HAVFORSKERMØDE 2026

Abstractbog

AARHUS UNIVERSITET

TÆNKE TANKEN Hav

23. Danske Havforskermøde

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Indhold

Key notes

Tirsdag kl. 10:10: Jacob Carstensen

Jacob Carstensen: The future of marine monitoring – promises and pitfalls

Aarhus University

Denmark has a long tradition of marine monitoring with continuous time series going almost 50 years back in time. These observations have provided important insights into the impacts of human activities on the marine environment and are fundamental to assessing compliance with policy objectives such as the Water Framework Directive and Marine Strategy Framework Directive. The methods currently employed for marine monitoring have not changed fundamentally over time, providing consistency for assessing trends. Nevertheless, new technologies have emerged in recent decades with the potential of providing more accurate and precise information at lower cost. However, they typically produce large amounts of data that may not provide ecologically relevant information without developing complex methods for post-processing, e.g. using statistical algorithms and artificial intelligence. This presentation will give an overview of the new technologies for biological monitoring, including remote sensing, eDNA, optical instruments and citizen science, with potential to complement or possibly substitute current monitoring methods, as well as it will address the challenges and weaknesses for implementing these methods.

Tirsdag kl. 13:10: Outi Tevo

Outi Tevo: What do you hear?

Grønlands Naturinstitut

Marine mammals rely on sound as their most important modality to get information on their surroundings, and to communicate with conspecifics. Because of this, all marine mammals produce sounds, and their vocalisations can provide valuable information about their presence, behaviour, and habitat use. This unique behavioural feature makes bioacoustics a powerful tool for research and monitoring, especially in remote regions like the Arctic. The narwhal *Monodon monoceros*, an Arctic whale species, is particularly suited for acoustic research. Living year-round in remote, often ice-covered areas, narwhals are increasingly impacted by climate change and human activity. In this talk, I will explore the unique acoustic world of the narwhal and show how advances in bioacoustics and data analysis can help inform conservation and management decisions. I will also highlight how these approaches can be used to foster greater public interest and engagement in Arctic marine life.

Onsdag kl. 8:30: Poul Holm

Poul Holm: What Did Danish Fisheries Look Like Five Hundred Years Ago?

Imagine standing on the Danish coast in the year 1550. The sea is teeming with life, and fishers are landing catches on a scale that wouldn't be matched again before the 20th century. Thanks to advances in archival research, archaeological excavation, and genetic analysis, we now know the structure and scale of historical Danish fisheries. The evidence reveals that by the close of the Middle Ages, Danish fish catches had reached levels that would not be seen again until the early twentieth century, when motorized fishing vessels revolutionized marine extraction.

My talk offers an overview of these findings, tracing when, where, and how much was drawn from the sea in the late medieval period. But it also asks deeper questions: What factors led to the collapse of these remarkably productive fisheries in the seventeenth century? And why did recovery prove so elusive until the modern industrial era? Ultimately, what does the past reveal about the present?

Onsdag kl. 13:10: Cornelia Jaspers

Cornelia Jaspers: Stressed-out: Fører globale forandringer til danske farvande domineret af gopler?

Technical University of Denmark, National Institute of Aquatic Resources (DTU Aqua)

Klimaændringer og en række andre menneskeskabte presfaktorer påvirker marine økosystemers fødenet-struktur og produktivitet. Særligt er nedgangen i danske nøgle-fiskearter og øgningen af gopler

bekymrende og rejser spørgsmålet om, hvorvidt fisk vil blive skiftet ud med gopler i fremtidens danske farvande.

Dette foredrag vil give et overblik over goplers – og mere generelt gelatinøst zooplanktons - biomasse I de danske farvande, med fokus på de danske fjorde, hvor opblomstring af gopler er vidtudbredt. Gennem en række nye koblede overvågningsinitiativer, forsøg og processtudier belyser jeg, hvordan globale forandringer kan favorisere gelatinøst zooplankton via deres karakteristike træk og modstandsdygtighed. Endvidere diskuterer jeg mulige afledte konsekvenser for økosystemets struktur og produktitet.

