formation in the Labrador Sea and thus have an influence on the Atlantic Meridional Overturning Circulation (AMOC). Warming of the SSTs imposes a threat to the Greenland Ice Sheet and increase of freshwater input to the ocean might have impact for the Northern Hemisphere climate through disruption of the AMOC.

This study aims to produce high-resolution record of ocean surface conditions (August SSTs and sea ice concentrations) from a marine sediment core MSM45-004 recovered from the SW Greenland Shelf for the last 2 000 years using diatom-based reconstruction methods.

Sedimentological proxies such as sedimentation rates, grain size distribution, IRD and XRF-scans are used to investigate iceberg discharge and meltwater pulses from the Greenland Ice Sheet.

Comparison with aSST-records around North Atlantic is used to identify possible temperature seesaw-pattern linked to the North Atlantic Oscillation (NAO). As well as to study variations in the warm water inflows and to detect regional differences in the timing of the known climate events; the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA).

During the last 2 000 years, aSSTs have varied in centennial and decadal timescales, with sea ice concentrations negatively correlating with the aSSTs. Results shows cooler ocean surface conditions from 1060 CE to 1420 CE (during the MCA) while warmer aSSTs prevailed after that until 1800 CE (during the LIA) and reached the highest temperatures of this record around 1600 CE. Similar temperature trend was discovered in the subpolar North Atlantic while the opposite temperature trend prevailed in the Norwegian Sea region. This seesaw pattern is likely to be linked to the NAO and to the strength of the Irminger Current carrying warm Atlantic waters to NW North Atlantic.

Water masses along west Greenland and their implication for glacier melt

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The mass loss from the Greenland ice sheet is increasing and currently contributing 25% of the observed global sea-level rise. Accelerated melt has been observed in west and south Greenland and suggested linked to an increase in subsurface ocean temperature in the mid 1990's along the west coast of Greenland due to inflow of warm water of Atlantic origin. The question is if this subsurface warm ocean water can reach the glaciers in the inner parts of the fjords and how important this heat source is for melting the marine terminating glaciers from the Greenland ice sheet. Here we investigate hydrographic conditions along west Greenland from Cape Farewell (59°N) to Melville Bay (75°N) and find that offshore slope and coastal water masses differ. Warm subsurface water of Atlantic origin is mainly found south of the Davis Strait on the slope and colder Baffin Bay Polar Water characterizes the conditions of the upper water column north of the strait. Coastal waters are substantially colder and fresher south of Davis Strait and slightly warmer and saltier to the north. We suggest that coastal water formed by mixing and winter convection on the shelf south of Davis Strait controls on the heat exchange between offshore waters and the glaciers connected to the Greenland ice sheet both south and north of Davis Strait.

SESSION 11: VANDRAMMEDIREKTIV, HAVSTRATEGI OG FYSISK HAVPLANLÆGNING

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Danmarks Havstrategi II: God miljøtilstand i havet – set med EU-briller

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Første del af Danmarks Havstrategi II er i Øjeblikket i offentlig høring, og det er muligt at komme med input til strategien indtil 21. Februar 2019. I strategien defineres god miljøtilstand for en lang række forskellige parametre. Den nuværende tilstand i havmiljøet beskrives, og der sættes miljømål for, hvordan god miljøtilstand nås.

God miljøtilstand er havområdernes miljøtilstand, når de giver Økologisk mangfoldige og dynamiske oceaner og have, der er rene, sunde og produktive inden for rammerne af deres naturlige vilkår, og havmiljøet udnyttes på et bæredygtigt niveau, så nuværende og fremtidige generationers muligheder for anvendelse og aktiviteter sikres. Men hvad betyder det mere konkret?

Rammerne for, hvordan god miljøtilstand skal defineres i henhold til havstrategidirektivet, blev Ændret i 2017 og består nu af 42 forskellige kriterier. I præsentationen dykker vi ned i nogle af kriterierne og beretter om historien bag deres tilblivelse og formålet med dem. Vi stiller også skarpt på, hvorfor det er vigtigt, at kriterierne er kendt stof i forskningsverdenen.

Danmarks Havstrategi II: Status og miljømål for eutrofiering

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Det danske havmiljø påvirkes af mange presfaktorer. En væsentlig presfaktor er næringsstoffer, der tilføres havmiljøet fra kilder til lands, til vands og i luften. En øget mængde næringsstoffer kan have negative effekter på havmiljøet.

I første del af Danmarks Havstrategi II vurderes miljøtilstanden i de danske havområder for en lang række parametre, herunder eutrofiering. Tilførsler af næringsstoffer til de danske havområder er faldet markant siden 1980'erne. På trods af det er der stadig store dele af de danske havområder, der ikke er i god tilstand. Denne vurdering er primært baseret på det arbejde, der er lavet i de regionale havkonventioner HELCOM (Østersøen) og OSPAR (Nordsøen).

I havstrategien fastsættes miljømål, der sigter mod at nå en god miljøtilstand i det danske havmiljø. I oplægget præsenteres baggrunden for de danske miljømål for eutrofiering. Der vil blive stillet skarpt på, hvordan miljøtilstanden vurderes, og hvordan der fastsættes tærskelværdier for god miljøtilstand.

Danmarks Havstrategi II: Status og miljømål for havbundens integritet

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Havbunden påvirkes af menneskelige aktiviteter såsom fiskeri og klapning samt installationer såsom vindmøller og havne. Visse aktiviteter fører til midlertidig forstyrrelse af havbunden, mens andre fører til decideret tab af havbunden.

I første del af Danmarks Havstrategi II er der lavet en opgørelse over tab og forstyrrelse for 16 forskellige havbunds naturtyper. Resultaterne viser, at der er høj grad af forstyrrelse på havbunden, mens tab generelt ses i væsentligt lavere grad. Der er dog fortsat en række udeståender så som at vurdere, hvornår en forstyrrelse medfører en negativ påvirkning. Ligeledes er der endnu ikke fastsat tærskelværdier

I oplægget præsenteres status for tab og forstyrrelse af havbunden sammen med de opstillede miljømål. Der stilles desuden skarpt på de afgørende spørgsmål omkring havbundspåvirkninger, som fortsat skal afklares såvel som fastsættelse af tærskelværdier.

Danmarks Havstrategi II: Status og miljømål for marint affald

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Marint affald udgør et problem for havmiljøet, da bl.a. havpattedyr og havfugle kan indtage og ophobe affald i maven og risikere at sidde fast i affaldsstykker eller blive kvalt. Da det globale forbrug af plastik er stigende, og plastikaffald formentlig kan opholde sig i havmiljøet i mange hundrede år, kan problemet på globalt niveau forventes at stige i fremtiden.

I første del af Danmarks Havstrategi II er den nuværende tilstand for marint affald i havmiljøet beskrevet. Omkring 70-90 % af det marine affald består af plastik - både mikroplastik og større stykker affald, f.eks. plastikposer og fiskenet. På de danske strande er fiskeri, turisme og andre rekreative aktiviteter de dominerende kilder til affald.

I havstrategien er der opstillet en række miljømål for marint affald. I oplægget dykker vi ned i, hvad der er god miljøtilstand, når det kommer til marint affald, og hvor meget affald der skal til for at gøre skade på miljøet. Marint affald er et relativt nyt emne, og vi vil derfor også stille skarpt på, om vi ved nok om, hvor meget affald der er i miljøet.

On the potential of a national marine physical seabed index for evaluating abiotic seabed characteristics

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The main goal of the EU Marine Strategy Framework Directive (MSFD) is to achieve Good Environmental Status (GES) of EU marine waters by 2020. The MSFD defines GES as “the environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive”. In addition, GES means that ecosystems, including their hydro-morphological, physical and chemical conditions, are fully functioning and resilient to human-induced environmental change.

The MSFD includes eleven qualitative descriptors which describe what the environment will look like when GES has been achieved. Two of these descriptors, i.e. D1 Biodiversity and D6 Sea-floor integrity, are highly coupled to the seabed with criteria on e.g. habitat distribution, extent and condition and physical damage in regard to substrate characteristics. However, to date there is no specific marine physical seabed index for evaluating abiotic seabed characteristics in support of these MSFD-descriptors.

Here, we suggest the introduction of a national marine physical seabed index for evaluating abiotic seabed characteristics. This will be in line with the Danish Physical Index (Dansk Fysisk Indeks - DFI) used to describe the physical quality of watercourses in relation to evaluating Good Ecological Status within the EU Water Framework Directive. We discuss the relevant parameters to constitute such a marine physical seabed index as well as the relations to the existing indicators under the descriptors relevant for benthic habitats and the sea-floor integrity.

On the added value of a transnational approach in mapping of potential cumulative effects of multiple human stressors

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Human activities such as shipping, pollution, tourism and fishing in both marine and coastal waters are causing cumulative pressures on the ecosystems. The anthropogenic use is constantly increasing and with “blue growth” as the new driver different actors may be interested in exploiting the same nature resources. Therefore, the need for an ecosystem-based management (EBM) to maintain sustainable economic growth and the demand for marine spatial planning (MSP) has been intensified, especially recently by the implementation of the European Commission’s Maritime Spatial Planning Directive (MSPD). Many human activities occur naturally over transnational borders, but MSP are typically national, although the MSPD requires international collaboration. We report a study on mapping the potential cumulative effects of multiple human stressors in the Sound, the strait between Denmark and Sweden. Ecologically relevant stressors and ecosystem components for the Sound were included. A special focus has been put on the importance of including cross-boundary effects, i.e. the influence of human activities from the Swedish parts of the Sound on ecosystem components in the Danish parts and vice versa. These analyses document that stressors having cross-boundary effects need to be included in national studies of cumulative effects for holistic and relevant future marine planning. Additionally, recreational and tourist activities were included as a stressor and ecosystem component and the spatial and relative importance were analysed. Further, archaeological sites (submerged Stone Age dwellings and ancient wrecks) were included as they can possibly be affected by various human activities. In the MSPD both tourism and underwater cultural heritage were taken into consideration for relevant interactions.

Sku ned! Et fælles indeks for skibsstøj i Østersøen

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Med havstrategidirektivet følger en forpligtigelse til at overvåge og sikre god miljøtilstand med hensyn til menneskeskabt undervandsstøj i havet. Baggrunden er en berettiget bekymring for den stigende støj i havet, der forårsages af bl.a. skibsfart, pæleramning af f.eks. vindmøllefundamenter, seismisk olieefterforskning og militære anti-bådssonarer. Da vand leder lyd langt bedre end luft, så kan disse lydkilder påvirke meget store havområder. Dette gør støjforureningen til et grænseoverskridende problem hvorfor der er igangsat en koordineret overvågning i Østersøen. I første omgang via EU Life-projektet BIAS (2013-2016) og senere via nationale overvågningsprogrammer i henhold til fælles retningslinjer vedtaget i HELCOM.

Et af de første resultater er fremstillingen af et fælles presfaktor-indeks for skibsstøj i Østersøen, til brug for HOLAS II vurderingen. Indekset har sit grundlag i målinger på 40 stationer i Østersøen i BIAS projektet, hvor støjen omkring 125 Hz (havstrategidirektivets indikator 11.2.2) blev målt gennem hele 2014. Baseret på disse målinger, samt data om skibstrafik fra AIS-systemet og meteorologiske data, blev den samlede undervandsstøj modelleret som summen af støjen genereret af vind og bølger og støjen fra fragtskibe og andre skibe med AIS. Presfaktorindekset går fra 0 (støjen domineret af naturlig støj fra vind og bølger) til 1 (støjen svarer til de højeste niveauer målt i BIAS-projektet).

Indekset er højest hvor skibstrafikken er høj, dvs. de danske stræder og bælter, farvandet nordvest for Bornholm, Midsjøbankerne og indsejlingerne til Stockholm og Helsinki. Store områder er imidlertid relativt lidt påvirkede, bl.a. vestlige Kattegat, sydøstlige Østersø, Rigabugten og Den botniske Bugt. Dette indeks er et væsentligt bidrag til vurderingen af miljøtilstanden i forhold til skibsstøj og kan vise sig som et vigtigt værktøj i reguleringen af undervandsstøjen og den marine arealplanlægning.

Same-Risk-Area Case-studie for Kattegat og Øresund

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FN's ballastvandskonvention (BWMC) trådte i kraft i september 2017. Formålet med BWMC er, at sikre at marine invasive arter ikke spredes med skibenes ballastvand. BWMC stiller krav til rensning af ballastvand før det udledes typisk i forbindelse med havnebesøg. Det er muligt at søge dispensation til skibe, som sejler i fast rute mellem to eller flere havne (og lande). En dispensation gives af de nationale myndigheder, og gælder i en periode på 5 år. En forudsætning for en dispensation er, at der foretages en risikovurdering. BWMC's guideline (G7) anviser procedurer for, hvordan en tilkendelse af en dispensation kan ske. I den oprindelige udgave var anvisningerne målrettet den enkelte skibsrute, således at der for hver enkelt skibsrute og skib kunne ansøges om en dispensation. I 2017 blev G7-dokumentet opdateret således, at det nu er muligt, at ansøge om en mere generel dispensation i form af et såkaldt "Same-Risk-Area" (SRA). Et SRA er et marint område indenfor hvilket, der kan gives dispensation til alle skibe, der sejler i fast rute. En vigtig del af en den risikovurdering, der skal ligge til grund for et evt. SRA, er at vurdere den potentielle naturlige spredning af marine invasive arter, hvis de introduceres. Hvis en art spredes naturligt og relativt hurtigt i et område så vil spredning via ballastvand kunne vurderes som ubetydeligt, hvorimod arter med en begrænset spredningspotentiale kan ende med at være bestemmende for størrelsen og udstrækningen af et evt. SRA. Andre forhold kan også indgå i en risikovurdering herunder øvrige spredningsvektorer, artens invasive karakter, den historiske udbredelse, reproduktionspotentiale, habitatforhold, temperatur- og salttolerancer mv. Her præsenterer vi resultaterne fra et case-studie, hvor vi har afprøvet SRA konceptet i Kattegat og Øresund, og vha agent-baseret modellering og kendskab til arters biologi og habitatkrav, har analyseret den potentielle naturlige spredning for udvalgte arter.

Marine spatial planning for wind and oil industry: A screening methodology for optimal for site selection

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The growth of some human activities at sea are creating an increase of marine space demand in Denmark. Different activities can impact or coexist with other human activities or natural environments, depending of their operational characteristics and the nature of the industry. The process to follow for a marine space allowance on specific uses is often long and complicated. COWI, via a range of projects have developed a screening method for the wind and oil industry, which could help authorities or private users to get a general overview of the Danish marine space and data availability. This general screening takes in consideration the marine environment and Human sensitivity of each location towards the placing of Oil platforms and Windmill parks. This method have been used in a number of projects, both national and international, at the North sea and the Baltic sea. Simplified, the method is a GIS tool, which include a range of parameters (layers) ranked on accordance to their sensitivity towards the new activity. All layers are weighted through, resulting on an overall sensitivity for each location. The environmental sensitivity analyses includes for instance parameters as protected areas, areas of especial importance for wintering birds, areas with importance for marine mammals, key habitats etc. The human activities sensitivity considers marine traffic, military activities, air traffic, fishing intensity etc. Overall, the idea is to get a general overview of a large marine area and identify those places that will be relatively less sensitive towards the new coming activity. To the date, there is not a standardized protocol to select and optimize marine uses in Denmark. Therefore, this method is subjected to discussion, both on the parameters selection and on the selected rankings. A side effect of these kind of study is the identification of data gaps. Hence, specific monitored data can be used later on, to improve the initial predictions.

Scenarier for arealanvendelse i Øresund

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En havplan for Danmark forventes offentliggjort primo 2019. Projektgruppen har gennemført et demonstrationsprojekt i Øresundsregionen, hvor vi, i samarbejde med alle væsentlige brugergrupper, har udarbejdet scenarier for en bæredygtig udvikling af erhvervs- og samfundsaktiviteter og miljøforhold i Øresundsregionen. Scenarierne omfattede en række antagelser, konflikter, muligheder for sameksistens, indsatser og konsekvenser. Der blev udarbejdet fire scenarier; ét hvor erhvervsinteresser blev prioriteret. Ét hvor naturen blev prioriteret og to scenarier, hvor der var en ligevægt af natur- og erhvervsinteresser, men adskilt geografisk i funktioner eller i en sameksistens. Den fremtidige udnyttelse af Øresunds arealer kan følge flere spor. Mange flere end de fire scenarier, som er analyseret her. Uanset hvilke veje man ønsker at gå og, hvilke prioriteringer, der bliver foretaget, så har alle beslutninger konsekvenser for samfundet. Dette gælder for jobskabelse og økonomi inden for både erhvervsudvikling, turisme og friluftsliv og for udvikling af havmiljøet.

Extending Shared Socioeconomic Pathways for the Baltic Sea region for use in studying long-run projections of nutrient loads

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The Baltic Sea is an ecologically vulnerable aquatic ecosystem that is greatly influenced by human activities and the climatic system. Diffuse and point nutrient loads from agriculture, industry and waste water treatment plants have caused strong eutrophication and large areas of dead sea bottoms in the Baltic Sea, threatening a range of important ecosystem services. Changing climate is expected to increase precipitation and runoffs, which in turn accelerates nutrient loads to the sea, while the resilience of the marine ecosystem is weakened due to higher surface water temperatures.

Global climate futures (RCPs) and socioeconomic futures (SSPs) were developed to address global challenges to mitigate and adapt to climate change. These can also be applied as tools when analyzing solutions to regional environmental problems, which would necessitate extending the pathways to regional sectors.

We extend SSPs for the Baltic Sea region and combine them with downscaled climate pathways (RCPs) for the period 2010-2100. The scenarios are used as input to integrated assessments to investigate how changes in nutrient emissions and subsequent responses in the ecosystem, combined with uncertainty about both future climate impacts and societal developments, may develop and what actions would be needed to obtain good environmental conditions.

We first present a collaborative effort to translate global climate and socioeconomic futures into regional drivers and pressures that drive pollution in the Baltic Sea. We propose sectoral narratives of the sustainability pathway (SSP1), the Middle of the Road (SSP2), Regional Rivalry (SSP3) and Fossil Fueled Development (SSP5) for the agricultural sector and other non-point sources, municipal wastewater treatment and shipping. Next, based on the SSP narratives, we present the quantitative assumptions, land use modelling and simulations of non-point and point nutrient source pollution and compare these to the Baltic Sea Action Plan targets.

”Marin vandplanlægning efter Vandrammedirektivet”

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Præsentationen vil give et indblik i den marine vandplanlægning i henhold til EU's vandrammedirektiv. Herunder præsenteres hvad der ligger til grund for miljø,tilstandsvurderinger og miljø,indsatsen i de nugældende vandområdeplaner 2015-2021. Endvidere omtales det igangværende forarbejde til næste generation af vandområdeplaner 2021-2027, herunder hvilke forskningsprojekter der er iværksat til understøtning af den marine vandplanlægning.

Andre presfaktorer end næringsstoffer og klimaforandringer

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Vandrammedirektivet foreskriver, at medlemsstaterne skal indsamle oplysninger om type og omfang af de signifikante menneskeskabte belastninger og deres virkninger på kystvandenenes tilstand. Forskning har tidligere vurderet, at den mest betydende presfaktor er belastningen med N og P. En række andre presfaktorer kan imidlertid belaste det marine miljø, men der findes ikke en samlet vurdering af betydningen af disse presfaktorer for miljøtilstanden i kystvandene, som den defineres i VRD. For at forbedre plangrundlaget i 3. generations vandplaner har Miljøstyrelsen derfor iværksat indsatser til belysning af andre presfaktorer.

I denne analyse har vi på baggrund af strukturerede reviews analyseret presfaktorerne:

Råstofindvinding, klapning og graveaktiviteter, fysiske konstruktioner, fiskeri, skibstrafik, plastik, miljøfarlige stoffer og invasive arter. De invasive arter er repræsenteret ved 4 karakteristiske arter. Analysen har taget udgangspunkt i, at tilstedeværelse alene ikke er tilstrækkelig, der skal være en påvirkningsmekanisme på et eller flere af kvalitetselementerne (fytoplankton, makroalger, angiospermer og bundfauna) og/eller støtteparametrene (iltforhold og sigtdybde), for at det kan siges, at presfaktorerne har en virkning jf. VRD. Da indsatser for at forbedre vandmiljøet bliver planlagt på niveau af vandområder, skal effekten af presfaktoren endvidere kunne detekteres på dette niveau. For at kunne beskrive og dokumentere en evt. betydende påvirkning af en given presfaktor på kvalitetselementerne i et vandområde er det endvidere nødvendigt, at der er et tilstrækkeligt datagrundlag til at analysere den konkrete sammenhæng mellem presfaktoren og kvalitetselementerne/støtteparametrene.

På baggrund af kriterier om dokumenteret påvirkningsmekanisme, potentiel væsentlighed og datagrundlag er de nævnte presfaktorer blevet gennemgået og vi præsenterer her resultater og anbefalinger vedrørende inkludering af presfaktorerne i analyserne i 3. generations vandplaner.

Hav og kysters anvendelse til friluftsliv og turisme

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Havet og kysterne er ikke kun vigtige marine habitater men har også en stor rekreativ betydning for menneskers trivsel og sundhed samt store positive samfundsmæssige effekter. Langt de fleste rekreative aktiviteter er rolige og foregår langs kyster med især sandstrande i en kortere sæson. De rekreative aktiviteter er meget afhængige af et rent havmiljø og et rigt marint liv, så beskyttelsen af havmiljøet, oplevelser og formidling af havet er tæt forbundne. Friluftsliv og turisme udgør et spektrum, hvor aktiviteter uden for nærområdet betegnes som dagsturisme eller egentlig turisme med overnatning. Danmarks 8.750 km kyster besøges årligt af mere end tre-fjerdedele af den voksne danske befolkning. De rekreative anvendelser af kyster og havområder er vigtige at inddrage i den igangværende maritime fysiske planlægning (havplanlægningen). Københavns Universitet har lavet en national kortlægning og dokumentation af havfriluftslivet til brug for havplanlægningen. Der indgår 92 forskellige rekreative aktiviteter fordelt på 16 hovedgrupper. Da undersøgelsen er husstandsaseret, indgår de internationale turister imidlertid ikke. Vi har derfor i samarbejde med Center for Regional og Turismeforskning (CRT) fået lavet en stor modellering og analyse af turistsektorens egne data med henblik på at identificere, kystzonens andel af turismen og de samfundsmæssige effekter. De foreløbige resultater viser, at kystturismen udgør en meget væsentlig del af turismen i Danmark og har store økonomiske og jobskabende effekter. En forståelse af hav- og kystturismens geografi og hvilken rolle oplevelsesøkonomien spiller i forhold til de mere traditionelle erhverv viser, at de rekreative anvendelser af havet har meget stor samfundsøkonomisk gavn, men en geografisk ujævn fordeling. Det er derfor vigtigt at de rekreative havaktiviteter inddrages i havplanlægningen, og at dataindsamling og modellering af turismedata fremadrettet tilpasses denne planlægning, som skal opdateres hver 10. år.

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N og P balance i Gyldensteen Kystlagune efter oversvømmelse af landbrugsjord med havvand

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Når havspejlet i fremtiden stiger, er oversvømmelse af marginaliseret landbrugsjord ved ”managed realignment” et muligt virkemiddel til at beskytte vore kyster. Storskala-forsøget ved Gyldensteen Strand, hvor 214 ha tidligere indvundet landbrugsjord i 2014 blev oversvømmet med havvand, har skabt et nyt og kystbeskyttende naturområde med stor rekreativ værdi. Årtiers ophobede næringspuljer i agerjorden blev dog frigivet efter oversvømmelsen og har muligvis påvirket havmiljøet udenfor kystlagunen i uheldig retning. Vi vil her præsentere N og P budgetter for Gyldensteen Kystlagune de første 5 år efter oversvømmelsen baseret på 3 uafhængige metoder: 1. DIN og DIP frigivelse fra jordbunden; 2. ændring af TN- og TP-puljer i jordbunden; 3. modelbaseret estimat af partikulært og opløst N og P eksport med tidevandet. Alle tre metoder frembragte sammenlignelige resultater med stor N og P frigivelse og eksport de første 2-3 år efterfulgt af et dramatisk fald i N-eksport, og kun et mindre fald i P-eksport. Transporten af N og P til havmiljøet udenfor var det første år efter oversvømmelsen så stor, at det svarede til hele den totale årlige gødskning i området før oversvømmelsen. Havmiljøet bliver derfor på kort sigt udsat for en ekstra belastning med N og P når landbrugsjord oversvømmes med havvand. Det er derfor vigtigt at kende miljøtilstanden i det omkringliggende havområde præcist før det besluttes om agerland skal oversvømmes ved managed realignment.

Drivhusgasser ved Gyldensteen deler vandene

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Vådområder spiller en vigtig rolle i forhold til klima. Ofte restaureres og genskabes vådområder med det formål at fjerne atmosfærisk kuldioxid (CO₂) samt at lagre kul i den vandmættede jord. Klimagevinsten ved disse vådområder er dog langt fra givet. Selvom oversvømmelse hæmmer den aerobiske respiration i jorden, er det på bekostning af forøget udledning af metan (CH₄). CH₄ er den næstvigtigste drivhusgas og yderligere er metan en 25 gange mere potent drivhusgas sammenlignet med CO₂. Ved Gyldensteen Strand, Fyn, Danmark er to landområder blevet genskabt som vådområder. Begge områder har været drænet i 150 år, har modtaget samme behandling mht. dyrkning og gødskning og er beliggende med kun et dige som adskillelse. Det første område, Gyldensteen kystlagune (214 ha), er blevet oversvømmet med havvand ved nedbrydning af diger ud mod bæltet og ved stop af aktiv udpumpning. Det andet område, Engsøen (144 ha), er blevet genskabt som vådområde alene ved nedbør og grundvandstilløb – området eksisterer nu som et lukket ferskvandssystem. Drivhusgasudledningen varierer meget mellem de to vådområder. Således har netto-CO₂ udledningen i kystlagunen nået 0, når man kigger på hele døgnet CO₂-fluxe. Faktisk, nærmer systemet sig autotrof tilstand. Oversvømmelse af landbrugsjorden har altså vist sig at være en klimagevinst i kystlagunen, sammenlignet med den høje CO₂-udledning målt før oversvømmelse. Engsøen derimod er blevet en større kilde til drivhusgasudledning end før oversvømmelsen. Dette skyldes den høje CH₄-udledning fra Engsøen i forhold til kystlagunen. Havvand hæmmer CH₄-dannelse i kystlagunen, da sulfaten i havvand er en mere favorabel elektronacceptor. Når der skal genskabes og restaureres vådområder i fremtiden, kunne det tilrådes i højere grad at oversvømme kystnære områder med havvand og dermed sikre en større klimagevinst sammenlignet med de CH₄-udledende ferske vådområder.

Produktion af østersyngel (*Ostrea edulis*) – en nøglefaktor i såvel naturgenopretning som akvakultur

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Den europæiske østers (*Ostrea edulis*) er efterhånden sjælden i Europa, hvilket bl.a. kan skyldes overudnyttelse, invasive østers og parasitten *Bonamia* spp. som har været med til at reducere bestandene kraftigt i Europa. I nogle lande er den helt forsvundet og den er nu på OSPAR-listen over truede arter. Man forsøger disse år at reetablere europæiske østersbanker på udvalgte steder i Europa og sætte fokus på problemet. Den europæiske fladøsters er desuden et højværdiprodukt, der har et unikt marked på grund af dens delikate smag og historie som kongelig spise og som der i disse år er står efterspørgsel efter.

Flaskehalsen til både genetablering og akvakultur er produktion af østersyngel (spat) som bedst produceres i landbaserede klækkerifaciliteter som dem der findes på Dansk Skaldyrcenter, DTU Aqua. Ikke mange steder i Europa er man som her i stand til regelmæssigt at producere spat på større skala.

Fokus er på udvikling af nye opdrætsteknikker som basis for en bæredygtig produktion af østersyngel samt optimering af alle trin i dyrkningprocessen.

I præsentationen gives en introduktion til arbejds- og optimeringsprocesserne i østersklækkeriet på DSC som omfatter alle led fra dyrkning af mikroalger, tilpasning af moderøsters, produktion og udvikling af larver, bundslåning og til sidst vækst af spat. Der gives eksempler på de seneste forskningsresultater.

SESSION 13: FORMIDLING AF HAVFORSKNING

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Når naturvidenskab fænger – fra skolebørn til pensionister

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Under hele Galathea 3-ekspeditionen fik elever fra grundskolen nyt fra de forskellige projekter, der var med ombord.

Efter ekspeditionens ophør blev en lang række af forskningsprojekterne omsat til undervisnings- og oplevelsesmateriale – primært for gymnasier og HF samt 7. - 10. klasse på hjemmesiden www.galathea3.dk.

Hjemmesiden har knap 100 undervisningsforløb indenfor bl.a. biologi, kemi, fysik, historie, naturgeografi samt naturfaglige grundbeløb. Her godt 11 år efter ekspeditionen lever siden lever i bedste velgående og 'Virtuel Galathea' har netop modtaget midler til at opdatere forløbene.

Hver tirsdag gennem foråret og efteråret samler fakultetet Science and Technology ved Aarhus Universitet ca. 10.000 gæster til naturvidenskabelige foredrag. Foredragene afholdes i Søauditorierne i Aarhus og livestreames til ca. 130 forskellige forsamlingshuse, biografier, gymnasier, kulturhuse o.l. rundt om i hele Danmark ligesom gæster fra Færøerne og Grønland oplever foredragene live. Gæsterne tæller alt fra gymnasieelever til trofaste pensionister, der møder op aften efter aften.

Gennem de sidste 1½ år har Nordea-fonden støttet projekt 'Hovedet i Havet', der henvender sig til børn i 6. til 10. klassetrin i grundskolen. Projektet udvikler tværfaglige marint baserede undervisningsforløb efter de fællesfaglige fokusområder fra undervisningsministeriet. Her får eleverne får mulighed for at møde og opleve havets natur på en ganske unik måde ligesom vi besøger skolerne eller invitere skoleklasser ombord på Aarhus Universitets forskningsskib, Aurora.

Trods den korte projektperiode har vi haft direkte kontakt til mere end 20.000 elever og lærer og vi oplever en kolossal interesse både fra elever og lærer, der er taknemmelige for et godt kompetenceløft.

Vi samler op på de forskellige projekter og vurderer, hvad det er, der får naturvidenskab til at fænge hos alle - fra skolebørn til pensionister.

Teaching at the Bottom of the Ocean

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Throughout the years, researchers, teachers and communicators of the natural environment have been challenged with giving life to communication and active learning about the ocean. Today, technology provides us with new and interesting possibilities of conveying the fascinating life below the surface of the sea. By means of a more vivid teaching focusing on a sunken ferry, this project aims at:

- Analyzing to what extent positive steps can be taken to increase the interest in and knowledge of marine biology among secondary and high school students
- Stimulating interest in the ocean by providing unique opportunities for learning about the ocean and experiencing it firsthand

In 2014 an old ferry was sunken in the ocean south of Funen. This primarily aimed at attracting divers to the area and has been a great success with nearly 10.000 dives on the wreck so far. This way, however, only divers have had the opportunity to observe the succession of the wreck. Establishing an 'underwater laboratory' on the wreck SDU enabled live streaming from the wreck to be used in teaching, communication about the ocean and to observe the succession over time. The underwater laboratory consisted of four cameras mounted on the ferry, from which they were connected to a video server on a pontoon floating on the surface above the wreck. On the pontoon a windmill and solar cells generate power to establish internet connection for the video server. As part of the project, live streaming from the wreck was used to substantiate teaching about eco systems, etc., thereby providing students with the opportunity to experience the ocean in a new and exciting way.

The talk will present data from 700 students interest in the oceans before and after a teaching program with the use of live stream from the ferry.

Formidlingsinstitution i et forskningsmiljø – Hvordan man kan drage fordel af hinanden.

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Øresundsakvariet i Helsingør har siden start delt faciliteter med Marinbiologisk Sektion (MARS). Oprindeligt startede det som udstillingsvindue for de organismer og miljøer der blev forsket i på Marinbiologisk sektion. Siden har det udviklet sig til at formidle Øresunds biologi i bred forstand, overfor en stor vifte af modtagere. Samtidig er forskningen på MARS blevet meget mere internationalt orienteret, med mindre fokus på Øresund. Derfor er der efterhånden meget lidt direkte overlap mellem forskningen og formidlingen på matriklen. Alligevel er den tætte tilknytning til stor gavn, idet den giver direkte til den nyeste forskning og viden inden for en lang række marinbiologiske områder. Viden der kan omsættes til perspektivere forholdene i Øresund og på den måde give en mere kvalificeret formidling. Ligeledes giver de fælles faciliteter i form af udstyr og både en unik mulighed for at lave formidling der knytter direkte op til marinbiologisk forskning.

Forskning til folket – en udfordrende balance mellem seriøs præcision og fængende forenkling

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Kattegatcentret varetager formidlingsopgaven i en del forsknings- og udviklingsprojekter, hvor vi arbejder sammen med universiteter, uddannelsesinstitutioner, GTS'er, myndigheder og virksomheder.

Hør om, hvordan langhåret forskning i blandt andet ernæring, sundhed, foder, fisk og tangdyrkning omsættes til engagerende undervisning, underholdende OG lødige formidling og anvendelig lavpraktisk viden. Kattegatcentrets målgruppe spænder nemlig bredt fra førskolebørn over skoleelever og familier til interessegrupper og beslutningstagere, og den omfatter også iværksættere og virksomheder.

Teaching teachers to test new teaching techniques

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The lack of students pursuing careers in natural sciences is of concern in many European countries. The problem may be alleviated by developing new, exciting teaching methods, moving away from traditional classroom teaching into activities inspired by exciting scientific investigations. We developed teaching materials in biology for public and high schools, translated into English, Danish, Swedish, French, German and Polish. The teaching materials were based on the biology of marine mammals, as it was assumed that these charismatic animals would be able to inspire students to get more interested in scientific topics. We tested the materials on teachers and students from several European countries. By asking participants to fill in questionnaires before and after each teaching event, we could show that these activities created a broader interest in science, both among teachers and students.

Lillebælt livestreaming – hvor videnskab og formidling mødes

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I Lillebælt, som er et af de mest trafikerede havområder i verden, lever også Danmarks tætteste bestand af marsvin (Phocoena Phocoena). Det er nu muligt for både forskere og befolkningen at følge den akustiske aktivitet fra marsvin og undervandsstøjen fra f.eks. skibe, broer og anlægsarbejde, ved at kombinere live video og lyd i et samlet output. Som en del af den igangværende forskning på området har Aarhus Universitet, Seiche Ltd. og Naturpark Lillebælt, i foråret 2017, installeret en lyttepost på 12 meters dybde, for enden af et udlagt stenrev, ved Middelfart. Formålet er at indsamle kontinuerlige data om marsvin og undervandsstøj i Lillebælt, samt øge den offentlige interesse for livet i havet. Lytteposten består af ét webcam der viser havoverfladen, AIS modtager der indsamler data fra alle de større skibe der passerer gennem bæltet, to undervands kameraer med justerbart lys samt to hydrofoner der optager henholdsvis de høje og lave frekvensbånd. Marsvin har en utrolig god hørelse under vand og bruger ekkolokaliseringsslyde omkring 130 kHz til jagt, kommunikation og navigation. For meget undervandsstøj har vist sig at påvirke deres lyst til fødesøgning og kan derfor påvirke deres levegrundlag. Data viser en høj aktivitet af marsvin om aftenen, natten og de tidlige morgentimer og en lav aktivitet om dagen. Dette mønster ses over hele året, hvilket indikerer at marsvin søger føde året rundt i Lillebælt. Tiltag som ”Lillebælt Livestreaming” gør det muligt at følge med i naturen på forskellige platforme uden begrænsning af tid og sted. Ud over den online platform, har lytteposten også skabt basis for bl.a. dykkerture og guidede ture med tilknyttet naturformidling. Vi arbejder på at videreudvikle systemet ved at installere et temperaturfølsomt kamera, der kan registrere den temperaturforskel der opstår på overfladen når marsvinet bryder den, og derved gør det muligt også at observere marsvin om natten.

Opdag Havet

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Hør, hvordan WWF arbejder på at styrke interessen for havet med projektet Opdag Havet 2.0. Fokus vil være på arbejdet med at udvikle rammerne for havbiologiundervisning i gymnasiet, herunder vores tanker om ocean literacy. Projektet formidler havbiologisk grundviden og aktuelle miljøfaglige temaer gennem alt fra lærebogstekster, explainervideoer og podcasts til Virtual Reality og kurser. Hør om vores erfaringer, og hvordan vi arbejder med kapacitetsopbygning på skoler. Materialerne fra projektet er udviklet til gymnasier, men vil også kunne bruges bredere.

SESSION 14: PLANKTON

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Kvælstof-fiksering i dansk havvand: hvem og hvordan?

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Nitrogen (N) fixation is fueling planktonic production in a multitude of aquatic environments. In estuaries, however, the contribution of N by pelagic N₂-fixation is believed to be insignificant due to the high input of N from land and the presumed absence of active N₂-fixing organisms. In this overview, I will talk about our work in Danish estuaries with emphasis on N₂ fixation by heterotrophic diazotrophs, including cultivation-based and field work. I will give examples of significant N₂ fixation by heterotrophic bacteria in coastal waters, discuss on their autecology, and highlight current gaps in our knowledge about these bacteria.

Prymnesins are clade specific compounds and chemotaxonomic markers in *Prymnesium parvum*

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The haptophyte microalga *Prymnesium parvum* is capable of forming blooms that lead to devastating fish kills worldwide. The suspected causative agents are large ladder frame polyethers called prymnesins. Currently, they are divided into three groups based on the number of carbon-atoms in the aglycon backbone (A: 91, B: 85 and C-types: 83).

We obtained 26 *P. parvum* strains with a wide geographical distribution and screened them for their potential to produce prymnesins. All tested *P. parvum* strains produced prymnesins and limited clustering of the different prymnesin types was observed. Although different analogs were identified within one strain, all of them belonged to the same prymnesin type. In total 51 different prymnesin-like molecular features could be tentatively identified by high resolution mass spectrometry (A: 9, B: 12, C: 30). This is a more than three-fold increase compared to the 16 different prymnesins known before-hand and showed that the diversity of prymnesins is larger than previously thought.

The internal transcribed spacer (ITS) regions of the nuclear ribosomal cistron are known for their high sequence variability, why they are regularly used as markers for phylogenetic analysis of closely related taxa. Based on both ITS-1 and ITS-2 sequences a phylogenetic analysis was performed. Three major clades were obtained which matched the distribution of prymnesin types and showed no evidence of biogeographic clustering. Furthermore, the three groups had very different within mean group distances with B-type showing the lowest (0%) and C-type prymnesins the highest (1.7%) variability.

Altogether, this study for the first time demonstrates a clear link between chemotyping and genotyping in microalgae that are in practice impossible to differentiate based on morphological taxonomy. The presented findings could potentially set the scene for a paradigm shift towards a more polyphasic taxonomic approach for identification of important toxic microalgae.

Harmful marine microalgae: the role and importance of allelochemicals in food web interactions – Status and recent progress

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Some marine planktonic microalgae produce organic substances, allelochemicals, which negatively affect the growth of algal competitors as well as zooplankton grazers and may lead to mortalities of fish and benthic invertebrates in natural environments as well as in aquaculture during blooms. This presentation will give a short overview of the current-state-of-the-art of the topic and present some recent progress. Allelochemicals leak to the surrounding water and affect the cell membranes of target cells leading to cell/animal immobilization and cell lysis/animal death. Typically, a threshold cell concentration is required for the chemicals to be present in high enough quantities to cause damage to the target cells or animals. The allelochemicals never affect the species producing the compounds and often not all tested target species are affected. In most cases, the causative compounds, are unknown or very poorly chemically characterized. Many suggestions of causative compounds have been disproved - the quantities required to elicit a toxic effect are not ecological relevant or are not produced by the algae at all. Recently, we have discovered and characterized new allelopathic compounds from common marine harmful microalgae. This includes a large number of new prymnesins from *Prymnesium parvum*, and karmitoxin from *Karlodinium armiger*. Methods for their detection and quantification are currently under development, which will allow for future studies of effects of the algae and their toxins on competitors and grazers. See the presentations by Elisabeth Varga et al. and poster by Sofie B Binzer et al. for specific recent outcomes of our work.

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Tolerances- and in-situ distribution of protistan- and metazoan grazers in a hyper-eutrophic high pH estuary

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Plankton succession was studied 9 days in August in a hyper-eutrophic estuary, Mariager Fjord, Denmark. There was a pycnocline with pH 8 at 15 m depth and anoxic water below. In the upper water column pH increased from initial 8.5 to 9.2 after 5 d of sunny weather due to high primary production. We hypothesize that this elevated pH structure the zooplankton community. The protistan grazers were dominated by heterotrophic dinoflagellates and mixotrophic and heterotrophic ciliates. Metazooplankton was dominated by meroplankton, rotifers, and the copepod, *Acartia tonsa*, all with a relatively low biomass. Cirriped nauplii occupied the upper strata while polychaete larvae could also be found below the pycnocline. Bivalve larvae occurred occasionally above the pycnocline even at very high pH. We conducted micro- and mesocosm challenge experiments with pH of 8-10. Some mixotrophic and heterotrophic protists were quite pH sensitive while others not. The mixotrophic ciliate *Mesodinium rubrum* was the least pH tolerant species, followed by *Strombidium* spp., which did not cope well with seawater pH >8.5. Some heterotrophic dinoflagellates were more tolerant with net growth at pH >9. The predominant rotifer *Synchaeta* sp. tolerated up to pH 9.5 and the copepod survived pH 10 but stopped producing eggs at pH 9.5 with unaffected egg hatching success. The polychaete and cirriped larvae tolerated pH 9.5, but bivalve larvae showed decreased survival already at pH 8.5. We conclude that pH act as a structuring factor and even modify plankton brought in by advection from open waters outside the estuary.