Torsdag kl. 8:30: Camilla Snowman Andresen

Camilla Snowman Andresen: Havets hukommelse: hvad marine sedimenter fortæller os om fremtidens klima

GEUS

Der er voksende videnskabelig opmærksomhed omkring de oceanografiske konsekvenser af global opvarmning i Nordatlanten - en region af stor klimamæssig betydning for Kongeriget. Særligt diskuteres samspillet mellem Nordatlantens varme havstrømme, accelereret afsmeltning af Grønlands Indlandsis, havis og potentielle ændringer i den Atlantiske Meridionale Omvæltningscirkulation (AMOC).

Dette samspil er komplekst og kræver klimamodeller, men manglen på observationsdata, der er ældre end de seneste 100 år, begrænser forståelsen. Havbundens sedimenter gemmer dog på masser af information om et foranderligt hav i fortiden. Ved at bore sedimentkerner kan man rekonstruere tidsserier over havstrømmenes udvikling i Nordatlanten - både de varme strømme fra Golfstrømssystemet, de kolde nordlige strømme med hav- og gletsjeris, samt de dybe strømme, der afspejler ændringer i dybvandsdannelsen.

I dette oplæg rejser vi tilbage til to tidligere varmeperioder for at undersøge, hvordan klimaet og havstrømmene i Nordatlanten reagerede på naturlig opvarmning. Først ser vi nærmere på Romertiden (ca. for 2000 år siden), hvor vi undersøger, hvor meget Grønlands største udløbsgletsjer, Sermeq Kujalleq, smeltede - for at blive klogere på om ferskvandsudløb kan have påvirket klimaet i Nordvesteuropa. Dernæst besøger vi sidste mellemistid, Eem-tiden (ca. 130.000-115.000 år siden), som globalt set var 1-2 °C varmere end det førindustrielle niveau og dermed minder om det klima, vi bevæger os ind i i dag. Under Eem-tiden blev tykke aflejringer af marine sedimenter afsat i Danmark, som kan bruges til at rekonstruere variationer i Golfstrømssystemet. Sedimentkerne-studier fra det dybe Nordatlanten viser, at AMOC under Eem-tiden oplevede perioder med markant svækkelse, så nu arbejder vi på at finde ud af, om dette påvirkede klimaet i Danmark.

Torsdag kl. 8:50: Ditte Mandøe Andreasen

Ditte Mandøe Andreasen: Havbeskyttelse og fiskeri i Danmark: Ser vi et grønt kursskifte og hvilken rolle kan havforskningen spille?.

Tænketanken HAV

De seneste år har budt på et markant politisk skifte, hvor havet i stigende grad er rykket op på den politiske dagsorden. Politiske aftaler viser en ambition om at vende den negative udvikling i havets tilstand. Samtidig er havmiljøets tilstand fortsat alvorlig, og afstanden mellem juridiske forpligtelser, politiske ambitioner og reel forbedring i havet er fortsat betydelig. Udfordringerne forstærkes yderligere af klimaforandringer samt planer om nye og flere aktiviteter på havet.

Dette oplæg giver et overblik over, hvor vi står i dag, hvad de politiske initiativer kan betyde for havmiljøet og hvordan forskningen kan spille en endnu større rolle i havforvaltningen. Med afsæt i beskyttede havområder, fiskeri og havplanlægning diskuteres centrale mangler i den nuværende indsats for havet. Marine hedebølger bruges som eksempel på, at Danmark skal inddrage klimaforandringerne i fremtidens havforvaltning i langt højere grad. Der sættes fokus på forskningens rolle i at kvalificere havforvaltningen. Ikke kun som leverandør af data, analyser og resultater, men som aktiv medspiller i udviklingen af scenarier og forslag til konkrete løsninger – til gavn for Danmarks havmiljø.