Copepods as live feed, what is all the fuss about?

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For the last 40 years copepods has been announced to be the next game changer within live feed for marine fish larvae. At present, rotifers and Artemia are still the predominant and preferred live feed in marine hatcheries, so what is all the fuss with copepods about?

Copepods are the most numerous and abundant animal on our blue planet. Such a large biomass is not unnoticed by predators, and therefore numerous marine fish and almost all marine fish larvae have included copepods in their natural diets. Within aquaculture, copepods were established early on to be a biochemical superior live feed with high content of essential amino- and fatty acids. The majority of copepods are biochemically reflecting what they eat as long as the fed algae contain the desired nutritional components. However, this dependency on live algae cultures has been one of the major constraints of copepod cultivation. Since this implies that a marine hatchery has to culture both algae and copepods, which is a very complex process and requires high investment costs in equipment and human resources. Both rotifers and Artemia are easier to cultivate since they can be fed inert food or algae paste. The problem with feeding copepod with inert food is that it does not trigger a feeding response in the copepods, hence they starve. The researchers have tried to solve this bottleneck with various success. Here we will share our present knowledge about boreal and tropical copepods as live feed in marine aquaculture, and point in future directions for a successful implementation of copepods as the dominant live feed in aquaculture.

BIOSYNTHESIS OF ESSENTIAL FATTY ACIDS BY COPEPODS & ITS POTENTIAL FOR LIVE FEED IN AQUACULTURE OF FISH

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Almost all polyunsaturated fatty acids (PUFA) are produced and transferred to higher trophic levels by primary producers. However, some marine invertebrates are able to biosynthesize certain essential PUFAs, making them a potentially valuable candidate as live feed in aquaculture of fish.

We investigate if and how the tropical copepods *A. royi* and *P. annandalei* "upgrade" fatty acids (FA) from algal and non-algal diets of different nutritional quality by bio-conversion of FA to the essential PUFAs, EPA and DHA. We produced liposomes to mimic the copepods' natural food particles and use these as "carrier vessels" for our tracer material in stable isotope tracer studies. Further, we investigate how differences in nutritional quality of algal and non-algal diets influence stock density and success to cultivate these copepods.

We show that i) some copepods have the ability to biosynthesize essential PUFAs, ii) that differences in stock densities arise from differences in diet quality and the potential of the copepod species to "upgrade" FA, and that iii) these copepods can be sustained by low quality non-algal diets without compromising its nutritional quality, thus enabling low-cost/high-quality mass cultivation of live feed for aquaculture.

Rurer larver, en overset brik i grønlandske fjordsystemer

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De arktiske økosystemer – de grønlandske i særdeleshed – er meget diverse og udviser store geografiske forskelle i både tid og rum.

Der er i grønlandske fjorde rapporteret om massive forekomster af larver fra rurer om foråret. Når rurer gyder frigives store mængde af larver, der fører til høje biomasser af larver i vandsøjlen i en kort periode. I denne periode udgør larverne en væsentlig del af zooplankton samfundet. Det antages, at larvernes timing og varighed i den pelagiske zone er forbundet med temperatur og at den falder sammen med forårsopblomstringen. Men timingen og strategierne for gydningen af larver er kompleks. Rurer larver er en vigtig trofisk komponent i det pelagiske, både som græsserer, men også som byttedyr til andre organismer. Det til trods er der især på larvestadiet begrænset viden om helt basale biologiske parametre og der er brug for fundamental viden på en række punkter. Det inkluderer blandt andet viden om deres biomasse i løbet af sæsonen, deres græsningsaktivitet og hvilke faktorer der kontrollerer og regulerer produktion af nye larver. Undersøgelser af meroplanktons sæsonmæssige dynamikker vil hjælpe os i at forstå vigtigheden af disse temporære gæster i det pelagiske økosystem. En bedre forståelse vil i sidste ende give en bedre base for rådgivningen og management af kystressourcer og kystzoner i arktiske områder.

Præsentationen under Dansk havforskermøde 2019, vil bidrage med en bedre forståelse af en af havets dominerende, men oversete organismer og vil beskrive nogle af de fremtidige ændringer de grønlandske fjorde står overfor i takt med at klimaet ændres og være med til at øge vores forståelse af artssammensætningen af dyreplankton i grønlandske fjorde.

SESSION 15: BUNDDFAUNA

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Succession of benthic fauna in a newly created coastal lagoon

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Gyldensteen coastal lagoon northern Fyn, Denmark was created in March 2014 by flooding 214 ha of agricultural land in a coastal realignment project. This study is part of an ongoing investigation in the lagoon with two goals: (1) to evaluate the succession of benthic fauna and the structural community shifts in response to environmental conditions, and (2) to compare the benthic fauna with natural communities and potential recruiting species outside the lagoon. There was a fast recruitment of the bivalves *Cerastoderma glaucum* and *Mya arenaria* (1500-3800 ind m⁻²) in spring after the opening of the dikes. However, in the summer of the same year, there was a massive death of these bivalves caused by macroalgae blooms due to eutrophication. In the next two years, the species richness of the benthic community increased (12 species) and shifted to dominance of burrowing pioneer species with high abundance of the polychaetes *Nereis (Hediste) diversicolor* and *Polydora cornuta*. This change in benthic fauna community structure was associated with improved ecological conditions and lower macroalgal cover. While in 2017, the abundance of dominant species and species richness declined markedly (1000 ind m⁻² and 3-5 species), which was probably a response to widespread cyanobacterial mats that covered most of the sediment surface during summer. The benthic fauna diversity and species richness inside the lagoon has throughout all years been impoverished compared with communities outside the lagoon. We conclude that unpredictable fluctuations in environmental conditions strongly affect the development of benthic fauna communities in the new coastal lagoon and can potentially hamper future recruitment of new species.

Artsspecifikke og tilfældige effekter på biodiversiteten i forstyrrede bundfaunasamfund

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Forstyrrelse af et bundfaunasamfund kan medføre både ændret artssammensætning og reduceret artsdiversitet. Det antages ofte, at ændringer i artsammensætningen kan henføres til de forskellige arters specifikke tilpasninger eller "biologiske træk" således at de arter, der har flest følsomme træk overfor forstyrrelsens karakter, bliver sjældne eller forsvinder. Fraværet af følsomme arter i forstyrrede miljøer kan nogle gange i sig selv forklare nedgangen i artsdiversitet. I modsætning til mål for faunaens følsomhed, så gør diversitetsmål ingen antagelser om artsspecifikke tilpasninger og diversitetsmål kan i højere grad anvendes på tværs af forskellige miljøer. Når bundfaunaen anvendes til at vurdere den miljømæssige eller økologiske tilstand af et område, så kan man anvende både følsomhedsmål og diversitetsmål, og de anvendes oftest i kombination i multi-metriske kvalitetsindeks. Analyser af en række forskellige datasæt fra danske og udenlandske havområder, som dækker gradienter af forskellige presfaktorer, viser imidlertid at det helt overvejende er bundfaunaens diversitet, der i første omgang responderer på en forstyrrelse. De effekter, som en række studier har dokumenteret på bundfaunaens følsomhed, forekommer ofte over en længere tidshorisont og kan karakteriseres som langtidseffekter. Det tilsyneladende fravær af artsspecifikke korttidseffekter kan blandt forklares med, at mange former for forstyrrelse af bundfaunaen samtidigt påvirker sedimentbundens habitatkvalitet, og at det er denne mere indirekte påvirkning, der medfører tilfældige effekter på bundfaunaens artsrigdom og diversitet.

Describing the *Halichondria panicea* (phylum Porifera) holobiont and its responses to oxygen stress: a comprehensive 'omics' approach

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The world's oceans face many anthropogenic stressors, which can affect dissolved oxygen concentrations. Globally, climate change is causing oxygen minimum zones (OMZs) to expand, and locally, increased nutrient runoff can deplete oxygen concentrations following eutrophication. The effects of decreased oxygen concentrations on animals are generally assumed to be detrimental given the importance of oxygen in aerobic respiration. However, some sponges (Porifera) exhibit hypoxic and anoxic tolerance, but the mechanisms underlying this tolerance are not known. Sponges are known to host dense, highly specific microbiomes, including microbes with anaerobic capabilities, which can have interlinked metabolisms with their hosts. Since sponges lack key components of the hypoxia-inducible factor (HIF) pathway responsible for hypoxic response in other animals, it is hypothesized that the sponge tolerance to hypoxia and anoxia is facilitated by the anaerobic activity of its microbiome. To investigate this hypothesis, this project will focus on the common and ecologically important sponge *Halichondria panicea* and its microbiome, collectively referred to as the *H. panicea* holobiont (HPH). This project will sequence and annotate the hologenome, i.e. the genome of the host and symbionts, of the HPH, and search for possible anaerobic and hypoxic tolerance pathways therein. Using the hologenome as a reference, holotranscriptomes and holoproteomes, i.e. the transcriptomes and proteomes of the holobiont, of HPH exposed to various oxygen concentrations will be compared to directly determine the molecular and genetic pathways involved in hypoxic tolerance. Understanding the response of the sponge holobiont to hypoxic and anoxic conditions will provide insights into the future ecosystems.

FN2020-MÅL, KLIMATILPASNINGER I HAVET OG DANSK CENTER FOR HAVFORSKNING

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Ocean primary production is a function of nutricline depth

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The IPCC projects (with medium confidence) that global ocean primary production (PP) will decrease in response to climate change, primarily in response to increased intensity of thermal stratification. There is, however, little empirical evidence relating intensity of thermal stratification and PP. Indeed, Saba et al. (2010) report increasing rates of PP at the permanently stratified HOT (sub-tropical Pacific) and BATS (sub-tropical Atlantic) over recent decades, where warming of the surface layer has been on-going. Using our own and archived (HOTS, BATS, CARIACO) data, we demonstrate that total water column PP decreases with nutricline depth. Thus, nutricline depth in a future ocean may be more important for determining PP than the intensity of thermal stratification. By considering insolation and nutricline depth, it is possible to identify the regions of the global ocean potentially having the highest PP. The study also shows that the vertical distribution of PP changes with nutricline depth and that PP in oligotrophic regions is higher than normally assumed. The recognition of the relationship with PP and nutricline depth combined with knowledge regarding insolation potentially opens for new approaches to estimating ocean PP.

Klimatilpasning og sikring langs kysterne

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Foranlediget af bl.a. Klimatilpasningsplanerne, Udpegninger som følge af Oversvømmelsesdirektivet samt seneste års oplevede stormflodshændelser arbejdes der i disse år målrettet frem imod, at sikre samfundets værdier mod oversvømmelser som følge af stormflodshændelser. Hændelser, som over tid forekommer hyppigere som resultat af de igangværende klimaforandringer, hvorved konsekvenserne stiger. COWI har for REALDANIA lavet en opgørelse over risikobilledet for de 48 største kystnære byområder i Danmark. Over en 100 årig periode er de samlede forventede skadesomkostninger ved stormflod opgjort til 100 mia. dkk i nettonutidsværdi, 1 mia. pr. år i 2017 stigende til 43 mia. pr. år i 2117. Dette er med andre ord et solidt argument for nødvendigheden i at etablere sikring af eksisterende værdier eller ændre tilgangen til hvordan vi fortsat planlægger og udvikler vores kystbyer. Argumentet har medført flere tiltag til sikring mod stormflod i Danmark og vi har endnu kun set toppen af isbjerget. Men hvad med naturen og det åbne land? Tab af natur medregnes ikke i de samfundsøkonomiske beregninger og f.eks. indgår oversvømmelser af dyrkede arealer kun sporadisk ift. tab af værdi. I et nyligt studie udført af COWI er der evalueret på den forventede stigning i middelvandspejl ved Limfjorden. Naturen omkring Limfjorden indeholder mange uerstattelige værdier herunder flere §3 områder. Studiet viste at op imod 2% og 10% af hhv. dyrkede og natur arealer, vil blive permanent oversvømmet over de næste 100 år. Flere vil hyppigt være oversvømmede, hvorved f.eks. dyrkning vanskeliggøres. Disse tab vil medføre konsekvenser i forskellige aspekter. Tab af diversitet og forringet tilbageholdelse af næringsstoffer. Ifølge nyt studie vil tabet af landbrugsarealer muligt bidrage til en stigning i TN og TP belastningen af specifikke områder i Limfjorden. Desuden vil f.eks. 80% af de nuværende strandenge være forsvundet i 2100. Alt i alt et område som (måske) fortjener en større opmærksomhed.

UN Decade of Ocean Science for Sustainable Development

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De Forenede Nationer har proklameret 2021-2030 et international tiår for havforskning for bæredygtig udvikling for at vende tilbagegangen i havets sundhedstilstand og for at samle interessenter i havet verden over bag en fælles ramme der sikrer, at havforskning i højere grad støtter beslutningstagere i at skabe bedre betingelser for bæredygtig udnyttelse af havet. UN Decade of Ocean Science for Sustainable Development er et direkte svar på FN's Bæredygtigheds mål 14. 'Livet under vand'.

Den første 'UN Global Ocean Assessment', der blev udgivet i 2016, konkluderede, at sundhedstilstanden i store dele af havet er alvorligt forringet, med ændringer og tab i struktur, funktion og udbytte fra marine økosystemer. Desuden forventes virkningen af flere og kombinerede stressfaktorer på havet at øges efterhånden som klodens befolkning vokser mod de forventede 9 milliarder i 2050.

Tilpasningsstrategier og videns informerede politiske handlinger som svar på disse ændringer er påkrævet.

Videnskabelig forståelse af havets respons på stressfaktorer og på vores forvaltningspraksis er afgørende for en bæredygtig udvikling. Havobservationer og havforskning er også vigtigt for at forudsige konsekvenserne af global forandring, udvikle afværgemuligheder og for at kunne vejlede beslutningstagere om tilpasning.

FN's Generalforsamling har givet mandat til 'Intergovernmental Oceanographic Commission (IOC) of UNESCO' til koordinere Tiårets forberedende proces og opfordrer det globale havforskningsmiljø til at planlægge de næste ti års havforskning og teknologiudvikling til sammen at levere det fremtidige havmiljø vi har brug for i den fremtid vi ønsker os; 'The ocean we need for the future we want'.

'UN Decade of Ocean Science for Sustainable Development' vil blive præsenteret inklusive de muligheder FN's tiår forventes at give på nationalt plan for at løfte havforskning og havforvaltning fagligt og for at løfte havet i offentlighedens og beslutningstageres bevidsthed.

SESSION 16: REETABLERING AF ÅLEGRÆS – NOVAGRASS

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NOVAGRASS: Using mechanical models to identify potential areas for reestablishment of eelgrass vegetation.

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Eutrophication is regarded a key factor the dramatic reduction of eelgrass during the 1970-80ties in Danish waters. During the past 3 decades the load of N from the open land cities and industry have been reduced about 40-50%. Despite this the eelgrass vegetation in Danish coastal water haven't recovered. During the 4-year project Reelgrass stressors for eelgrass regrowth was identified and incorporated in a combined hydrodynamic-ecological model describing the growth. The model has been used and further developed in the recently finished 5-year project NOVAGRASS simulating potential sites for replanting of eelgrass. The model including stressors for eelgrass growth and results for two fjords have been presented at the 19. Havforskermøde and in (Kuusemäe et al. 2016). Due lack of measurements a comparison between "measured" and modeled biomasses have not been presented so far. Using an empirical relation converting measured eelgrass vegetation cover to dry weight pr. m² (Christensen et al 2015) makes such a comparison possible. A model using one year 2005 seems to be able to mimic the "measured" biomasses on a transect in the Sydfynske Øhav from the year 2001-05. Simulating one "average" year is however not sufficient as one year with wide spread anoxia and high temperatures can diminish the eelgrass vegetation as happened in the Sydfynske Øhav in 1994 and probably also in 2018. The fast recovery of eelgrass in Nibe-Gjøl broad on the other hand shows that recovery process can be surprisingly fast.

To be able to analyses these events and establish the potential for eelgrass to recover a multiyear (10-20 years) simulation including years with calm weather and increased water temperatures is needed.

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Retablering af ålegræs – hvad bestemmer overgang fra frø til spire?

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Ålegræsfrø er af altafgørende betydning for den naturlige genetablering efter forstyrrelser og udsåning af frø kan med fordel anvendes i områder, hvor den naturlige frøpulje er begrænset. Ålegræs producerer mange frø, der med forholdsvis lille indsats kan høstes og spredes over store arealer. Udfordringen er at andelen af frø, som udvikles til veletablerede frøplanter er varierende og ofte meget ringe. Et mål med NOVAGRASS projektet var derfor at undersøge hvilke miljøforhold, der regulerer overlevelse og spiring af frø for derigennem at kunne optimere opbevaring og udsåning af frø.

I en række laboratorie – og feltforsøg undersøgte vi hvorledes forhold som temperatur, frøenes dybde i sedimentet samt sedimentforhold (organisk stof, sulfid) indvirker på ålegræsfrøenes spiringsevne og kimplanternes efterfølgende etablering. Resultaterne viste at frø fra danske bestande har størst spiring efter en kuldeperiode, og at optimum temperatur for spiring er mellem 6 og 9 oC. Spiringen af ålegræsfrø induceres af anoxiske forhold og var derfor væsentlig lavere i sedimentoverfladen end for frø begravet i sedimentet. Enkelte frø dannede spirer, der nåede sedimentoverfladen fra 8 cm dybde, men størst spiringssucces fandt sted i de øverste sedimentlag (1-2 cm). Frø udsået i naturligt organisk rige sedimenter (4% DW) viste høj spiringsevne, men overlevelsen af kimplanterne var meget lavere end i sandet sediment. Frø udplantet i organisk berigede sedimenter overlevede flere måneders eksponering til høje sulfid koncentrationer >2mM, men spiringen var hæmmet indtil frøene blev overflyttet til ikke-beriget sediment. Resultaterne diskuteres i relation til bevarelse og retablering af ålegræs i danske kystområder.

Udvikling af teknikker til reetablering af ålegræs med frø

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Potentialet ved at anvende ålegræsfrø frem for transplantation af hele ålegræsplanter er meget betydeligt. Dette er vist med overbevisende resultater af især Virginia Institute of Marine Science på den Amerikanske østkyst. Instituttet har over de sidste 10-15 år stået for 80 % af den globale ålegræsrestaurering ved at anvende frø.

I NOVAGRASS projektet har et af formålene været at videreudvikle teknikker med henblik på at optimere høst af frø, separering, opbevaring og såning. Drivkraft bag den tekniske udvikling i projektet har været en række erhvervspartnerne, som har været i stand til at udvikle nye teknikker, som mekaniserer processerne og resultatet har været, at det i dag vil være muligt at høste meget store mængder af frø, separere frøene og så frøene med maskine med betydeligt mindsket arbejdskraft.

Til trods for succes med høst- og så-teknikker, så er de sidste barrierer for en succesfuld ålegræsre-etab-lering med frø ikke overvundet. Det har vist sig, at de stressfaktorer som påvirker en succesfuld spiring og opvækst til stor ålegræsplante, endnu ikke er kortlagt og forstået i danske farvande. Mens forsøg på land har vist fine resultater for spiring, har resultaterne hidtil været nedslående i felten. Færre spiringer end forventet og spirer i tilsåede områder ikke været i stand til at overleve en sommers stressfaktorer. Indtil videre må vi konstatere, at hvad angår brug af frø - så ”lykkedes operationen” (ny effektiv teknik), ”men patienten døde” (ingen overlevende spirer). Potentialet for succes er dog stadig tilstede, det har naturen vist ved forskellige lejligheder, bl.a. i Gjøl/Nibe Bredning i Limfjorden i perioden 2010-2014, hvor en kraftig fremgang af ålegræs har fundet sted baseret på frøspredning. Der er imidlertid ingen tvivl om, at det kræver en bedre forståelse for de stressfaktorer, som påvirker ålegræsspirer, og der samtidig skal udvikles strategier som imødegår disse faktorer.

Transplantation af ålegræs i Danmark - Udvikling og test af teknikker

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Havgræshabitater er i stigende grad på tilbagegang over hele verden, et problem som primært er drevet af eutrofiering. Denne udvikling understreger behovet for beskyttelse af det tilbageværende ålegræs i Danmark kombineret med genetablering af tabte habitater. En succesfuld indsats vil fastholde og styrke ålegræssets unikke økologiske rolle (f. eks. optag og tilbageholdelse af næringsstoffer og kulstof, samt sikre en høj biodiversitet). Det fortsatte tab af ålegræsbede i Danmark var udgangspunkt for NOVAGRASS-projektet med fokus på udvikling af teknikker til genetablering af tabte ålegræsbede under danske forhold. Her præsenteres resultaterne fra test af nyudviklede teknikker til transplantation af ålegræs. En række teknikker blev testet i flere fjordsystemer, på forskellige vanddybder og ved forskellige næringsstofbelastninger.

Udviklingsarbejdet havde udgangspunkt i teknikker til mindske af stress fra f. eks. drivende makroalger, sandormens bioturbation og skadevirkninger fra krabber. Desuden viste forankring af ålegræsskud sig at være essentiel i den følsomme fase lige efter udplantning. Fysisk beskyttelse førte til > 700% flere skud, hvorimod ubeskyttede transplantationer blev tabt. Skadevirkning på transplantationer fra sandormens bioturbation kunne effektivt begrænses med eksklusionsmembraner. Transplantation på dybere vand (2,4 m) var ikke mere succesfulde end på lavere vand (1,2 m) i Odense Fjord, da det reducerede fysisk stress fra bølgeslag blev modvirket af vigende lysintensitet. Samtidigt var der på dybt vand større deponering af makroalger sammen med et fortsat højt pres fra destruktive krabber. Udviklingsarbejdet med ålegræstransplantation har ført til identifikation af de mest relevante stressfaktorer samt de mest relevante forankringsteknikker og beskyttelsesmetoder. Resultaterne fra dette arbejde med ålegræstransplantationer understøtter udviklingen af retningslinjer for fremtidig genetablering af ålegræs i Danmark.

Retningslinjer til udvælgelse af lokaliteter for retablering af ålegræs ved transplantationsmetoder

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SDU har gennem en årrække undersøgt diverse presfaktorer som hindrer ålegræssets naturlige retablering og efterfølgende udviklet retableringsmetoder. Vi har testet en suite metoder til frøspredning og transplantation af ålegræsskud. Ved samtlige frøsprednings-forsøg med ca. 20.000 frø blev frøene hurtigt vasket væk fra lokaliteterne på trods af disse blev injiceret ned i sedimenterne eller inkorporeret i membraner under sedimentoverfladen. Vi konkluderer derfor at frøspredning ikke er en brugbar løsning med de meteorologiske forhold som præger Danmark.

Vi fokuserede i stedet på at udvikle transplantationsmetoder og baseret på disse aktiviteter, har vi udformet de første guidelines for udvælgelse af egnede retableringslokaliteter. Screeningsmetoden indeholder følgende aktiviteter:

- 1) Mulige lokaliteter undersøges for hydrodynamisk stress ved modelsimuleringer.
- 2) Tidligere ålegræsforekomster og generelle miljøforhold beskrives ud fra historiske flyfoto.
- 3) Lokale belastningsforhold undersøges for at beskrive risikoen for stor epifytvækst.
- 4) Lokaliteterne besigtiges i vækstsæsonen for at få indtryk af flora, fauna og sedimentforhold.
- 5) Test-udplantninger af ålegræsskud udføres på potentielle transplantationslokaliteter og monitoreres kontinuerte med loggere og kameraer.
- 6) Vækst- og tabsprocesserne følges og følgende presfaktorer identificeres: opportunistiske makroalger, epifytter og iltforhold (eutrofieringsbetinget); lys, temperatur og bølgepres (fysik); samt ballistisk pres fra flerårige makroalger og tab forårsaget af krabber og sandorm (biologisk).
- 7) Lokaliteter med størst skudtilvækst udvælges til storskala-transplantation.
- 8) I forbindelse med storskala-transplantation reduceres de mest betydende presfaktorer ved beskyttelse af de transplanterede ålegræsskud.

Economic costs and benefits of protection and restoration of eelgrass beds

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Eelgrass beds constitute important marine ecosystems, being important for nutrient and carbon regulation, fish spawning areas as well as for coastal protection. Protection of these ecosystems are, therefore, favorable. From an economic perspective they will be gainful if the benefits of protection and restoration outweigh the costs of protecting eelgrass beds and/or restoring them by transplantation of eelgrass or sawing.

The economic value of eelgrass beds is reflected through the flow of the ecosystem services that they derive, mainly by the regulating services provided in the coastal zone. These regulating services include carbon sequestration and storage, the regulation of water quality by nutrient retention as well as the services these habitats derive as important spawning areas for fish. The regulation of nutrients and carbons do not have a market price, and the value therefore has to be derived using valuation methods. Eelgrass ecosystems also contribute to biodiversity and services, that we might not be aware of today. It is likely that a number of services related to eelgrass beds are difficult or impossible to value in monetary units. Valuation is therefore complicated, but it is possible to value some important services: regulation of nitrogen and carbon regulation, that lead to improved water quality and climate change mitigation.

Based on the NOVAGRASS project and the project Marine Forests in Denmark (Havets skove) this presentation deals with the values of nitrogen and carbon regulation by eelgrass beds, and contrasts these to the costs of protection and restoration of eelgrass beds. Spatial differences in benefits and costs are discussed. The findings indicate that restoration by transplantation is costly, and that restoration by seeds is very difficult. Costs might be reduced by reducing manpower needs as much as possible, as that constitute the main cost component, and by choosing favorable sites for restoration. Furthermore, the benefits derived by eelgrass beds vary across sites, and therefore the optimal choice of sites for restoration should take both feasibility, efficiency of the restoration and the value of the provision of the ecosystem services into account.

Recent trend reversal for declining European seagrass meadows

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Seagrass meadows, key habitats supporting fisheries, carbon sequestration and coastal protection among other services, rank among the most threatened ecosystems globally, and conservation efforts have been done in the last decades to halt their losses. Europe is a distinctive case for having well documented seagrass assessments over the last century and for having implemented legislation at the continental level aiming at conserving seagrass and improving water quality, especially during the 1990s and 2000s. Here we collated existing assessments of changes, and their drivers, in the extent and density of European seagrass meadows to report a 147-year (1869-2016) observational record of seagrass trajectories to test the expectation that loss rates must have slowed down or re-verted following the implementation of management actions and European Union (EU) legislation, as well as other national or local regulations. We showed that about 1/3 of European seagrass area was lost through a cascade of pressures shifting from disease to deteriorated water quality and coastal development, with losses peaking in the 1980s. Since then, loss rates declined to experience a trend-reversal between 2000 and 2010 reflected in a 26 % increase in seagrass area, mostly due to recovery of fast-growing species, with no significant decline in seagrass density or depth limits. The results presented here demonstrate that policy actions, such as those delivered through the Habitats and Water Framework Directives of the EU, among other initiatives, are effective tools to decelerate and revert the seagrass declining trends, bringing back their benefits in terms of ecosystems services. \r\n

SESSION 17: SAMSPIL MELLEM FORSKNING OG FORVALTNING

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Udfordringer i forvaltning og rådgivning af udledninger til havet

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Danmarks kystnære havområder modtager miljøfarlige stoffer og næringsstoffer fra udledninger af forskellig art, som inkluderer industrispildevand, udledninger fra renseanlæg, spulefelter mm. Det praktiske arbejde med at rådgive og vurdere potentielle påvirkninger på havmiljøet fra sådanne udledninger i forhold til forpligtelser og krav i Vandrammedirektivet, Danmarks Havstrategi og Habitat- og Fuglebeskyttelses-direktiverne beskrives ud fra erfaringer fra 3 førende rådgivningsfirmaer i Danmark indenfor miljøvurderingsområdet. Fokus for dette oplæg vil være på udfordringer i forhold til vurderinger og myndighedsbehandling af udledninger til havet, her eksemplificeret ved sager omkring udsivning og udledning til marine recipienter fra spulefelter i Esbjerg og Odense.

Følgende emner vil blive behandlet:

1. Hvordan vurderes i forhold til overholdelse af meget lave miljøkvalitetskrav, hvor detektionsgrænsen for de kemiske analyser ligger flere størrelsesordener over kravet? Dette vil blive belyst med PFOS eller benzo(a)pyren som eksempler.
2. Hvordan vurderes påvirkningen af udsivningen til vandområder, hvor flere forhold er ukendte, som eksempelvis tilstandsvurderinger for området, 'den i forvejen forekommende koncentration' af relevante stoffer og den naturlige baggrundskoncentration (for metaller). Dette vil blive belyst med eksempler fra Odense Fjord.
3. Hvordan bruges miljøkvalitetskrav for enkeltstoffer i vurderinger af udledninger med multiple stoffer. Hvordan kan vi håndtere "cocktaileffekter/kumulativ påvirkning" i samme udledning?

Udover disse 3 emner, vil oplægsholderne forsøge at beskrive eksisterende videnshuller samt anvisne mulige tiltag for at optimere grundlaget for vurderinger af udledninger.

Assessing the ecological state of the ocean by integration of models and observations using data assimilation in MIKE 21/3 FM biogeochemical models

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MIKE 21/3 FM is a family of unstructured grid models well suited for high-resolution coastal downscaling applications. In addition to the physical modelling in MIKE 21/3 FM, the modelling family also allows for MIKE ECO Lab, a generic equation solver, where process oriented models, such as ecological or biogeochemical models, can be developed without explicit programming.

Data assimilation based on the Ensemble Kalman Filter have been used in MIKE 21/3 FM during many years for assimilation of tide gauge data, mainly for operational forecasting applications.

As part of the SeaStatus project (<http://seastatus.dhigroup.com/>) data assimilation is currently being implemented in the coupled physical-biogeochemical models (MIKE ECO lab), with the main purpose of providing high-quality dataset on the ecological state of the ocean.

One important objective of the SeaStatus project is to be able to assimilate a wide range of observations, such as data from continuous sensors, discrete water samples, autonomous gliders, ferry-box transects and satellites, irrespective of variable type (e.g. chlorophyll-a, nitrate, dissolved oxygen, etc.).

The assimilation framework has recently been extended to include two non-hydrodynamic modules, 1. the Transport module, describing advection/dispersion and exponential decay of a tracer without interactions with other tracers, and 2. The MIKE ECO Lab module describing advection/dispersion along with an arbitrary number of tracers and processes.

The ensemble spread is created by perturbing model parameters such as decay rate, maximum growth rate, sedimentation rate, riverine source concentrations or open boundary concentrations.

Eutrofiering i Østersøen: tidligere, nuværende og fremtidige

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Vi modellerede og vurderede eutrofieringstilstanden i Østersøen for en 350-årig periode fra 1850 til 2200. Tilstandsvurderingen er baseret på: (1) modellerede koncentrationer af opløst uorganisk kvælstof (DIN), opløst uorganisk fosfor (DIP), chlorophyll-a, Secchi-dybde samt iltgæld under forskellige næringstilførselsscenarier og (2) anvendelse af et multimetrisk indikatorbaseret værktøj til vurdering af eutrofieringstilstand (HEAT 3.0). Vi finder betydelige ændringer i eutrofieringsstatus fra 1850 til 2200. I 2 tilførselsscenarier, hvor målene for reduktion af næringsstofreduktion for Østersøen er opfyldt, vil der opnås god fremtidig status i de fleste bassiner i Østersøen. Under to scenarier, hvor næringsstofftilførsler forbliver ved niveauet 1997-2003 eller øges, opnås god status ikke. Ændringen fra en god tilstand uden eutrofieringsproblemer begyndte i de åbne farvande i slutningen af 1950'erne og begyndelsen af 1960'erne. Efter den første indsats for reduktioner i næringsstofftilførslen begyndte genopretningen i nogle bassiner i slutningen af 1990'erne, mens det i andre begyndte i nullet. Baseret på modelresultater forventer vi, at det første bassin der opnår en status uden eutrofiering bliver Arkonabassinet i 2033. I 2060-2070 forventes det at Kattegat, Bornholmerbassinet og Den finske Bugt også opnår en status uden eutrofiering, efterfulgt af De danske Stræder omkring 2090. For Østersøen og Det botniske Hav kan der ikke forventes en god status før 2200. Sandsynligvis kommer ikke alle bassiner til at opfylde de aftalte mål om en status uden eutrofiering, dvs. Rigabugten og Den botniske Bugt. Disse resultater, især forudsigelsen af, at nogle bassiner ikke opnår en god status, kan bruges til støtte for løbende udvikling og implementering af den regionale økosystembaserede eutrofieringsstrategi, HELCOMs Østersøhandlingsplanen.

Ecosystem services provided by benthic habitats as viewed by benthic experts

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We present results from a survey to identify the ecosystem services (ES) provided by different coastal and marine benthic habitats. The ES concept provides an important way to value ecosystem components and provide a framework for conservation, policy, and resource management decision making. However, ES studies are not comprehensive and have primarily been focused on valuing economic activities such as recreational and commercial fishing, resource extraction and tourism. It is, however, more difficult to measure non-market values and to identify the ES values of less visible environments such as benthic habitats. One method to identify ES is to survey stakeholder or expert views. The ICES Benthic Ecology Working Group performed such a survey of 27 benthic ecologists from Europe and the United States. The experts were asked to evaluate 9 benthic habitats (rocky intertidal, mud flats, marsh, coral and oyster reefs, bay bottoms, seagrass beds, beaches, continental shelf, and deep sea) adapted from the European EUNIS habitat classification scheme for the provision of 23 ES (defined by the Millennium Ecosystem Assessment). The top three benthic habitats providing the highest percentage of the 23 ES were marshes (54%), seagrasses (51%), and mud flats (47%). The top three highest percentage of ES provided by the nine benthic habitats were Science and Education (80%), Nutrient Cycling (72%), and food (61%). Benthic structure determines which ES is provided by benthic habitats and habitats with foundation species (such as reefs, marshes, and seagrass beds) scored higher than featureless habitats (such as flats, bottoms, and offshore environments). Habitats with similar structural elements such as hard structures or vegetation were deemed similar in the ES provided. This assessment by benthic experts of the ES provided by a full range of benthic habitats provides a basis for management decisions and from which other assessments or valuations can be made.

Ny viden - nye udfordringer: Forvaltning af den grønlandske torsk

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Torsk (*Gadus morhua*) har siden 1950'erne været en vigtig kommerciel art i Grønland, med årlige fangster på over 200.000 t i en årrække i perioden 1955-1970. Bestanden kollapsede i ca. 1970, og har ikke nået de tidligere fangstniveauer siden. Fangsterne er dog steget det seneste årti, og lægger nu på ca. 50.000 t årligt. Indtil 2011 blev torsken i Grønland i rådgivningsmæssig forstand, betragtet som en samlet bestand. Baseret på mærkeforsøg, surveys og senest genetiske undersøgelser er der i dag identificeret fire forskellige bestande af torsk i Grønland. Bestandene har distinkte gydeområder, men blandes i Vestgrønland som juvenile, og dermed i fiskeriet. Fiskene er ikke morfologisk forskellige, men via genetik er det muligt at skelne de enkelte bestande og tilhørsforholdet for hver enkelte torsk med høj sandsynlighed.

Vi viser resultater fra et projekt, hvor vi dokumenterer opblandingen af bestandene og viser hvordan den indsamlede viden om bestandsproportioner kan benyttes som tilgang i den fremtidige forvaltning. Resultaterne viser, at alle bestandene findes i fiskeriet, men med forskellige proportioner afhængig af årstiden og hvor der fiskes. Særligt vigtigt er det, at den vestgrønlandske udenskærsbestand udgør en betydelig andel, og at de samlede fangster på denne bestand derfor må formodes at påvirke genopbygningspotentialet betragteligt. Projektet giver ligeledes en mulighed for at afstemme den anvendte bestandsvurderingsmodel for bestanden mod empiri fra fiskeriet. Implementeres tilgangen fremadrettet vil det give en væsentlig forbedret rådgivning og i særlig grad forvaltning.

The spread of the invasive Pacific oyster in inner Danish coastal waters – distribution and potential impacts

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The Pacific oyster (*Magallana gigas* – ex. *Crassostrea gigas*) is an invasive species that was introduced in European waters for aquaculture due to a series of events (e.g. overfishing and diseases), which reduced the available stocks of the native oyster (*Ostrea edulis*) and the anciently introduced Portuguese oyster (*C. angulata*) for human consumption. Aquaculture activity was also the reason why Pacific oysters were introduced in Danish coastal waters in the 1970's and 1980's, establishing small and distinct wild populations in restricted areas e.g. Limfjorden, Wadden Sea and Isefjord. For several decades, these wild populations seemed stable and not spreading elsewhere. Since the middle of the 2000's, the Pacific oyster has been spreading beyond established populations and to new areas like Øresund, Roskilde Fjord and the east coast of Jutland and is now widely distributed in inner Danish coastal waters.

Invasion by the Pacific oyster can be a potential threat to native species, especially native bivalve species with whom it competes directly with for food and space, but impacts on e.g. birdlife, soft bed habitats and eelgrass have also been reported. Furthermore, Pacific oysters can also have an indirect impact on native bivalve species e.g. diseases from co-travelling pathogens and parasites. To forecast the impacts of the Pacific oyster invasion on ecosystems is a complex task, strongly dependent on the local conditions such as the non-tidal nature of several Danish fjords.

The presentation will show an overview of the current knowledge of the spread of Pacific oysters in Danish coastal waters, the challenges to address the different spreading patterns along the Danish coast and mitigation tools for reducing the spreading impact of its spreading.

Iltsvind

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Iltsvind er den ultimative konsekvens af eutrofiering, men udspiller det meste af sit til tider dramatiske liv skjult under havets overflade. Men ind imellem bliver iltsvindets konsekvenser synlige især i form af opskyllede døde fisk – lige som misfarvning af vandet og lugten af rådden æg også er tegn på, at det står slemt til under overfladen. Da iltsvindets omfang og styrke er afgørende for balancen mellem liv og død i havet, har iltsvindssituationen forholdsvis stor opmærksomhed i forvaltningen af havmiljøet og i de offentlige medier. Derfor er iltforholdene en vigtig indikator for miljøtilstanden, og der behov for værktøjer til at beskrive iltsvindets status og udvikling. Den mest sikre tilgang er at måle iltindholdet i vandet. Men sådanne målinger er omkostningstunge og udføres derfor ikke i et omfang, så de geografisk og tidsmæssigt er dækkende i forhold til at beskrive iltsvindssituationen i de danske farvande.

Det er således oplagt, at modellere iltsvindets udbredelse i tid og rum med udgangspunkt i målingerne af iltindholdet i vandet. I dette oplæg præsenteres en model til beskrivelse af den geografiske udbredelse af iltsvind i bundvandet. Der vises modelresultater fra iltsvindsovervågningen i 2018, som sammenstilles med det modellerede iltsvind i tidligere år – og på den baggrund diskuteres, hvad der regulerer iltsvindets udbredelse og styrke.

Afslutningsvis omtales et projekt, som netop er igangsat (januar 2019). I dette projekt skal iltsvindsmodellen udvikles yderligere bl.a. med baggrund i den ny viden, som projektet forventes at tilvejebringe om iltsvindets dynamik og regulering.

Erfaringer med at koble museumsdata og biodiversitetsundersøgelser

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Danske naturhistoriske museer ligger inde med unikke og undertiden gamle samlinger, nogle genstande er samlet ind tilbage i 1700-tallet. Alt for ofte betragtes disse samlinger som statiske og kun af interesse for systematikere eller måske skal der tages en DNA prøve. Imidlertid er det muligt at få ny viden ud af gamle samlinger, også på områder som det slet ikke var tiltænkt. Det kræver ofte lateral tænkning og viden om samlingerne. I min PhD brugte jeg indsamlinger fra slutningen af 1800-tallet og frem til at vise udbredelser af blandt andet koralline rødalger og visse typer koraller i Grønland.

For at få fuldt udbytte af museumsdata er det imidlertid nødvendigt at have adgang til både samlingerne og den originale litteratur. Hvis det er gamle indsamlinger kan det være vanskeligt tilgængeligt (og litteraturen på små sprog som f.eks. dansk). Mange nyere artikler undlader derfor fuldstændigt at bruge gamle og ofte værdifulde data, enten fordi de ikke er klar over at de eksisterer eller fordi de er svært tilgængelige.

Traditionel indsamling tager ofte et eksemplar af hver art og ofte kun af de sjældne arter. Altså en slags verificering af at arten findes i området. Selv om det er muligt at trække ny viden ud af gamle samlinger ville det imidlertid være oplagt at samle ind på en anderledes måde. Flere nyere artikler beskæftiger sig med brugen af gamle data på nye måder, især fra områder hvor det er vanskeligt at indsamle (f.eks. dybhavet). For at fremme brug af data kræver et moderne syn på hvad og hvordan man skal indsamle til museumsbrug, naturligvis uden at gå på kompromis med traditionel indsamlingsteknik.

SESSION 18: MARIN GEOLOGI OG GEOFYSIK

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Contourites and current pattern SW of the Faroe Islands, NE Atlantic based on interpretation of 2D reflection seismic

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A significant portion of the Norwegian Sea Overflow Water (NSOW) flows south and west of the Faroe Islands through the Faroe-Shetland Channel (FSC) and Faroe Bank Channel (FBC) NE Atlantic Ocean. These bottom currents or contourites erode and deposit sediments forming large-scale features including contourite drifts, sediment waves, channels, moats and furrows. Features related to the contourites are identified through the interpretation of the entire database of 2D seismic profiles from the area. A map showing the distribution of these deposits has been constructed and the current pattern and direction interpreted. Large sheeted drifts were identified in the bottom of most large basins. Most drifts were interpreted as elongate mounded drifts, and one instance of a channel related drift. The dominant net flow direction across the area is from east/southeast. Coriolis deflection and topographic forcing cause eastern flow, particularly on the northern face of the Bill Bailey Bank (BBB) and associated basin. This was identified by the progression of drift systems from a high energy morphology to a lower energy form as the system progressed eastward. NSOW flows over the Wyville Thomson Ridge and portions enter the Rockall Trough circulation system, and others flow west. Overflow of bottom currents were identified over the Ymir Ridge due to erosion and drift deposition. A system of normal faults in the western portion of the study area was seen to partially capture east-moving NSOW flow and redirect them along the northwest trending strike of the fault scarps.