Præsentationer:

Tirsdag 20.1

Damgaardssalen

Succeshistorier fra over 50 års natur- og miljøforvaltning (10:40)

Lige ved og næsten: Den ufuldstændige genopretning af eutrofieringstilstanden i danske kystvande

Jørgensen, Marie Neel[1,2]; Meilholm, Nanna[1,2]

[1]University of Copenhagen, [2]NIVA Denmark

Danske farvande var stærkt påvirkede af eutrofiering igennem 1980'erne, hvilket resulterede i en række nationale indsatser for at mindske udledningen af næringsstoffer til havmiljøet. Formålet med dette studie var at udforske udviklingen af eutrofiering i de danske farvande efter implementeringen af næringsstofreducerende indsatser ved brug af det multimetriske værktøj HELCOM Eutrophication Assessment Tool (HEAT), samt at rapportere på udviklingen af syv udvalgte eutrofieringsindikatorer: opløst uorganisk fosfor, opløst uorganisk kvælstof, klorofyl *a*, lyssvækkelse, dybdeudbredelsen af ålegræs, dansk kvalitetsindeks (DKI) og iltkoncentration i bundvand. Vi rapporterer på den tidslige og rumlige udvikling af eutrofiering i 109 danske vandområder i perioden 1980-2023. Analysen viste, at på trods af en forbedring i eutrofieringstilstanden i mange vandområder, så er store områder fortsat påvirket af eutrofiering i de danske kystvande. Den nationale eutrofieringstilstand viste en forbedring indtil omkring år 2000, hvorefter den positive udvikling stagnerede. Den samme tendens blev observeret for landsgennemsnittet for opløst uorganisk fosfor og kvælstof, hvorimod andre indikatorer var relative stabile igennem hele perioden såsom iltkoncentration, ålegræs og DKI. Landsgennemsnit for klorofyl *a* og lyssvækkelse viste forbedringer henholdsvis indtil 2012 og 2021, hvorefter en forværring blev observeret for begge indikatorer. Resultaterne tyder på, at implementeringen af de næringsstofreducerende indsatser har været en drivende faktor i at forbedre tilstanden i danske kystvande, men at nuværende indsatser tilsyneladende er utilstrækkelige for at sikre, at danske kystvande klassificeres som 'ikke påvirket af eutrofiering'.

Danish

Restaurering af stenrev - Fra Blue Reef projektet til etablering af Havnaturfonden

Dahl, Karsten

Stenfiskeri har foregået langs de danske kyster og på egentlige rev i mere end 100 år helt frem til 00'erne. Når man vil arbejde med restaurering er det vigtigt at vide hvordan stenfiskeriet er foregået og hvordan det med stor sandsynlighed har efterladt de udnytte lokaliteter.
Denne præsentation vil beskrive udviklingen i både viden, indsats og den politiske interesse fra det første store marine naturgenopretningsprojekt i Europa og frem arbejdet med rev restaurering i 2025 og etablering af Havnaturfonden i 2025. Den markante biologiske gevinst i form af øget biomasser, markant flere bunddyr samt effekter på fisk og marsvin ved at restaurere stenrev bliver belyst med resultaterne fra Blue Reef projektet ved Læsø Trindel. Projektet er det bedst undersøgte restaureringsprojekt i Danmark, om end det fulde billede endnu ikke kendes. Præsentationen vil også beskrive hvordan er vi blevet klogere med at tilrettelægge restaureringsprojekter gennem årene, herunder hvordan man undgår at komme i konflikt med målsætninger for de marine direktiver.

Danish

Når regulering virker – TBT-forbuddet og dets betydning for havmiljøet

Strand, Jakob[1]