The study shows the complete overall distribution of contourites and the dominant flow pattern in the region. Compared to the few previous studies touching very localized areas, this study confirms and integrates previous results into a large scale model for the area.

A review of Holocene Subpolar Gyre variability based on investigations of marine sediment cores from the Irminger Sea, Labrador Sea and Baffin Bay regions

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The subpolar gyre (SPG) is a major feature controlling climate and ocean circulation of North Atlantic region, with significant variability of cold and warm ocean currents feeding into the gyre. The western sector of the SPG, the Labrador Sea, is a major deep water formation site, thus also directly influencing the Atlantic Meridional Overturning Circulation (AMOC). Here we compare records of SPG circulation from selected sites off south Iceland, west and southeast Greenland and Newfoundland in order to establish a combined record of SPG circulation through the Holocene. Our records combine multi-proxy studies (foraminifera, diatoms, dinoflagellate cysts, sediment properties, biomarkers, elemental composition and environmental magnetism) from a range of marine sediment cores to test for large-scale changes in ocean circulation in the Holocene. The SPG region has experienced several major changes in ocean circulation, with a major reorganisation occurring during the deglaciation and again at approximately 7.5 kyr BP and 3-4 kyr BP. Especially during the late Holocene, climatic conditions were largely antiphase in the Labrador Sea to the general North Atlantic region climate due to influence of the Northern Annular Mode affecting the strength of the Atlantic component of the West Greenland Current as well as the flow of the Labrador Current. This again influenced the strength and expansion of the SPG and exemplifies that the SPG has undergone significant variability at multi-decadal to centennial time scales during the Holocene.

The Ammassalik Basin: A Mesozoic and older? rift basin off SE Greenland

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The amalgamation and breakup of the Pangean supercontinent during the Paleozoic–Mesozoic is recorded in the geologic terranes around Europe, Greenland and North America. Breakup culminated in the opening of the North Atlantic and Arctic oceans, eventually linking the northern sedimentary and ocean basins to the global ocean system. An important question for understanding the paleogeography, paleoenvironment, and the development of the oceanic gateways in the region is the degree of inter-basinal connectivity during the Paleozoic and Mesozoic eras, but this remains a major unresolved question (see Stoker et al., 2017).

This contribution will present seismic reflection data and shallow core results that document a mid- to Late Cretaceous rift basin offshore near Ammassalik. The data show that the basin is at least 4 km thick and interpretation of gravity data suggest that it is regionally extensive, covering an area of nearly 100 000 km². Samples from near the top of the stratigraphic succession have been dated to Albian. In addition to sedimentary strata of Mesozoic age, the seismic reflection data show that the seafloor distinct morphological domains that are interpreted to reflect differences in the geological age and composition of the underlying substrate. One domain shows a very rough seafloor with only local Quaternary fill and chaotic reflectivity and is suggested to be underlain by older metasedimentary rocks subcrop, implying that the Mesozoic stratigraphic succession is underpinned by even older sediments. If correct, then the Ammassalik Basin may be the missing link needed to establish older basinal connectivity suggested by some paleographic maps of the North Atlantic region. Ultimately, however, this can only be tested by systematic sampling of the basin fill.

Major advance phases of the northwest Greenland Ice Sheet over the past 2.7 million years

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The Greenland Ice Sheet is drained by ice streams that over millions of years have deposited thick sedimentary successions on the continental margins. With global temperature projected to rise within the next few decades, an improved understanding of past ice sheet dynamics is essential. However, due to a paucity of long-term archives our current understanding of these changes is currently limited. In this study we apply a dense grid of high-quality 2D seismic data that is partly age constrained to examine the stratigraphy and evolution of a major glacial outlet of the northwestern Greenland Ice Sheet flowing into Baffin Bay. Progradational units separated by onlap surfaces record eleven major phases of shelf-edge ice advance and subsequent transgression since the first ice sheet expansion, likely ~2.7 Ma. We infer that an abrupt change in ice flow conditions occurred during the Mid-Pleistocene transition at around 1 Ma, when uniform ice advance across the shelf margin was replaced by focused ice streams contained within precursors of the present-day glacial troughs. Our results provide constraints for paleo-ice sheet modelling that is aimed at understanding the long-term evolution and past dynamic responses of the Greenland Ice Sheet.

Marine environmental conditions at the North Water Polynya during the Holocene Climate Optimum. A window into the future?

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The North Water Polynya sustains a particularly rich and diverse marine food web and is sensitive to changing conditions in the ocean and atmosphere and therefore especially vulnerable to climate change. This assignment aims to reconstruct the marine conditions during the Holocene Climate Optimum to predict response to future climate changes. Cores AMD16 117Q and AMD16 117Q BC1 were retrieved from Qaanaaq (NW Greenland) in 2016. They were logged and analyzed for grain-size distribution and a chronology was created, using both ^{14}C techniques and ^{210}Pb and ^{137}Cs analyses. The results were compared with XRF data and biogenic silica fluxes were used as proxy for productivity so the sedimentological results could be linked with the oceanic conditions. Finally, the results were compared, which made it possible to predict that the Holocene Climate Optimum is a good indicator of the consequences climate change can have on the North Water Polynya, and thereby the entire ecosystem.

Last glacial maximum to Holocene biogeochemical cycling and sea ice dynamics in the Bering Sea

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The Bering Sea is characterized by a seasonal sea ice cycle. Together with upwelling along the eastern continental margin, sea ice provides important nutrients to maintain high rates of primary productivity. As such, low oxygen concentrations are pervasive in mid-depth waters. Changes in the ventilation and primary productivity in the past, however, are expected to affect this oxygen minimum zone. On glacial/interglacial (G/IG) timescales, sea ice likely plays a pivotal role for intermediate water ventilation in the Bering Sea. Enhanced sea ice cover limits the light availability and contributes to surface ocean stratification, restricting the nutrient supply from below. Further, evidence from the Bering Sea points towards glacial formation of well-ventilated North Pacific Intermediate Water (NPIW) via brine rejection during sea ice freezing. Enhanced formation of NPIW may have important implications for the efficiency of abyssal North Pacific carbon storage, however the spatial and vertical extent of glacial NPIW remains poorly constrained.

We use a multi-proxy approach to study the interactions of sea ice and biogeochemical cycling at International Ocean Discovery Program Site U1343 in the eastern Bering Sea across the last glacial maximum (LGM) to Holocene (7-30 ka). Sedimentary redox chemistry, dysoxic benthic foraminiferal assemblages, and the $\delta^{18}\text{O}$ composition of seawater all point towards periodic entrainment of NPIW at 2000 m water depth across the LGM and early Heinrich Stadial 1 (HS1). This is supported by biomarker-based sea ice reconstructions, demonstrating enhanced seasonal sea ice cover during the LGM and early HS1, indicating that NPIW may have been formed locally in the Bering Sea. Additionally, eastern Bering Sea sea ice dynamics are in-phase with deglacial North Atlantic climate oscillations, contradicting an Atlantic-Pacific seesaw with increased overturning leading to enhanced northward heat transport in the Pacific.

When did the Danish/German/Swedish straits form?

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The timing of the formation of the Danish/German/Swedish straits and the first marine influence in the Baltic Basin has been much debated. Here we present new radiocarbon ages from sediment cores retrieved from Danish waters. Most ages are based on shells of marine molluscs, which means that the ages are uncertain because we do not know the reservoir age in the past. We use a reservoir age of 400 years, which is based on dating of museum specimens collected before testing of nuclear bombs started. It is clear from the ages that the Great Belt (Storebælt) was inundated before the Sound (Øresund). The oldest ages from the northern part of Great Belt are about 8700 cal. years BP. From the central part of the Great Belt the oldest ages are about 8100 cal. years BP and in the southwestern Baltic Basin ages vary from 7200 to 7600 cal. years BP. Sediments deposited prior to the occurrence of marine molluscs contain brackish-water ostracodes (*Cyprideis torosa* and *Cytheromorpha fuscata*); these sediments are usually laminated and non-bioturbated. The brackish-water phase may have lasted 500 to 1000 years.

Late Quaternary geological processes in the southeast Skagerrak

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The Skagerrak has been a vital component of the northwest European geo-system since its formation during the Quaternary glaciations. During glacial periods it acts as a major ice stream for the Fennoscandian ice sheet and during interglacials it is the deepest element of the North Sea and a major sediment sink. Using high-resolution marine geophysical data we map a number of different geological features that are diagnostic of different stages of the area's late Quaternary evolution. These include deeper water seabed features such as contourite waves, eroded ridges and pockmarks; as well as a glacial surface that is buried by up to 50 m of post-glacial material, and a number of stratigraphic units that are truncated. In shallower waters, uplifted outcropping units show variation in strike from northeast to southeast. Combined, these features demonstrate a varied geodiversity that may have important implications for biodiversity. Additionally, they provide evident of different bottom current flow regimes operating in glacial and interglacial periods. These different regimes are driven by the switch in the Skagerrak's situation from a glacial embayment to a deep water trough in the North Sea and reflect the changing oceanographic circulation from glacial, to early Holocene and, following the initiation of the Jutland Current, the mid to late Holocene.

SESSION 19: KELP ECOLOGY

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The production and fate of sub-arctic kelp detritus.	147

What Really Killed the Sugar Kelp - effects of simulated heat wave scenarios on *Saccharina latissima*.

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Kelps are important foundation species in coastal cold-water ecosystems, and loss of these organisms is a threat to global biodiversity. Severe reduction in the abundance of the kelp has been observed in Northern Europe during recent decades, likely caused by increasing water temperature. To test the heat tolerance of *S. latissima* we exposed the kelp to simulated heat wave scenarios of 15, 18, 21 and 24°C followed by a recovery period at 15°C. While growth rate and photosynthesis decreased significantly with increasing temperature, mortality remained low among treatments, except at 24°C where >90% died halfway through the heat wave. Although 21°C had limited effect on mortality of *S. latissima*, the kelp exposed to this heat wave temperature lost weight and started to dissolve during the subsequent recovery period. It seems that the observed mortality and loss of biomass was mainly due to heat related damage (e.g. oxidative stress) rather than carbon starvation, as net photosynthesis remained positive throughout the experiment (except at 24°C) and mannitol storage levels were similar among treatments. Oxidative stress may have been caused by discrepancy between photosynthetic electron transfer rate and photosynthetic capacity at high temperatures. Overall, our results indicate that extreme heat events pose a serious threat to the Danish populations of *S. latissima*.

The production and fate of sub-arctic kelp detritus.

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The production and fate of kelp detritus from coastal habitats is an unknown in the global C-budget why it is critical to understand how organic C is produced, released, transformed and transported within and across ecosystems. Kelp forests are abundant and highly productive in arctic and cold temperate ecosystems and may play a significant role as a resource subsidy to adjacent systems. We quantified the production and fate of detritus by sub-arctic *Laminaria hyperborea* in northern Norway over two years. The annual production of kelp detritus amounted to 480 g C m⁻² kelp forest; distal erosion of blades (i.e. FPOM) made up ca. 22% of the total production while the loss of whole individuals through dislodgment during storms (i.e. CPOM) corresponded to ca. 24% of the total detritus production. Phenologically related losses of old blades took place in spring as new blades were formed and made up more than 50% of the annual production of kelp detritus. Coarse kelp detritus accumulated close to the kelp forests after the spring cast of old blades, but a substantial fraction of that detritus was transported to the deep subtidal and into deeper area (>400 m) within weeks after the disposal. Sea urchins function as important shredders on kelp detritus within the kelp forests since >60% of the ingested detritus is excreted as undigested kelp in fecal pellets (FPOM). Depending on density, sea urchins captured and consumed up to 80% of the released kelp detritus within few days, corresponding to an annual conversion of CPOM to FPOM of 100-400 g C m⁻². Modeling showed that the transformation of CPOM into FPOM by sea urchins increased the export distance four-fold, indicating that sea urchins accelerate and extend the export of C to neighbouring areas. We suggest that the detritus produced by *L. hyperborea* serves as an important subsidy to secondary production, not only within the kelp forests, but also in deeper, adjacent areas where primary production is otherwise low.

SESSION 20: OCEANOGRAPHI

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Hvorfor er hydrodynamiske modeller så lækre og hvordan ser der ud i motorrummet?

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En dynamisk model er en matematisk beskrivelse af et system som definerer den tidslige udvikling i systemets tilstand. Det kender vi f.eks. fra vejrudsigten, hvor luftens bevægelse, tryk og temperatur bliver forudsagt af en matematisk model. Helt tilsvarende kan man lave en sådan model for havets strømning, temperatur og saltindhold: en hydrodynamisk model. En af styrkerne ved denne type modeller er deres evne til, at beskrive hvordan systemet vil opføre sig under andre forhold, f.eks. i fremtiden, under et varmere klima eller hvis der bliver tilført mere ferskvand. Hvis den matematiske beskrivelse af processerne er tilstrækkelig god og vores løsning tilstrækkelig præcis vil vi kunne bruge modellen til, at forudsige hvordan et system opfører sig under ændrede forhold. Dette gør en dynamisk model et stærkt forvaltningsværktøj. Til sidst kigger vi lidt på hvordan en sådan model er lavet i det marine modelleringsværktøj FlexSem og på et eksempel på hvad den kan bruges til.

Operational Ocean modelling for the coastal zone, an example from the TASSEEF project"

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Adaptive coastal water management requires model applications and services that cover the basin scale, but zoom in seamlessly onto coastal and estuary scales, in hundreds of meter resolution. In the frame of the TASSEEF project: DTU Aqua, Aarhus university (DCE) and DMU are assessing very locally in Limfjord area around Logstør and Lovns Bredning the environmental impacts of mussel fishing. To ensure a seamless model application, DMU's operational ocean circulation model HBM was extended with a 185 meter horizontal resolution setup that was 2-way nested into the Waddensea, modelled in 1nm resolution and the Danish Straits, modelled in 0.5nm resolution. The results show that HBM is computational efficient to run these large applications. It is able to provide high-quality sea level forecast and reasonably good quality predictions of temperatures, salinity and currents in very high resolution. Its computational efficiency makes it well suited for long-term studies.

SESSION 21: MIKROPLASTIK I HAVET

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EFFECT OF CAR TIRE AND RUBBER GRANULES ON COASTAL COPEPODS

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Particles originating from car tires are one of the most abundant and potentially harmful forms of microplastic in the coastal waters. In addition, recent studies have suggested that thousands of tons of rubber filling, made of car tires, from the artificial football fields disappear annually, and potentially end up in the ocean. We studied the effects of tire wear and rubber granules to the feeding and reproduction of the coastal copepods *Acartia tonsa* and *Temora longicornis*, at environmentally relevant concentrations of 10-10 000 particles l⁻¹. We hypothesized that 1) the effect of microplastic will depend on its concentration and toxicity so that the new car tires will have negative effects on copepod feeding and reproduction at the lower concentrations than old car tires or rubber granules, 2) the toxic substances in the new tire will leak into the water column causing adverse effects also in the absence of particles and 3) the effect of microplastic on copepods will be more pronounced in the low than high food concentrations. Feeding, egg production and hatching success of both copepods was unaffected by plastic particles, irrespective of the concentration or type of the particles or food concentration. However, fecal pellet production tended to increase at high concentrations of plastic particles, suggesting potential (limited) effects on assimilation efficiency.

Flocculation of PVC microplastic particles

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We have examined the flocculation potential and settling velocity of PVC microplastic particles (mean size 8 μm) in natural seawater, in lake water and in tap-water. The plastic flocculated in all treatments but flocs grew larger in lake- and sea-water and settling velocities were typically in the order of 0.4 mm s⁻¹ for the largest flocs. The effective densities of the flocs are generally lower than that of natural sediment flocs of similar size, reflecting a relatively slow settling of the microplastic flocs compared to natural sediments. This tendency for lower settling velocity is probably at least partly caused by the lower density of the PVC particles (1.4 g cm⁻³ compared to about 2.65 g cm⁻³ for minerogenic particles). We expect that microplastic particles in nature will be incorporated into flocs composed of natural organic and inorganic particles and they may therefore settle at rates similar to that of the remaining flocculated particles. This hypothesis is currently being investigated with various mixtures of microplastic particles, natural sediments and natural seawater.

The potential role of microorganisms on the fate of marine plastic debris

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The presence of plastic particles of macro to submicron size in marine ecosystems is directing new research into the potential impact and environmental fate of this anthropogenic material. Once emitted to the environment, synthetic polymers undergo weathering due to chemical, physical and biological forces that affect aggregation, vertical transport, particle fragmentation, leaching and polymer degradation. The interactions between synthetic polymers, (micro)organisms, and biogeochemical cycles likely involve a broad set of pollutant pathways whereby secondary fragments and degradation intermediates become available to further chemical and biological processes. The repercussions of microbial impact on marine plastic fate, however, remain largely unconstrained. Our work focuses on various aspects of microbe-plastic interaction and the biogeochemical cycling of marine plastic waste. We use a combination of microbial community and eco-physiology studies, bioimaging, and isotopic and elemental analysis to elucidate plastic-associated microbial element cycling. We here present our current laboratory-based and field experiments in Denmark and abroad and discuss potential knowledge gaps as impetus for future work

Jellyfish as marine refineries

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Over the last several decades, a significant increase of both frequency and severity of jellyfish (JF) blooms were reported worldwide¹. Blooms of these organisms can extend for thousands of square kilometers, with drastic consequences and economic losses. There are a significant and increasing number of clients and stakeholders worldwide, who faced a serious seasonal problem from JF attacks. Besides severe negative consequences on human health and coastal tourism (due to painful stings), a JF bloom pervading in aquaculture cages can destroy the entire stock in one fell swoop or it makes the yield worthless when caught in the net of fishing boats. The problem will increase; say the forecasts and the population of the JF appear to be on the rise. Though, management and adaptation strategies have to be developed aiming to prevent negative impacts. On one hand, jellyfish already represent an impressive stock of organisms and biomass with very little human exploitation at a global scale. Moreover, different species of JF offer a range of bio-compounds which can be used for a number of valuable products, like organic fertilizers, sustainable feed for aquaculture and stock farming or healthy food for humans. Up to now, there is still a huge knowledge gap about JF and their bloom forming due to their complex life cycle. Also, the biochemical features of their bio compounds, as well as the elaboration of processing needs preparatory work. GoJelly project (Horizon 2020, 774499) is organized in such a way that it will address and fill all these knowledge gaps in order to assess and forecast JF blooms and to define the strong points as well as the possible limitations for product development.

Jellyfish benefits- Mucus fluid is an excretion produced naturally by JF during reproduction, when stressed, during digestion (to precipitate rejected particles from the water column) or when dying (Patwa et al. 2015). By testing different sources of JF mucus the ability to trap microplast

Microplastics in the Baltic Sea catchment: emissions and pathways

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In order to predict the fate of microplastic litter in marine environment, the emissions and pathways of the microplastics from major sources into the Baltic Sea have to be mapped. This study is part of H2020 project CLAIM (Cleaning Litter by developing and Applying Innovative Methods in European seas), which developed a systematic method for estimating the microplastics inputs in a sea-basin catchment scale. The microplastic source mapping in this study is divided into three stages: the first stage is to estimate the microplastic emission per category (e.g. tyre wear) per country. Existing research from a limited number of countries are extrapolated to all Baltic catchment countries by using socioeconomic data, e.g., amount of passenger cars and utility vehicles, population density etc. The second stage is to assess the fate of the emitted microplastics through their pathways by combining incomplete research results with socioeconomic data and measurements in WWTPs. The outcome of the stage 2 is the amount of emitted microplastics into the surface waters or into the sea per country. The third stage is to distribute the national load to a gridded field and per catchment. Population density and river catchment model are used.

The method is then applied to calculate the spatial distribution of the emissions into the Baltic Sea, including microplastics from tyre abrasion, wash of clothes and use of Personal Care and Cosmetic Product (PCCP). The results show that the estimated microplastics into the Baltic Sea are 12079 t/y for tyre wear and 16.5 t/y for PCCP. The emitted microplastics from the laundry to the surface waters are estimated as between 232 – 417 t/y. The high emissions are found in the urban areas with high population density. Wastewater treatment plants play an important role in reducing the microplastic discharge into the sea. Small particles (size < 10 µm) may take account a significant part of the total amount of the microplastics into the sea.

A holistic approach to address plastic pollution on a local scale - The Roskilde Fjord case

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Plastic pollution largely stems from peoples everyday use of plastic. This implies that even though the pollution has a magnitude where it can be characterized as a global problem, the main sources are found locally. Local solution can therefore play a dominant role in our efforts to change the current consumption patterns towards more sustainable use of plastic and thus reduce the environmental impact of plastic pollution.

In the 3-year project presented here, we addressed local plastic pollution with a holistic and interdisciplinary approach in semi-closed estuarine water body – Roskilde Fjord, Denmark. The aim of the project was to characterize the magnitude, composition and impact of plastic pollution in the fjord along with dominant exposure routes to the water body. The project furthermore worked with local stakeholders, including citizens, authorities and wastewater treatment plants with the aim of identifying suitable solutions to the plastic pollution.

The interdisciplinary approach, drawing upon science, social science and humanities generated a comprehensive understanding of pollution patterns and potential impacts and furthermore initiated different mitigation processes such as citizen science activities, political attention and enhanced focus on point sources.

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Seabed evidence of channelized dense winter water flow from the Greenland shelf into the deep Labrador-Irminger Sea basin

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A compilation has been made of high-resolution (shallow) seismic and bathymetric data from the Southwest and Southeast Greenland margin^{1,2}. Results from this investigation reveal a seabed topography characterized by the presence of many channels and several larger canyons. Some of these canyons are incising the shelf break and connected to shelf troughs or tunnel valleys on the shelf. These channels on the shelf are sometimes eroded into bedrock substrate and presumably formed beneath a (glacial) ice sheet by strong meltwater erosion. Others may have formed in proglacial environments with powerful meltwater discharge in front of the (glacial) ice margin. On the slope a system of tributary channels is observed that often join a central channel continuing on the deep-sea basin floor. Most of these channels on the slope are thought to have acted as a conduit for glacial sediment-laden hyperpycnal meltwater flow. Seabed evidence in form of the lack of a recent (Holocene) sediment cover on the channel floor, as for instance documented in the Fylla Bank canyon, and a markedly ‘fresh’ channel topography demonstrate, however, that downslope sediment transport and erosion in parts of this channel system still must be active. In the latter case we propose that cascading of dense winter water formed on the Greenland shelf has been responsible. This conclusion is supported by recent oceanographic studies^{3,4} reporting formation and occurrence of such water masses on the shelf of West and Southern Greenland.

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Diversity of diazotrophs in Mariager Fjord

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Biological fixation of dinitrogen (N₂) is classically considered most active in nutrient-depleted surface waters. However, recently it has been shown that N₂ fixation can also take place at high rates in oxygen (O₂)-depleted deeper waters. Those waters were now predicted to expand and further deoxygenate as a result of increasing atmospheric carbon dioxide concentrations and global warming. With this, the habitat of N₂-fixers in those waters will expand, and they may be of increasing importance in the future. One example of an O₂ depleted marine ecosystem is the Danish Mariager Fjord. This fjord is characterized by a highly stratified water column with O₂ depleted and sulfidic waters, and it has been suggested to be a site of active N-loss.

We present a systematic investigation of N₂-fixation in Mariager Fjord, including direct rate measurements, phylogenetic and statistical approaches. We, for the first time, detected active N₂ fixation in Mariager Fjord. The N₂ fixer community was dominated by *Ralstonia solanacearum*, however, our statistical model revealed that N₂ fixation has been performed mostly by sulphur-bacteria and cyanobacteria. Active N₂ fixation was present at extremely anoxic and sulfidic conditions, a situation that resembles an anoxic future Ocean. We understand from our data, that N₂ fixation is able to persist at those conditions and will possibly allow for a positive enforcement of primary production, thus promoting eutrophication and euxinia.

Effects of environment and life-history on diversity correlations in Baltic estuarine benthic communities

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Biodiversity is traditionally assessed by looking at the distribution of species in a community, but it can also be investigated by calculating genetic richness of the taxa within the respective communities (Hughes et al., 2008). Though the methods follow different approaches to measure diversity they certainly can be related, as the respective drivers of biodiversity at these different biological levels might be similar (Vellend, 2005). By combining ecological community studies and molecular population genetic techniques, the degree of similarity of species (community)- and genetic biodiversity patterns can be investigated by assessing the species genetic diversity correlations (SGDCs).

This PhD project focuses on SGDCs in estuarine marine ecosystems, by investigating relations between population and community dynamics on one hand, and genetic diversity on the other. These changes are affected to various degrees by environmental factors (such as salinity, temperature, sediment composition, etc.), biological factors (e.g., species interactions) and anthropogenic disturbances. This study is the first large scale comprehensive study of SGDCs in an aquatic ecosystem, investigating the relationship between population dynamics and genetic diversity in benthic invertebrate communities throughout the Greater Baltic Sea. By studying the changes in communities over a large distance and time, we can investigate which members of the benthic community are most relevant for understanding SGDCs and whether SGDCs can help us understand ecosystem-level consequences of biodiversity change.

We will present the preliminary results of the spatial study focusing on the species diversity within and between benthic fauna communities using the Baltic Sea as a proxy for a salinity gradient. By assessing a broad spatial range of communities, as well as a range of biological and environmental factors, it is likely to detect changes in diversity, and which factors that are driving them.

Towards a socioeconomic action plan for the Baltic Sea

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The HELCOM Baltic Sea Action Plan (BSAP) is presently under revision, and following HELCOMs declaration from 2013 economic analyses should be included in the next revisions. The present BSAP from 2013 is based on innovative modeling of the Baltic Sea environment, combining riverine loading and transfer of nutrients with an ecological description of eutrophication in the sea and its sub-regions. The assigned country-wise targets of nutrient loading did not reach the same level of sophistication, however, because they were not based on careful economic and policy analysis. An increasing gap exists between the state-of-the-art policy alternatives and the existing command-and-control-based approach to the protection of the Baltic Sea. It is time to raise the socio-economic design of nutrient policies to the same level of sophistication as the ecological foundations of the BSAP, and this presentation suggests and outlines at a strategic level the most important steps to improve nutrient policies in the Baltic Sea region. Based on that key aspects for a Baltic Sea Socioeconomic Action Plan are suggested.

GenoJaws: Population Genomics of Archived Shark Samples

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Museum and private trophy collections worldwide represents a valuable source of historical material of numerous species. In project GenoJaws we take advantage of the hidden treasures of historical samples to perform retrospective genetic analysis on populations of white (*Carcharodon carcharias*), tiger (*Galeocerdo cuvier*), sand tiger (*Carcharias taurus*), and mako (*Isurus oxyrinchus*) sharks. The four species of the project have different characteristics, behavior and distribution, but they are all of important social, biological and economic significance around the world. However, knowledge of the genetic structure and important demographic parameters of the species are sparse.

Dealing with historical material is challenging. However, by following specific protocols for historical material, we are able to extract DNA from the archived shark samples and get DNA of good quality and concentration. Along with DNA from contemporary sharks, we will perform a spatiotemporal genomic study of the four sharks. This will allow us to compare temporal and spatial differences in large numbers of coding genes. From this, we can make robust estimates of population size, population connectivity and gene flow, population stability and look for signatures of genetically based adaptation. The information gained in this project will form the basis of good management policies and conservation of the species in the future.

Spatial and temporal variation in lipid accumulation of Northern Sand Lance (*Ammodytes dubius*) along West Greenland

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Sand lances or sandeels (*Ammodytes* spp.) are key forage fish in the Northern Hemisphere and constitutes a vital link in the energy flow between phytoplankton and marine top predators. The sand lance has a peculiar life cycle as it buries itself into the seabed for overwintering. During winter lipid storages are spent and the Sand lance re-emerges in spring where it will feed on zooplankton during the summer to re-gain lost lipid storages. The lipid content of [PG1] Sand lances is highly dependent upon the presence of energy-rich copepods, [PG2] making the body condition of sand eels sensitive to environmental fluctuations. In this study, the spatial and temporal variation in lipid content was examined in Northern sand lance, *Ammodytes dubius*. Sampling of Sand lances occurred during the months May, June and November 2013-2018 on western Greenlandic banks from 62.5 to 67 °N. The lipid content is determined individually for each Sand lance using hexane for lipid extraction on a Dionex ASE 350. Lipid contents are expected to increase over the summer period and current results show a high variation in lipid contents in Sand lances caught during May. The lipid content will be further examined in relation to location and time of year, gender and size. Due to its importance as a forage fish and its sensitivity to alterations in copepod communities and seasons, the Sand lance could be considered an ideal indicator species for the productivity in the marine environment. The importance of this indicator function is emphasized by the present climate changes

Give or take a year

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Correctly determining the age of fish is a key challenge when working with age-based stock assessment models in fisheries management. Different methods can be used to determine the age and one of these, uses of the formation of translucent and opaque zones that develop in the otolith in bony fishes. These zones indicate annual seasons with more or less food available and interannual ring formation allows us to count years of growth (annuli). One of the main problems using this method is to pinpoint the first and last translucent zone and the timing of their formation. Wrongful interpretations will typically lead to a one-year change in age estimates. This project explores the timing of the last translucent zone formation in Atlantic cod from East Greenland, analyzing otoliths sampled throughout the year.

Currently, there is an institutional discrepancy between age readings of Atlantic cod from Greenland. The consequences of an over- or underestimation of age will later be quantified using the age-based state-space model (SAM) currently used for the assessment of this stock. Findings from the study on annuli formation will be used to optimize the assessment model.

Use of underwater camera technology in fisheries and marine monitoring

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In recent years, underwater cameras have undergone accelerated development and innovation, increased technical performance, and reduced in prices. Despite this, underwater cameras are rarely used in Danish commercial fishing, where they can be used by fishers to optimize the sustainability of fisheries, and by marine scientist as a platform for cost efficient monitoring of marine organisms. The overall objective of this project was to develop and disseminate the necessary technological and knowledge platforms for large-scale use of underwater camera technology in commercial fisheries and marine monitoring. This project have introduced and tested underwater cameras in Danish fisheries. The most important elements for large-scale use of underwater camera technology is the transfer of knowledge, and the solution of simple technical problems such as mounting, external light sources, and data management. Additionally, it is important to find effective methods for connecting cameras to other relevant sensors (e.g., oxygen, temperature, GPS). In the future, vision technology will become an increasingly important element for analysing video recordings of the marine environment. Object detection, species identification and quantification in an environment with fluctuating turbidity, refraction, and absorption creates challenges for future research. The project is funded by the European Maritime and Fisheries Fund (EMFF).

A study of discard survival in European plaice (*Pleuronectes platessa*) from trammel net and Danish Seine

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European plaice (*Pleuronectes platessa*) is a key species for Danish commercial and recreational fishing. A discard ban in the reformed European Union's Common Fisheries Policy includes the possibility of exempting from the landing obligation "species for which scientific evidence demonstrates high survival rates". Although smaller coastal fishing vessels make up a substantial part of the commercial Danish fishing fleet, discard survival in plaice from these vessels is not well studied. To address this issue, a study on discard survival in plaice from trammel net and Danish Seine was established as a cooperation between Aalborg University, Copenhagen University and Foreningen for Skånsomt Kystfiskeri. Methodology was developed to collect, assess and observe discard survival in plaice. Experiments were conducted in 2017 and 2018 from three commercial coastal fishing vessels. Livewells were designed to house captured individuals for up to 11 days for observation of short-term survival rate. Catch-damage-index (CDI) and Reflex Action Mortality Predictor (RAMP) were used to assess fish condition immediately after capture and at the end of the observation periods. Results showed 100% survival rate in plaice from trammel net and 87% survival rate in plaice from Danish Seine. For the majority of fish assessed after capture, reflex impairments were absent and injuries were primarily minor bruises, fin fraying, and net marks. Assessments of injuries and reflex impairments after observation showed the condition of the fish generally did not worsen during the observation periods. The project is financed by the European Fisheries Fund and the Ministry of Environment and Food of Denmark.

Diving and foraging of the Atlantic walrus in high Arctic Greenland and Canada

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Investigations of diving behaviour of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in the high Arctic Greenland and Canada are important for understanding behavioural adaptations and area utilization of this Arctic benthic feeder. Furthermore, such information along with estimations of annual consumption and carrying capacity of walruses are needed in management decisions of this utilized species. From 2010–2013, 27 walruses in Smith Sound were tagged with satellite-linked transmitters providing data on positions and diving. Dive rates, haul-out periods, vertical speeds and depths of dives were estimated. Majority of dives targeted depths <100 m, which is also the main bathymetric distribution of walrus preferred prey. Two female walruses dived to extraordinary depths between 500–600 m; the deepest dives ever documented for a walrus. It was estimated that walrus in NW Greenland consume ~28 kg bivalves day⁻¹ and that predation on the standing bivalve biomass (within 5–100 m of depth) was 3.2% based on mean biomass of walrus preferred prey. Based on equal percentages of walrus annual consumption of bivalve biomass in the Smith Sound region and Beringia it is hypothesized that the Atlantic walruses in NW Greenland might act locally as bioturbators at specific walrus feeding grounds as the Pacific walruses in Beringia. As such the walrus may fulfil an important ecological role in Arctic ecosystem functioning. From a correlation between shallow water habitat, current population size (n=2544) and walrus pre-exploitation population sizes it is proposed that the carrying capacity in the Smith Sound region do not exceed 5000 walruses.

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An innovative and non-invasive method to study the social behavior of harbour porpoise (*Phocoena phocoena*) calves in the wild.

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The harbour porpoise (*Phocoena phocoena*) is the only whale regularly found in inner Danish waters. It is probably one of the most widespread and best studied of all the Phocoenids. Even so, significant gaps in our knowledge about these animals still remain, especially when it comes

to understanding their behavior and development in the wild. Such information is of great interest for managing and mitigating human activities to protect this species.

Studying how the calf's dependence on its mother changes during growth is especially important for protecting porpoises during their most vulnerable period of their life cycle. For this reason, I am developing a non-invasive method for measuring the length of harbour porpoise calves and the distance to their mothers in the wild using a drone. These length measurements will be later used to estimate the age of the animals so specific social behaviors observed between calves and their mothers as well as their level of independence can be analyzed over their first year of

life. In order to do so, I first investigate the performance and accuracy of the drone for measuring the size of porpoises and the distance between them. Later I will use the calibrated measurements to better understand mother-calf interactions for different calf ages.

Keywords: social behavior, harbour porpoise, mother-calf pair, UAVs, unmanned aerial vehicles, drone, photogrammetry, morphometrics.

Predator prey interactions between harbour porpoises and fish studied by use of drone

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Harbour porpoises (*Phocoena phocoena*) feed on small fish. The details of prey capture have been studied in captivity and by onboard acoustic tags. Here we used a drone to observe prey capture from above in shallow waters while porpoises fed on both schooling and individual fish. Porpoises usually swam slowly towards the school and then speeded up in the final attack. The fish reacted by moving away in the same direction as the porpoise, or by the school splitting up in vacuoles or spreading in all directions. These visual field observations of porpoise prey capture corroborates previous data obtained with captive animals and by acoustic tags.

Marine mammal conservation status in a changing Arctic

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Marine Arctic mammals are highly exposed to anthropogenic global change and their future survival is under risk. To better understand the future fate of marine Arctic mammals the recent temporal trends in IUCN conservation status for all Arctic mammals has been assessed and compared to how external (type of main threat) and internal factors (species traits) explain differences in conservation status.

Many of the Arctic marine mammals do not apply that well to the global conservation priority criteria and lack of data on species and populations makes it difficult to assess the species. By using biological trait analysis we can understand the ecological function of the species but also how future changes will affect them and their capacity to adapt to the changes.

Precocious underwater sound production in harbour seal (*Phoca vitulina*) pups

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Harbour seal pups are born on land in early summer. As opposed to other pinnipeds they right after birth get accustomed to being in the water. They are known to produce contact calls to address their mother on land, but it is not known if they also communicate underwater with sound. Here we observed two harbour seal births in a captive facility with natural sea water. We video filmed and made acoustic recordings in air and underwater throughout the first week after the births. Already 41 to 46 min after birth, the pups went voluntarily into the water. The first underwater sounds were heard 60 minutes after birth, or within 20 min after the pups entered the water for the first time. Afterwards, calls were heard about once every hour for the first several days post-partum. Underwater sounds from the calf were more commonly produced compared to aerial sounds. This indicates that harbour seal pups are highly adapted for underwater sound communication already within the first hours after birth.

PorCC: A new high-accuracy click classifier to study harbour porpoises in the wild

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Harbour porpoises are difficult to observe at sea, even with good weather conditions, due to their small size and cryptic behaviour. However, they are highly vocal, producing narrow-band high-frequency (NBHF) echolocation clicks, which makes them well suited for passive acoustic monitoring (PAM). Such PAM systems must be coupled with a classification algorithm to identify the likely porpoise signals among other transient signals. We present a new harbour porpoise click classifier (PorCC) for full-waveform signals, with an improved performance over current classifiers. PorCC was developed in MATLAB and uses the coefficients of two logistic regression models in a decision-making pathway to assign each signal to one of three categories: high-quality click (HQ), low-quality click (LQ), or high-frequency noise (N). The first model uses click duration and QRMS (RMS-bandwidth / centroid frequency) to separate HQ from N. The second model uses click duration, QRMS, ratio between peak and centroid frequency, peak cross-correlation coefficient (against a model click), centroid frequency, and -3dB bandwidth to separate LQ from N. PorCC achieved hit rates > 90% for HQ clicks while keeping false alarm levels < 1%. The performance of PorCC was compared to that of PAMGuard's Porpoise Classifier module (with standard settings) and the receiver operating characteristics curve was generated for both classifiers. The precision for HQ (HQ clips classified as HQ / total clips classified as HQ) was 31.2% for PAMGuard and 96.1% for PorCC, and the detectability index (d') was 2.2 for PAMGuard versus 4.1 for PorCC. Results of this study show PorCC is a rapid, highly accurate method to classify NBHF clicks, which could be applied for real time monitoring, as well as to study harbour porpoises, and potentially other NBHF species, throughout their distribution range from data collected using towed hydrophones or static recorders.

The seasonal buoyancy budget of porpoises during dives

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The harbour porpoise (*Phocoena phocoena*) is one of the smallest species of cetaceans. They populate temperate and Arctic waters with large temperature fluctuations between seasons. Therefore, this is a marine mammal characterised by extreme blubber accumulations in preparation for cold winter conditions. As blubber has a smaller density than sea water, one may wonder if the large accumulation of blubber during winter months imbalances the equilibrium of buoyancy forces for the animal while diving. Density measurements of tissues from harbour porpoises were used as input to a model investigating the effect of variations in blubber thickness of the animal's buoyancy. Both data from lactating females, pregnant non-lactating females, immature males and females as well as calves were used. The model shows that animals are positively buoyant while being at the surface, but neutrally buoyant at 10 to 20 meters of depth depending on blubber mass augmentation. The largest variation in buoyancy for a surfaced animal is caused by the amount of air inhaled; at 10 m depth, the lung volume only contribute with approximately 30 % to the animal's buoyancy and its contribution continues decreasing with depth. The results indicate that the increased blubber thickness during winter time has little effect on the buoyancy of porpoises while foraging.

On the uncertainty of the projection of extreme sea level in future in the Danish coastal area

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The regional projected changes in winds combined with sea level rise and land rise challenge our present knowledge of extreme storm surges in the Danish coastal area. In particular, the source of the uncertainty is difficult to trace back in the long climate simulations. In ‘Climate Atlas’, a new national climate service initiative, the Danish Meteorological Institute (DMI) will investigate changes in the extreme statistics of sea-level in the 21st century. The study will make use of multi-scenarios, multi-models and multi-parameters approach to focus on the uncertainty of the projected change in extreme statistics of sea level.

RCP4.5 and 8.5 are the two IPCC scenarios to be used in this study. We take the atmospheric forcing from 24 members of CORDEX (Coordinated Regional Climate Downscaling Experiment) RCM (Regional Climate Models) simulations. We will select some RCM members as the forcing to drive a high resolution storm surge model for the North Sea and Baltic Sea area. In parallel, operational model at DMI will be evaluated against other ocean models in the Baltic Sea area in the hindcast period. This way we are able to trace back the source of the uncertainties in the simulations. Of course, the uncertainty estimates will be combined with a thorough evaluation of global sea-level changes and their imprint on the North Western European Shelf Seas.

The evaluation of the uncertainties will be taken into account in the municipal planning about climate variability and change, impacts, and response options. An authoritative source of quality climate information is important for the Danish Municipalities to ensure coherent and timely adaptation measures. Main priorities of our geographical area are extreme precipitation and storm surges.

The potential of *Fucus serratus* to acclimatize to multiple stressors (low salinity and high temperature).

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Marine macroalgae play a major ecological role as foundation species in coastal marine systems. Ongoing climate changes lead to elevated summer temperatures and increased precipitation that may periodically lower the salinity leading to multiple stressor effects on marine organisms. We studied how reduced salinity and high water temperature affect the performance of an important macroalga – *Fucus serratus* - and whether the effect(s) of the two stressors were additive or non-additive. We examined further the potential of *F. serratus* to acclimatize to these stressful conditions

We exposed *F. serratus* to various combinations of salinity (13 and 25 PSU) and temperature (15, 23 and 28°C) for 4 weeks and used growth, chlorophyll fluorescence (PAM), photosynthetic performance and the pigmentation (content and composition) as end-points. The results show that high temperature (28°C) had a profound negative effect on *F. serratus* leading to 100% mortality at both salinities after a few weeks. Algae exposed to 23°C showed reduced performance, but survived the experiment and acclimated somewhat the increased temperature. Low salinity had a weak negative effect on algal performance, but more interestingly, seemed to have a positive (antagonistic) effect on plants exposed to high temperature during the initial part of the experiment. This indicates that some of the mechanisms induced to cope with low salinity may also aid *F. serratus* in coping with elevated temperature.