[1]Aarhus Universitet, Ecoscience

Forbuddet mod anvendelsen af det miljøfarlige biocid tributyltin (TBT) i antibegroningsmaling til skibe udgør en af de mest markante succeser i dansk miljøforvaltning. Danmark indførte allerede i 1991

restriktioner for lystbåde, efterfulgt af et bredere internationalt forbud hos IMO i 2003, der også omfattede påføring på større skibe, og et endeligt forbud i 2008, hvor alle TBT-malede fartøjer i EU havne blev omfattet.
Før reguleringen var TBT-forureningen udbredt i danske farvande, med høje niveauer påvist i både åbne og kystnære områder samt i dyrelivet i toppen af fødekæden som marsvin. Tydelige biologiske effekter blev dokumenteret, herunder hormonforstyrrelser i en række arter af havsnegle (imposex og intersex), selv i de dybere dele af de åbne farvende. Derudover var mange havneområder særligt hårdt ramt med kraftigt forurenede sedimenter og påvirkede økosystemer.
Som dokumenteret i NOVANA overvågningen faldt TBT-niveauerne markant efter indførelsen af forbuddene, især i perioden 2003–2010, og er i dag i de fleste danske vandområder reduceret til et niveau, hvor koncentrationerne i sediment og blåmuslinger ligger under detektionsgrænsen, og forekomsten af hormonforstyrrede snegle næsten er ophørt. Enkelte havne viser dog i dag fortsat forhøjede koncentrationer af TBT i sediment og muslinger og også med tydelige effekter på snegle, der lever her. Nogle af de forurenede havne kan dermed stadig pga TBT have udfordringer i forbindelse med opgravninger og klapning af havbundsmaterialer.
Samlet set illustrerer TBT-historien, hvordan målrettet international regulering kan føre til betydelige forbedringer i havmiljøets tilstand.

Danish

International fisheries, international management decisions and the chance of seeing a bluefin tuna jump near Denmark

MacKenzie, Brian[1]

[1]DTU Aqua

Bluefin tuna, Thunnus thynnus, is a charismatic large highly migratory fish species which now again visits Danish waters after a long period of rarity or absence. The species was a common seasonal resident until the early 1960s but then within a few years became extremely rare. This situation lasted for decades until they started coming back in large numbers in the early-mid 2010s. This species has high value both as a recreational and commercial fishing species, and for eco-tourism. While present in Danish and neighboring waters (e. g., North Sea, Norwegian Sea) the species is a predator of herring, mackerel, garfish and other species. The reasons for its disappearance and reappearance are speculative and have not been fully described or identified. In addition the timings of the disappearance and reappearance were not forecasted by scientists or managers so the events were unexpected. In this presentation I will summarize some of the hypotheses for these changes, including the roles of international (including Danish) fisheries and international management on these events. These factors have most likely had major roles on both events. In particular, a new international recovery plan implemented in 2008-2010 following years of unsustainable, unreported and illegal fishing has led to a rapid and major increase in biomass, geographic range and fishery yields. And now it is possible to see this species attacking and jumping for prey in Danish waters again. The recovery of biomass and range of this population, which was on a trajectory of collapse and which migrates across and through multiple national and international jurisdictions, demonstrates that some management actions can be successful if supported by societal and political will.

English

Successful management of seals in Denmark since mid 1970s

Jonas Teilman[1], Anders Galatius[1]

[1]Department of Ecoscience, Aarhus University

Harbour seals were extensively hunted in Denmark and have been driven to local extinction in some areas. After protection from hunting in 1977 and establishment of protected areas where seals can rest without disturbance, all sub-populations of harbour seals in Danish and adjacent waters have shown an overall abundance increase. This is despite several epizootic events, with regional mortalities up to 60% of all harbour seals. Besides harbour seals, also grey seals are slowly reestablishing their former distribution in Danish waters. The grey seal was the more abundant seal species in Denmark, but was driven to extinction due to hunting, as their pups were easy to kill on the beach. This presentation show how effective protection and management can successfully help reestablish populations of large predators, but it also show that human interactions and disturbance may be limiting factors that require constant adjustments in wildlife management.