COAST_SEQUENCE – exploring Danish marine biodiversity using environmental DNA

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Despite their economic and recreational value, the shallow coastal waters around Denmark are one of the ecosystems in Denmark we know least about.

Without a fundamental knowledge on the distribution of marine biodiversity and its drivers, it is difficult to evaluate and follow the biological composition and ecological status of the Danish coastal waters.

A new project funded by the Velux Foundation will therefore use environmental DNA (eDNA) to monitor marine life along the Danish coasts. Over the next three years, scientists from Aarhus University and voluntary citizen scientists from all over Denmark will collect water and sediment samples from more than 100 different coastal sites. By mass-sequencing DNA from all marine organisms, we will obtain new insight into marine life along the Danish coasts and create a baseline map of marine biodiversity in Denmark

Sedimentdynamikken i områder med stiksugningshuller og slæbesugningsspor fra råstofindvinding: eksempel fra Disken i Øresund

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Miljø- og fødevareminister Jakob Ellemann-Jensen meddelte i løbet af efteråret, at det skal være helt slut med at grave sand og grus i det nordlige Øresund, og at det nordlige Øresund vil blive udpeget som beskyttet havområde under EU's havstrategidirektiv.

Tidligere undersøgelser har kortlagt dele af det nordlige Øresund ift. både naturtyper og råstoffer, og ligeledes er effekten af råstofindvinding på havmiljøet blevet vurderet i flere undersøgelser. Dog eksisterer der begrænset viden om sedimentdynamikken i områder med stiksugningshuller og slæbesugningsspor, som opstår ved råstofindvinding alt afhængig af indvindingsmetoden.

I 2017 foretog Rambøll i samarbejde med De Nationale Geologiske Undersøgelser for Danmark og Grønland (GEUS) og Institut for Geovidenskab og Naturforvaltning (IGN) ved Københavns Universitet (KU) en miljøundersøgelse for Miljøstyrelsen og Länsstyrelsen Skåne af både den danske og svenske del af Disken i Øresund, hvor der frem til 2014 var foretaget råstofindvinding med både stik- og slæbesugning på den danske del. Miljøundersøgelsen i 2017 var en opfølgning på en tilsvarende miljøvurdering af den danske del af Disken for Naturstyrelsen i 2014 med henblik på at vurdere udviklingen af de fysiokemiske og biologiske forhold på Disken siden ophøret af råstofindvinding tilbage i 2014. Derudover gav disse undersøgelser en unik mulighed for også at undersøge sedimentdynamikken på Disken og specifikt sedimentdynamikken i områder med stiksugningshuller og slæbesugningsspor.

Vi præsenterer her en geomorfologisk kortlægning samt en overfladesedimentkortlægning af Disken. På baggrund af morfologien i 2014 og 2017 estimeres sedimentdynamikken i området med fokus på områder med stiksugningshuller og slæbesugningsspor, og vi diskuterer den potentielle morfologiske reetablering af disse områder. Til slut diskuterer vi effekten af råstofindvinding på morfologien i dynamiske marine områder.

Holocene history of the Zachariae Ice Stream, northeast Greenland

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On the NorthGreen 2017 research cruise to NE Greenland onboard R/V Dana, a 585cm long marine sediment core (DA17-NG-ST08-92G) was retrieved from the inner continental shelf in Norske Trough offshore the Zachariae Ice Stream. By utilizing various proxies such as XRF data; grain size distribution; variation of stable oxygen and carbon isotopes in microfossils; and marine biomarkers it is possible to reconstruct the paleoclimate and paleoceanography at the site. The release of meltwater to the site from continental ice streams is thought to have had a great influence on the palaeoceanographic changes in the region. Therefore, through this knowledge; it should be possible to reconstruct events of increased or decreased glacial runoff from the nearby Zachariae ice stream and its influence on local climate and oceanography. Preliminary results from XRF and grainsize analysis shows variations of continental input of sediment, as well as changes to the velocity of the dominating ocean currents at the site during the time of deposition of the sediment. Future priorities in the project will be to obtain stable isotope and biomarker data in order to further investigate the changes to ocean temperature, salinity, marine productivity and other factors. The data will be supported by radiocarbon dating of marine microfossils from the core to obtain a broad perspective on the impact of climate change to the area in the past.

A new sea ice biomarker facility at Aarhus University – scope and opportunities

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Sea ice is an integral part of the climate system, influencing short- and long-term climate change via its albedo, interactions with the ocean and the atmosphere, and its impact on primary productivity. Especially with regard to the accelerating loss of sea ice in the Arctic Ocean due to anthropogenic climate change it is more than ever important to understand the implications of changing sea ice dynamics for the global climate. Reconstructions of sea ice conditions past the instrumental record are complicated by its transient nature, however IP25 (ice proxy with 25 carbon atoms), a sea ice-related biomarker has provided valuable insights into past sea ice dynamics during the last decade.

Biomarkers are naturally occurring molecules found in soils, lakes and marine sediments and have become a widely applied tool in paleoenvironmental reconstructions. Source-specific highly branched isoprenoids (HBIs) are characteristic to seasonal sea ice environments, enabling the reconstruction of past sea ice conditions in high northern and southern latitudes. IP25 is an HBI produced by certain species of sea ice diatoms, living in brine channels at the bottom surface of seasonal Arctic sea ice. In conjunction with additional biomarkers, such as sterols for general phytoplankton productivity or HBI III, a diatom-specific biomarker enhanced in sediments underlying the marginal ice zone, IP25 allows semi-quantitative reconstruction of past sea ice dynamics and has been detected in sediments of up to Miocene age.

Only a few laboratories worldwide are specialized in the analysis of sea ice biomarkers today. Here we present the first results from a new biomarker facility at Aarhus University. This offers a wide range of opportunities regarding sea ice reconstructions in the Arctic and sub-Arctic realm and provides a unique chance for collaborations to explore other biomarkers for environmental analyses.

The radiocarbon reservoir age of the eastern Arctic Ocean

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Radiocarbon (^{14}C) dating is the standard method for obtaining the age of marine sediments of Holocene and late Pleistocene age. For accurate calibrations, however, this tool relies on precise knowledge of the local radiocarbon reservoir age of the surface ocean, i.e. the regional difference (ΔR) from the average global marine calibration dataset. This parameter has become impossible to measure from modern mollusk samples because of ^{14}C contamination from extensive testing of thermo-nuclear bombs in the second half of the twentieth century. The local reservoir age can thus only be calculated from the radiocarbon age of samples collected before AD 1950 or from sediment records containing absolute age markers, derived from e.g. tephrochronology or paleomagnetism. Knowledge of the marine reservoir age in the Arctic Ocean is extremely sparse, and relies on work by only a few studies. No information exists for the Kara Sea or East Siberian Sea, and the Laptev Sea and Chukchi Sea are represented by very few measurements. This study presents new radiocarbon measurements on historical mollusk collections and new reservoir age estimates for the eastern Arctic Ocean.

What kind of diatoms are there in Trinity Bay in the east of Newfoundland?

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The Holocene marine sediment core AI07-08G was taken from Trinity Bay in the east of Newfoundland during a scientific cruise on R.V. Akademik Ioffe in September 2007 (48°05.10'N 53°29.9'W, 434.5 cm, water depth 585.9 m). The sediments of the core covers the last approximately 3000 years, providing the possibility to study the palaeoclimatic and palaeoenvironmental history of the southwestern Labrador Sea region at a very high temporal resolution. This site is today highly influenced by surface waters of the inner Labrador Current, which transports cool polar-influenced water southwards along the coast of Canada. The main purpose of the present study is to investigate the different kinds of marine diatom species and their diversity throughout the core. Diatom assemblages are known as paleoceanographic indicators that are very sensitive to changes in environment such as sea-surface temperature and salinity, and they are thus excellent proxies of paleoenvironmental change. To obtain this goal, 86 samples were collected at 5 cm intervals from the core. All carbonate content and organic matter were removed through treatment with 10% HCL and H₂O₂, respectively, before preparing permanent slides. These slides will be studied under light microscope to identify the diatom taxa and their frequency in each sample. The changes in diatom assemblages in the core will be compared with the multi-elemental composition obtained through XRF core scanning and results will also be compared with data from other sites. Based on the diatom assemblage of throughout the core, it will be possible to obtain a high-resolution time series of surface water conditions in Trinity Bay.

Fluctuations in advection of Atlantic water during the Mid to Late Holocene: A comparison between the eastern and western North Atlantic

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Ocean and climate of the North Atlantic region is highly dependent on the water exchange between the Arctic and Atlantic Oceans. In the Mid to Late Holocene this interaction seems to have resulted in an opposite trend in the advection of Atlantic-derived water masses between the Northeast Atlantic and the Northwest Atlantic, as observed in several proxy studies of marine sediment cores from the area. The alternation in the advection of predominantly northward flowing Atlantic and southward flowing Polar water masses is believed to be controlled in part by the overall strength of the Meridional Overturning Circulation and by changes in the atmospheric circulation systems in the Arctic (Arctic Oscillation) and North Atlantic (North Atlantic Oscillation), which together affect the strength of the major ocean currents in the North Atlantic and Arctic. The present study aims to investigate this Arctic-Atlantic water pathway by studying and comparing two marine sediment cores retrieved from the eastern Baffin Bay (core AMD14-204C) and the northeastern Greenlandic shelf (core DA17-NG-ST3-39G), thus representing the two main gateways of water masses between the Arctic and Atlantic Oceans. The multiproxy studies of these marine sediment cores, which include benthic foraminiferal assemblage analyses, XRF core scans and CT-scans supported by radiocarbon datings, will allow the reconstruction of the paleoceanographical and paleoclimatic development of these gateway regions through the Mid to Late Holocene. Preliminary results from the eastern Baffin Bay core indicate significant fluctuations in the entrainment of warmer Atlantic water masses into the West Greenland Current, reflecting changes in the overall circulation system in the western North Atlantic during the last 9000 cal. BP.

Paleolandscapes in the eastern North Sea Basin – applications for marine geo-archaeology

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The Late Quaternary geological history of Northern Europe results from a complex interplay of glacial and sea level forcing on erosion and deposition. As a key location, the North Sea experienced several rearrangements, evolving from a partly ice-covered tundra at the Last Glacial Maximum through fluvial drainage and estuarine deposition to a marine intracontinental basin at the present day. Along the coastlines of this dynamically changing landscape, prehistoric humans are likely to have lived and settled down, occupying the former Doggerland. Thus, an ancient but hidden landscape, which is of significant archaeological and geological relevance, resides below the waters of the North Sea. During recent years, novel use of geophysical data has increased our ability to map and study submerged landscapes, and on the global scale the research field of marine geo-archaeology is in rapid evolution. For the North Sea, these new possibilities have sparked intensive research at and around the former Doggerland in particularly the British, Belgian and Dutch sectors while the eastern North Sea and the Danish sector remains sparsely investigated both with respect to paleolandscape mapping and archaeological importance.

This study reviews the existing information already present for the eastern North Sea Basin with respect to mapping of the paleolandscape since the LGM. Important geological structures include the eastern margin of the Doggerbank, the Paleo Elbe Valley and other fluvial systems. With time, the project aims to produce a coherent mapping of the evolving paleolandscape in the eastern North Sea and constrain the areas where the paleolandscape has been preserved. Such areas could potentially represent key locations for further marine geo-archaeological studies.

Marine sediment accumulation rates on the Northeast Greenland shelf since the last glacial maximum

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Variability of sediment accumulation rates on the Greenland continental shelf depends on different parameters, including the presence of sea ice, marine productivity, ocean current strength, runoff from land and iceberg rafting. This study combines previously published chronologies of marine sediment cores with newly collected material from Northeast Greenland. During the NorthGreen Cruise in 2017, a multi-disciplinary marine scientific expedition to the North eastern Greenland shelf, more than 100 meter of marine sediment cores were collected between 80° to 74° N. Our study deals with variability of sedimentation rates in this region during the last glaciation (from 21.000 years to today). To obtain the sedimentation rate of the different localities and of the different ages, we rely on radiocarbon dating. A minimum of 2 milligram of biogenic carbonate (shell fragments and foraminiferal tests) were taken in the core sediments at different depths, is analysed for radiocarbon content by AMS to determine the age of the sediment layers. This age-depth data will also provide us data on the variability of the Northeast Greenland ice sheet and its melting during the last deglaciation. The study of past ice melting and high latitude ocean circulation can reveal some clues for the near future related to global warming and the current acceleration of ice sheet melting.

Integrated modelling of geophysical and geotechnical data to assess geological conditions of offshore areas

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Many different methods are used in relation to the ‘Marine Geoscience’ discipline. This study focusses on the geophysical and geotechnical methods, and how these can be used together to provide better knowledge of the geology in the subsurface. Both methods are widely applied for offshore and onshore purposes – this study focusses on the offshore applications. Recovery of data offshore typically involves larger equipment setup (i.e. charter of survey vessels) and thus offshore geophysical and geotechnical surveys are typically more expensive.

The geophysical methods addressed in this study include multibeam bathymetry, Ultra High Resolution Seismic (UHRS) data, and Sub-Bottom Profiling (SBP) high-resolution acoustic data. These geophysical methods provide information on the morphology and spatial architecture of the seafloor and subsurface to different depths depending on the resolution. A geomodel for the subsurface can therefore be defined from interpretation of the seismic and acoustic data.

The geomodel is useful for the comparison with the geotechnical data from which soil properties are investigated. There are many different ways of geotechnical investigations offshore. Some methods are the Standard Penetration Test (SPT), the Cone Penetration Test (CPT), and the Flat Dilatometer (DMT). They use different methods for characterizing the soil types. In this study, the focus is on data from CPTs and the properties of soils. The processed data provide results from which the soil type can be identified (i.e. Soil Behavior Type Index ISBT). Another geotechnical method widely applied offshore is geotechnical coring, which is very useful in combination with CPTs.

Lithology and soil types from the geotechnical data are integrated with the seismic interpretations and the spatial geomodel to provide a complete geological model of the subsurface. Such models are critical in relation to offshore constructions of for instance windfarms.

Late Holocene Oceanography and Climate in the Northeast Labrador Sea Margin

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Reconstructing past climate and oceanography is a key for understanding natural variability and projecting future climate scenarios. The North East Labrador Sea is an essential region for studying the past ocean currents, ocean productivity, sea ice cover, and freshwater input from the Greenland Ice Sheet (GIS) and the Arctic Ocean as it is the area of the North Atlantic Deep Water formation. Meltwater discharges from the GIS can have major impacts on the deep-water formation and cause disturbances on the Atlantic Meridional Overturning Circulation (AMOC) which can affect the climate on a global scale. So far similar studies have been conducted for the last deglaciation and for the Early and Mid Holocene, but little is known of the Late Holocene climate variability in the Labrador Sea, despite that several climate events such as the Medieval Warm Period (MWP) and the Little Ice Age (LIA) took place during the last 4000 years.

The core MSM45-004-4 from the southwestern Greenland shelf about 135 km south of Nuuk, covering the last ~3900 years, is studied to reconstruct past oceanographic and climatic conditions using foraminifera assemblages, isotopic analysis of benthic foraminifera, and sedimentological proxies. Benthic foraminifera were selected as the primary proxy as they are excellent paleoenvironment indicators for the subsurface water, the ocean currents strength, salinity, and temperature. In addition, sedimentological proxies such as XRF, grain size, IRD, and sediment description are used to give indications of iceberg discharge, sea-ice cover, and freshwater input. The results from the foraminifera assemblage analysis will be compared with dinoflagellate cyst and diatom assemblage data from the same core in order to detect changes between subsurface and surface waters.

Sea-ice variability in North-East Greenland

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Arctic sea-ice extent and volume are decreasing continuously, and according to model simulations, the Arctic Ocean may become seasonally ice-free in about 20 years. However, despite the extreme societal and environmental relevance, our understanding of natural sea-ice variability and its response to external natural and human-induced forcing is associated with significant uncertainties. The insufficient knowledge about natural sea-ice states makes it essential to develop high-resolution sea-ice reconstructions extending back in time beyond the instrumental and satellite era. For this purpose, a sediment core sampled with a Gravity corer on the North East Greenland shelf (79°06'N, 11°90'W) will be analyzed in order to establish multidecadal to millennial-scale time series of sea ice and general oceanic conditions during the Holocene, with primary focus on the last few millenia. The sea-ice record will be based on IP25 and IRD analyses. General oceanic conditions will be reconstructed combining benthic foraminiferal assemblage, stable isotope, Mg/Ca and sedimentological analyses. Sea-ice variability will be linked to Greenland ice-sheet dynamics, ocean circulation and natural and human-induced climate forcings. Moreover, this multi-proxy reconstruction will help to define the pre-industrial baseline of Greenland sea-ice cover.

Challenging the traditional categorization of geological and geophysical data

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Traditionally, geological and geophysical surveys are categorized as either offshore or onshore. The practicalities of data collection including either ships or trucks are natural motives behind this. With the increasing use of new technologies in geological and geophysical data acquisition, challenging the classical offshore-onshore categorization becomes relevant.

This poster takes a starting point in a current Master's thesis focusing on synthetisation of different marine and non-marine data sets, in the coastal area between Gilleleje and Rågeleje in the northern part of Zealand, Denmark where severe coastal erosion has been a problem for many years. The aim is to investigate if an increased insight in the deep geology of the study area can be obtained by complementing marine reflection seismic and bathymetric data with LIDAR data and a drone-based 3D photogrammetric model from the coastal zone. Furthermore, the value of additional geological knowledge is related to understanding and describing the erosional processes along the coast of the study area.

Our initial results show that the photogrammetric model is of higher image resolution than the data provided by the Danish Agency for Data Supply and Efficiency. This enables a relatively detailed geological description from 2D and 3D imagery of the cliff face. The current state of coastal erosion has been described based on this. Similar drone models have never been used for such detailed geological investigations before at the Department of Geoscience and this study thus serves as a forerunner for future similar studies focussing on geological characterisations.

Late Holocene paleoclimate and environmental changes in the Persian Gulf and Oman Sea, south of Iran, based on investigations of sedimentological, geochemical and biogenic proxies of marine sediment cores

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The Persian Gulf is a classic example of a shallow-water mixed carbonate-siliciclastic ramp setting. The salinity and water temperature of The Gulf are higher than expected for the latitude due to the narrow strait of Hormuz, restricting the water exchange between the Gulf and Indian ocean. Geological investigations of the Persian Gulf have mostly been carried out in relation to its economic issues particularly the petroleum industry and only rarely investigated for paleoclimate or environmental change. Therefore, two sediment cores T2S2-2 and T5S1-2, with 83 and 77 cm long, respectively, were selected from the Persian Gulf and Oman Sea, respectively, in order to investigate variation in temperature or humidity during the Late Holocene. The cores were first studies for their physical sediment properties such as color, structure and texture. Secondly, grain size analyses were carried out via laser diffraction for identification sediment particle size. Thirdly, XRF analysis along with magnetic susceptibility were conducted to show the concentration of elements on both cores. Finally, around 85 subsamples have been sieved and subsequently washed to pick and counting all foraminifera species in each core and nine samples were chosen to radiocarbon dating (^{14}C). In addition to mentioned data, some tasks such as organic geochemistry in the framework of pyrolysis analysis via Rock-Eval facility, CNS (% carbon, % nitrogen and % sulfur elements) and isotope analysis (probably C and O) are planned. In concert, these analyses will provide information on changes in water temperature, salinity, freshwater flux from land, primary productivity and sediment source. All results will be compared to each other to achieve a high-resolution record of late Holocene paleoclimatic and paleoenvironmental history of the Persian Gulf and the Oman Sea.

Spatial modelling and development of a multi-criteria site selection tool for mussel farms as a mitigation measure in eutrophic Danish coastal waters

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Eutrophication of coastal water bodies by massive anthropogenic nutrient inputs is a serious global challenge. For Denmark, a range of mitigation measures has successfully led to reduced amounts of nutrients and algal biomass within its surrounding coastal water bodies over the past decades. At the same time, however, a considerable decline in the abundance of benthic filter feeders, in particular of blue mussels (*Mytilus edulis*), was observed. Blue mussels play a substantial role in filtering different kinds of particles out of the water and this strongly contributes to reduced phytoplankton concentrations and improved light conditions in the aquatic environment.

The implementation of blue mussel farms in Danish coastal water bodies has therefore been recently suggested as a potentially effective tool for mitigating coastal eutrophication on a national scale. The general idea in this study is, to utilize the capability of these strong suspension-feeders to extract large amounts of suspended particle loads and algal biomass from the water column. Incorporated nutrient loads in harvested mussels will be recycled as organic protein source and bottom light conditions in the water will improve. Blue mussel farming itself, of course, requires to be economically feasible and cause least constraints to other important utilizations of Danish coastal waters. In a national-scale spatial context, we therefore assess (a) potential yields of blue mussel farms by numerical and spatial modelling, (b) possible risks of loss to the farms by e.g. predators and physical exposure, (c) possibly conflicting interests such as protected areas, economic utilization, tourism/recreation, and public acceptance. These evaluations will be based on a range of layered spatial datasets. Finally, we aim to develop a multi-criteria site selection tool for optimized and scientifically based decision-making for blue mussel farms as an effective mitigation tool in Danish coastal waters.