English

Sensing the Sea – Advancing Marine Monitoring I – Remote Sensing and Habitat Modelling (13:40)

Advancing Satellite-Based Monitoring of Water Clarity and Chlorophyll-a in Danish Marine Waters

Holbach, Andreas[1]

[1]AU-ECOS

Accurate monitoring of water clarity and chlorophyll-*a* (Chl*a*) is essential for assessing marine ecosystem health and eutrophication, particularly in optically complex coastal environments. This contribution presents two novel remote sensing approaches developed at the example of Danish marine waters, both utilizing operational and publicly available Sentinel-3 OLCI Level 2 data products processed with the Case 2 Regional CoastColour (C2RCC) algorithm.
The first approach introduces a spectral modelling framework for estimating diffuse light attenuation across the photosynthetically active radiation (PAR) range between 400–700 nm (Holbach et al., 2025a). It integrates satellite-derived inherent optical properties (IOPs), applies multivariate outlier filtering, and employs an iterative method that mimics *in situ* PAR profiling. Validation against 1,458 *in situ* profiles (2018–2023) from the Danish marine monitoring program NOVANA showed strong agreement (R = 0.63), outperforming existing satellite-based methods and enabling improved spatial and temporal coverage of water clarity.
The second approach focuses on enhancing Chl*a* retrievals from the same Sentinel-3 OLCI data (Holbach et al., 2025b). A geographically weighted regression (GWR) method was developed using cost-distance metrics to derive spatially resolved scaling factors linking satellite-derived pigment absorption to *in situ* Chl*a* concentrations from NOVANA (2018-2023). The optimized method significantly reduced bias and root mean square error, enabling for regionally tuned and spatially continuous Chl*a* mapping.
Together, these methods demonstrate the potential of satellite-derived IOP products and spatial optimization techniques to improve marine monitoring in support of the EU Water Framework and Marine Strategy Framework Directives. Although developed for Danish waters, both approaches show strong potential for spatial upscaling and broader application in other coastal regions.

English

ARGO bøje teknologi som en supplement til havmiljøovervågning.

Stedmon, Colin[1]; Toftegård, Bodil[2]; Mariani, Patrizio[2]

[1]Technical University of Denmark, National Institute of Aquatic Resources (DTU Aqua), [2]Danmarks Tekniske Universitet, Institut for Akvatiske Ressourcer

EU's Havstrategidirektiv forpligter lande til at dokumentere havmiljøets tilstand og kvantificere effekten af tiltag, der skal beskytte eller forbedre den. NOVANA, det Nationale Overvågningsprogram for Vandmiljø og Natur, har til formål at sikre, at Danmark lever op til direktivet samt national lovgivning og internationale konventioner om miljøovervågning.
De metoder, der anvendes til marineovervågning, har dog ikke ændret sig væsentligt de sidste 25 år, selvom der har været en rivende udvikling i sensor- og platformteknologi. Her viser vi, hvordan teknologi udviklet til det globale Argo-program kan bidrage til miljøovervågning i danske farvande. I en 20-måneders periode fra 2023 til 2025 har vi haft en profilerende undervandsbøje i Arkonahavet vest for Bornholm, med parkering på havbunden mellem profiler.
Data og resultater giver ny indsigt i: i) udviklingen og reguleringen af sæsonbetinget iltsvind i bundvandet, ii) betydningen af den fytoplanktonopblomstring, der udvikler sig om sommeren under blandingslaget, og iii) kvalitetssikring af satellitbaserede målinger af lyssvækkelse. Resultaterne demonstrerer, hvordan den høje tidslige og vertikale opløsning, der kendetegner Argo-målinger, afslører mekanismer, som hverken er tydelige eller økonomisk rentable at opnå med skibsbaserede overvågningsmetoder. Data fra disse bøje, når de er registreret under det globale Argo-program, er standardiseret, frit tilgængelige i realtid og bruges af en række aktører på tværs af forskning, forvaltning og private virksomheder. Danske marineovervågningsaktiviteter kan både bidrage til og drage nytte af synergien.

Danish

High-Resolution Species Distribution Modelling to Guide Eelgrass Management

Staehr, Sanjina[1]; Staehr, Sanjina; Göke, Cordula; Holbach, Andreas; Krause-Jensen, Dorte; Azhar, Mihailo; Carstensen, Jacob; Staehr, Peter

[1]Aarhus University

Global marine biodiversity is undergoing rapid change, highlighting the urgent need for scalable, cost-effective methods to map and monitor marine ecosystems. One example is eelgrass (*Zostera marina*) meadows, which are declining globally despite their ecological importance and role as indicators under the EU Water Framework Directive (WFD). With the EU Nature Restoration Regulation mandating ambitious recovery targets for key habitats, robust predictive tools are needed to guide restoration planning and prioritize areas for intervention.