Artsdiversitet efter sand-capping i Odense Fjord

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Danske fjorde har været udsat for omfattende eutrofiering i over 30 år, som har efterladt en organisk rig og mudret havbund. Muddret bliver let op hvirvlet og skaber derfor dårlige bundnære lysforhold i fjordene. Desuden er sedimentets vandindhold så højt, at ålegræssets reducerede forankring gør planterne mere sårbare overfor fysisk stress. Tilsammen fastholder disse forhold økosystemet i en dårlig økologisk tilstand. I Odense Fjord er to mudrede områder på ca. 1-1,5 ha i juli 2018 blevet belagt med et 10 cm sandlag (sand-capping). Sandet består af større og tungere partikler, der ikke bliver resuspenderet så let, hvilket giver bedre bentiske lysforhold og bedre forankringskapacitet for fremtidig ålegræs-retablering. Sandet skaber således en membran som indkapsler det flygtige mudder. Formålet med to specialeprojekter har været at undersøge, hvorledes individtæthed og artsdiversitet af infauna og epifauna udviklede sig i de sand-cappede områder af Odense Fjord. Resultaterne blev sammenlignet med nærtliggende områder med det oprindelige mudder. På de to sand-cappede områder udviklede der sig efter få måneder en højere artsdiversitet af både infauna og epifauna end på mudderbunden. Den hurtige succession på sandbunden var domineret af arter med præferencer for hårdt substrat. Resultaterne tyder således på, at sand-capping skaber en øget artsdiversitet og funktionel diversitet. Det er planen, at der skal udføres ålegræstransplantation på de sand-cappede områder baseret på erfaringer fra transplantationer i blandt andet Horsens Fjord. Hvis disse forsøg bliver succesfulde og skaber endnu højere artsdiversitet, vil det være et effektivt marint virkemiddel til at skabe habitater med god økologisk tilstand i vore fjorde.

PRODUCTION CHARACTERISTICS OF MITIGATION MUSSEL CULTIVATION

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Prior work has demonstrated that ‘mussel mitigation culture’ is an effective mechanism for the extraction of nutrients and can impact many aspects of local environmental conditions. As a countermeasure to nutrient enrichment, mussel mitigation culture is a potential management tool within the third management cycle of the Water Framework Directive. The present national production goal of 100K tons of blue mussels is anticipated to be directed mainly towards the marine feeds markets as an alternative protein source.

Mussel production capacity is currently being tested in multiple estuaries around the country to assess mussel mitigation culture as a national and regional tool. Over two growing seasons (2017-2019), six test-line sites and three full-scale mitigation cultivation farms were monitored. As principle factors, linear density of settling material, vertical coverage, cultivation substrate, and relative position within the culture unit were analyzed for yield in terms of total biomass and condition. In the 2017 growth cycle, differing configurations of traditional long lines were tested, yielding ~1400 t per model farm in the Limfjorden. In 2018, different technologies were tested; preliminary results demonstrate capacities for exceeding 3000 t per model farm. In other tested estuaries, settlement and growth of mussels have been positive, suggesting mitigation culture can be applied as a nutrient management tool for many coastal waters.

Modellering af miljøeffekter fra havbrug og mulig næringsstofkompensation ved hjælp af miljømuslinger

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Akvakulturproduktionen af regnbueørred ønskes forøget i de indre danske farvande iflg. Fødevarepakken. Havbrugene er planlagt til at ligge udenfor 1 sømilsgrensen for at begrænse de negative miljøeffekter af de kystnære vandområder. Havbrugene er planlagt til at producere ca. 2.200 tons fisk per år svarende til en ekstra udledning på 100 t-N og 13 t-P per farm. Vi anvendte en 3D model, Flexsem, til at beregne de rumlige og sæsonmæssige effekter af 2 potentielle havbrug beliggende i området øst for Samsø. Vandkvalitet (DIN og primærproduktion) blev mest påvirket i det åbne havområde omkring havbrugene og ændringer var ikke synlige efter at produktionsperioden sluttede i november. Det organiske stof i sedimentet blev forøget under havbrugene pga udsynkning af foderrester og fiskefækalier og nåede ikke at blive omsat inden den næste fiskeproduktionsperiode i området med lav resuspension. Omkring 20% af de udledte næringsstoffer fra havbrugene blev transporteret ind i de kystnære vandområder beskyttet af EU Vandrammedirektivet, men der var ikke tydelige ændringer i vandkvalitet. Den ekstra næringsstofudledning fra havbrug vil dog modvirke de nødvendige reduktioner fra landbaserede kilder for at opnå en god økologisk tilstand. Hvis flere havbrug skal implementeres i de indre danske farvande vil det kræve en detaljeret rumlig planlægning, en optimering af havbrug design og en næringsstofkompensation fra marine virkemidler, fx muslingefarme. Det i gangværende BONUS OPTIMUS projekt har til formål at optimere produktionen af miljømuslinger ift. næringsstoffjernelse ved høstning, udvælge egnede områder for miljømuslingerne og teste anvendelse af muslingerne som fiskefoder.

Høst af søsalat som marint virkemiddel

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Marine virkemidler er biologiske redskaber til at binde eller opsamle kvælstof fra det marine miljø. Et potentielt marint virkemiddel, der hidtil ikke er beskrevet er høst af søsalat. Søsalat optager næringsstoffer under væksten og forekommer lokalt i store mængder i mindre eksponerede områder med eutrofiering. Det er estimeret at der kan forekomme op til 100.000 tons søsalat ved de danske kyster. Søsalaten ender med at rådne, og forårsager dermed lugtgener og lokale tab af rekreativ værdi. samt frigivelse af den bundne kvælstof til miljøet.

I projektet Tang.nu er potentiallet for høst af søsalat som marint virkemiddel, blevet undersøgt.

Forekomsten af søsalat i udvalgte områder blev kortlagt med drone og biomasse opmålinger, og frigivelse af kvælstof og klimagasser under forrådnelsen af søsalat i vand og på land blev undersøgt.

Undersøgelsen viste, at søsalat indeholder op til 3,7% N, og at man potentielt ved at høste alle 100.000 tons, kan fjerne omkring 3 % af de 13.100 tons kvælstof, som ifølge Vandrammedirektivet skal fjernes inden 2021. Hvis man høster søsalaten før den rådner undgår man samtidig emissioner af klimagasserne metan og lattergas fra den rådrende søsalat.

De åbne spørgsmål er: hvordan høster man søsalat skånsomt? Og hvad skal man efterfølgende bruge biomassen til?

Artsdiversitet efter ålegræstransplantation i Horsens Fjord

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Størstedelen af danske fjorde har været udsat for kraftig eutrofiering siden 1960'erne. Dette har haft en negativ effekt på ålegræssets udbredelse på grund af dårligt vandmiljø med periodisk iltsvind og høj turbiditet. Ålegræssets tilbagegang de sidste 30-40 år er stærkt medvirkende til tab af vigtige marine habitater i Danmark. I forbindelse med forvaltning og restaurering af danske fjorde har Syddansk Universitet fået ansvaret for at teste storskala ålegræstransplantation som et marint virkemiddel for at forbedre udbredelsen af ålegræs. Denne teknik har forbedret ålegræssets trivsel og udbredelse i blandt andet Horsens Fjord. Det er dog uvist hvordan successionen af den associerede fauna udvikler sig i det genskabte habitat. I to specialeprojekter blev successionen af hhv. infauna og epifauna undersøgt i de nye miljøer skabt af det transplanterede ålegræs. Resultaterne blev sammenlignet med tilsvarende undersøgelser på nærtliggende barbund og i naturligt forekommende ålegræsbede. Artsdiversiteten af infauna steg med tætheden af ålegræsbevoksningen fra transplanterede til naturlige bede, og var koblet til et fald i antal pionerarter og en større stigning i antal klimaksarter. Epifaunaen, derimod, udviste højest artsdiversitet i det transplanterede ålegræs med en faunasammensætning bestående af små fisk og krebsdyr, som her var beskyttet mod predation fra større fisk. De hidtidige resultater tyder derfor på, at artsdiversiteten af både infauna og epifauna stiger, når man planter ålegræs på sandbund. Der vil dog fortsat foregå en succession af fauna så længe skudtætheden i de transplanterede bevoksninger stiger og nærmer sig tilstanden i de naturlige ålegræsbede.

Spatial variance in production of *Saccharina latissima* as an effect of timing of deployment and seeding procedure in Danish waters

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Recent findings has shown that inner Danish waters can be used for the production of eg. *Saccharina latissima*, but that timing of deployment is crucial in order to obtain a high production (Boderskov & Schmedes, 2013). Especially when using direct seeding methods, timing is of high importance to avoid fouling, but also to have substantial growth before winter.

In order to understand better the right time and method for deployment of *Saccharina latissima* on different sites in Danish waters, different seeding materials were deployed monthly in fall, 2017 on a range of different locations. The length and biomass growth were then monitored until harvest in spring/summer 2018.

The results show that there is a large variation in obtainable production volumes between sites in DK, but also that seeding method and deployment timing is of high importance in order to obtain high production volumes.

Plastic occurrence and microbial communities in the tropical South Atlantic

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Microorganisms, such as bacteria, archaea and fungi, close the major biogeochemical cycles in aquatic environments. Concerns about marine plastic debris in global ocean ecosystems has arisen, but the magnitude to which microorganisms are involved in the transport and fate of plastic remains uncertain. In May/June 2018, the FS Meteor (M148) carried an expedition from Belém (Brazil) along the tropical South Atlantic at 11S until the eastern boundary upwelling regions off Angola and Namibia. Complementary to other cruise investigations, samples were collected for DNA/RNA analysis at selected depths in order to identify the microbial community potentially associated with marine plastics. In parallel, samples for microplastic identification were obtained. Microbial community profiling is carried out using the Qiagen All Prep-kit DNA, followed by quantitative polymerase chain reaction (qPCR) and metagenomics sequencing, while microplastic identification is being developed for these particles using Raman spectroscopy. This investigation aims to provide a microbial community comparison between the open Atlantic Ocean and the upwelling regions off Angola/Namibia as linked to the Atlantic occurrence of plastic debris.

Nyt grønlandsk forskningsskib

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Fisk- og rejebestande i Grønlandsk farvand er siden 1988 blevet undersøgt af RV Pâmiut. Pâmiut er nu forældet og bliver i 2021 erstattet af et nybygget forskningsskib. Skibet bliver 60*16 meter, og skal anvendes til bund- og pelagiskundersøgelser. Hovedfokus bliver på bestandsvurdering af rejer, hellefisk, torsk, makrel og lodde, men i stigende grad bliver kortlægning af benthossamfund og havbundsstrukturer en integreret del af de årlige undersøgelser. Skibet forventes at sejle fra juni til november hvert år.

Skibet bliver udstyret med tre trawlbaner og et trawl optimeret til et blandingsfiskeri på alle dybder. Der bliver monteret en A-frame, et hydrografirum med separate spil og kraner som samlet giver mulighed for varetagelse af alle typer af opgaver. Der er en fabrik, våd- og tørlaboratorier på et sammenhængende dæk, samt arbejdsrum på trawldækket, hvorfra der kan arbejdes med tungt udstyr samt bundprøver og –fauna.

Skibet kommer til at have en fast besætning på 12 personer. Der er derudover plads til 24 forskere/studerende, hvoraf otte har enkeltkahytter og 8 dobbeltkahytter. Skibet får en marchfart på 12 knob, og er udstyret med azimuth thruster, sænkekøl og bliver klassificeret som et såkaldt ”silent F” fartøj. Skibet forventes klar til søsætning i 2021.

Applied method for mapping seagrass beds with digital aerial orthophotos

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Mapping the distribution of seagrass is important for optimal management of seagrass meadows, a key element in coastal ecosystems that is sensitive to eutrophication. The ecosystem services provided by seagrass scale directly with their distribution area, but we lack cost-effective methods to map them. We have evaluated the potential in using a series of archived digital aerial orthophotos to map and quantify the Danish eelgrass distribution. In combination with ground reference data on eelgrass, we performed supervised image classifications based on RGB color bands on summer photos from 2012, 2014 and 2016 of 4 study areas, ranging between 73 and 111 km² in size. The image analysis was restricted to above -2.5 m depth in closed fjords and -5 m on the open coast. A general linear discriminant model displayed an accuracy higher than 95% when applied to all areas and validated by ground reference data. We quantified eelgrass cover in all 4 areas and display short time-series of changes in eelgrass cover. The model performed poorly in areas with excessive sunglint, lack of color normalization, lack of photo coverage and/or other vegetation types. We suggest that with some changes to future photo acquisition and further development of the image processing, to enable nationwide monitoring of eelgrass with this archive of aerial orthophotos. A particular strength of this archive compared to drones or satellite is the long time series that it holds (1954 - 2018), potentially enabling analysis of decadal time series in eelgrass distribution in Denmark. For future mapping, we also see a great potential in combining the use of this archive with other remote-sensing methods such as satellite or drone mapping. Other countries may have similar archived image data, offering the opportunity to implement larger scale monitoring, and study how seagrass areas respond to changes in environmental status. According to the Water Framework Directive, EU member states are obliged to monito

Generel poster for DCH

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Generel poster for DCH, der kort forklarer, hvilke muligheder vi kan bidrage med i forhold til Havforskning (Skibstid, muligheder m. forsvaret, muligheder m. Marinehjemmeværnet, udstyr etc.)

VERMIX: High rates of new production over the shelf edge in the northeastern North Sea during summer

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The VERMIX cruise was carried out in July, 2016 on board R/V Dana and the focus was on investigating the role of vertical mixing and mesoscale variability on biological productivity and ecosystem structure. New production, i.e., that driven by allochthonous nutrient inputs, is the only form of primary production that can lead to net increases in organic material and is, therefore, important for understanding energy flow in marine ecosystems. The spatial distribution of new production in the North Sea is generally, however, not well known.

Using data (turbulence, CTD and water chemistry) , we analysed the potential for vertical mixing to support new production in the northeastern portion of the North Sea. Relatively large nitrate fluxes due to turbulent vertical mixing into the euphotic zone were found over the shelf-edge, while low values were found in the deeper open area north of the shelf-edge. In the shallow (< 50 m) southern and central part of the study area, inorganic nutrients were low and nitrate undetectable suggesting negligible new production here, despite relatively high concentrations of chlorophyll a being found in the bottom layer. Thus, high rates of new production seem to be concentrated around the shelf-edge zone and in association with localised features exhibiting enhanced vertical mixing. Overall, this suggests that the shelf-edge zone may be the major nutrient supplier to the euphotic zone in this area during the period of summer stratification.

Karlodinium armiger produces a lytic toxin (karmitoxin) that kills fish

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The toxic dinoflagellate *Karlodinium armiger* occurs in Atlantic and Mediterranean waters. It regularly forms blooms in Mediterranean waters and these blooms are often associated with severe mortalities of fish and benthic invertebrates [1]. Recently a new toxin, karmitoxin, from *K. armiger* was chemically characterized and a method to purify and quantify the toxin was established [2][3].

In this study, the response of juvenile rainbow trouts, sheepshead minnow fish larvae and a rainbow trout gill cell line to *K. armiger* was studied. All target cells/organisms were killed by the *K. armiger* culture in ecological relevant concentrations. Although rainbow trouts were the most sensitive of the three targets, fish larvae and gills cells may be used as substitutes. Fish larvae and gill cells were exposed to purified karmitoxin and the responses of the target cells/organisms towards this toxin were similar to those observed with *K. armiger* cultures. However slightly higher toxin concentrations were needed in case of the purified toxin to cause mortalities of the target cells/organisms as compared to the amount of toxin found in the live algal cultures. Mortalities were prevented if some of the excreted toxin (30% of total toxin amount) was removed from the algae culture by adsorption to HP20 beads. Some effects were still observed on the fish larvae, probably caused by excreted toxins from the algae during the exposure experiment. A final study revealed that cellular toxin content was constant in an algal culture during 23 days of growth and independent of nutrient source (presence of prey or ammonium). Toxicity of the same culture towards fish larvae correlated with cell concentration and therefore also total karmitoxin content. Altogether, the results show that karmitoxin plays a crucial role in fish kills by *K. armiger*.

References: [1]Garces et al. (2006) J. Phycol. 42, 1096–1112; [2]Rasmussen et al. J (2017) Nat Prod. 80; [3]Andersen et al. (2017) Mar. Drugs. 15, 278

Ålegræs i Vejle fjord

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Eelgrass (*Zostera marina*) used to dominate the seabed in Vejle Fjord and most danish inner inlets. But decades of excessive nutrient loading has lead to decreased eelgrass distribution. Despite a significant well-documented improvement of the water quality in the past 10 years, the eelgrass has a low coverage rate. We have observed that the areas once covered by eelgrass is now either naked sandy bottom or covered with soft organic matter. This change seems to have happened due to increased pollution from the rapid expansion of the city of Vejle from 1940-1980. We entered a collaboration ved The Southern Danish University and the district of Vejle to research the best spot for a larger eelgrass planting. The purpose of this macroscale project is to expand the covered area of eelgrass in Vejle Fjord and in the long term see a larger biodiversity of fish and sealife. Our project started in the spring, where we planted eelgrass at 6 different spots throughout the inlet and we have been surveilling the spots all summer and autumn. Both visually, counting the development of eelgrass shoot, and analysing the water quality, with regards to, nutrients free floating in the water. Our results show that the inner/mid section is the ones with the most growth, and our outer section has been completely covered with sand.

EMODnet: Det europæiske marine data netværk

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EMODnet (The European Marine Observation and Data Network) er et netværk af 160 europæiske organisationer, der arbejder sammen om at indsamle, bearbejde og standardisere eksisterende marine data efter internationale standarder og gøre disse og dataprodukter frit tilgængelige uden restriktioner. Ud fra devisen ”collect once – use many times” vil marine aktører kunne drage nytte af den direkte adgang til data inklusiv erhvervsliv, forskning, forvaltning, politiske beslutningstagere eller offentligheden som helhed. Det er anslået, at en sådan integreret, europæisk, marin datapolitik vil spare Europa for mindst 1 mia. euro/år.

Projektet, der indtil videre fortsætter til og med 2020, er finansieret af EU Kommissionen (DG-Mare) og det understøtter EU’s Marine Knowledge 2020 Strategy.

Fra EMODnet’s dataportaler kan marine operatører se, hvilke data der er tilgængelige for et bestemt havområde på tværs af økonomiske grænser, og frit downloade både oprindelige observationer og afledte dataprodukter såsom digitale terrænmodeller, kort over havbundens sedimenter eller marine habitater. Det er således muligt at foretage fit-for-purpose datasøgning og datavurdering, som det er demonstreret i projektets 6 check-point projekter (<http://www.emodnet.eu/checkpoints>).

EMODnet giver adgang til de europæiske marine data på tværs af 7 disciplin-baserede temaer:

Danmark bidrager til EMODnet via mange forskellige institutioner:

GEUS i EMODnet Geology og EMODnet Seabed Habitats; Geodatastyrelsen i EMODnet Bathymetry, Aarhus Universitet i EMODnet Chemistry, DMI i EMODnet Physics og Energistyrelsen i Human Activities.

På Havforskermødet vil vi præsentere EMODnet initiativet som poster og demonstrere nogle af de data og dataprodukter, projektet giver adgang til.

Mere information findes på www.emodnet.eu

Modelling mussel larval distribution for optimal site selections of mussel farming

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Eutrophication is one of the largest threats to the Baltic Sea manifested by algal blooms, turbid waters, loss of submerged vegetation and hypoxic and anoxic conditions at the sea bottom in large areas. It is well known that marine suspension-feeders possess a significant capacity for clearing the water column of particles. The potential of using bivalves such as blue mussels to mitigate effects of eutrophication in the coastal zone has been proved to be cost-effective in Danish waters.

However, it is still a challenge to optimize mussel farms and mussel production and thereby further reduce costs in order to compete with other mitigation measures. The farm design and locations need to be adapted to different environmental conditions in order to handle e.g. high predation pressure, low salinity, exposure to high wind, waves or ice coverage, but also in terms of efficient mussel larvae settling on the long-lines. Spawning takes place in the natural mussel beds in May-June and the resultant larvae are spread by the water currents to other areas before settling on the bottom or on the long-lines in the mussel farms. In the following study, we used 3D ecosystem modelling to estimate the mussel larval distribution on fine spatial and temporal scales in a local set-up of the Limfjorden. We coupled a 3D physical Limfjord model with an agent based model (ABM) using the Flexsem system, where mussel larvae were defined by several biological parameters. The model provided maps of mussel larvae distribution and will be used for site-selection processes of mussel farming in the Limfjorden. These results are of fundamental importance for the development of mussel farming as a measure to mitigate eutrophication.