Traditional survey methods often struggle to capture the complex spatial patterns of benthic habitats, especially in shallow coastal zones. To address this, we developed a high-resolution (50×50 m) species distribution model (SDM) for *Z. marina* across Denmark's >7,000 km coastline using machine learning techniques and long-term monitoring data (2011–2022). The model was trained on ~30,000 field observations from the Danish NOVANA program and validated on ~8,000, achieving strong predictive performance and spatial generalizability.

Beyond mapping current distributions, the SDM enabled estimation of depth limits (Zmax) of Z. marina, which were compared against Zmax values reported under VP3 water bodies-standardized ecological units used in Denmark's WFD implementation. The SDM also offers potential for scenario modelling to assess restoration feasibility under improved water clarity and future climate conditions.

The methodology is adaptable to other species and regions, offering a scalable framework for continuous marine monitoring. It aligns with emerging trends in AI-powered environmental sensing and supports integration with remote sensing platforms for broader ecosystem assessments. By combining machine learning with long-term ecological data, this work contributes to the development of automated, repeatable, and policy-relevant tools for marine habitat mapping. It advances the goals of nature restoration and biodiversity conservation in Denmark and beyond and demonstrates how AI-enhanced modelling can inform adaptive management under changing environmental conditions.

English

Kystnær kortlægning på alle skalaer: Satellitbaseret opgørelse af undervandsvegetation understøttet af dronemonitering

Svane, Niels[1]; Tangaa, Lisbeth[2]; Huber, Silvia[2]; Boye Hansen, Lars[2]

[1]University of Southern Denmark, [2]DHI A/S

Traditionel monitering af undervandsvegetation, især ålegræs, ved de danske kyster er en både vigtig og arbejdstung opgave. Moniteringen af ålegræs er pt. baseret på dykker- og videotransekter med en ganske lav rumlig dækning, men med høj informationsværdi. For at integrere stor arealdækning – potentielt på national skala – med høj detaljegrad, samarbejder DHI og SDU om en kombination af hhv. fly, satellit- og dronebaseret data, hvor hele fjordsystemers sammensætning kan kortlægges. To gennemgående klassifikationsmetoder præsenteres her:

- En egenudviklet deep-learning (DL) model til analyse af satellit- og fly-data (DHI) (Stæhr et al., 2024).
- En GIS-orienteret objekt-baseret machine-learning (OBML) model til analyse af højopløst dronedata samt dronebaseret ground truthing (SDU) (Svane et al., 2021).

Begge modeller viser gode resultater på deres respektive skalaer (drone: 50-1200 hektar, satellit: hele fjordsystemer), og er relativt robuste overfor svingende datakvalitet. DL-modellen viser stor styrke ved klassifikation af undervandsvegetation på varierende dybder, forskellige lokaliteter og ved varierende billedkvalitet. OBML-modellen er især optimal til kortlægning af ændringer på begrænset geografisk skala, sporing af stresspåvirkning på ålegræsset og detaljeret indsigt i bed-vækst og -tab.
DL-modellen kræver en omfattende forudgående træningsfase, mens OBML-modellen kræver omfangsrig korrektion i post-processering, og er følsom overfor lokale miljøforhold. Vi præsenterer her de to metoders styrker og svagheder, samt hvor de understøtter hinanden, eksempelvis brug af drone-data som validering af den satellitbaserede model. Et færdigt workflow, med anvendelse af begge modeller, samt et case-study fra Odense fjord vil blive gennemgået, og metodernes integration i national monitering og kortlægning af bl.a. restaureringsaktiviteter bliver berørt.

Danish

Use of Copernicus Sentinel satellite data products for water quality evaluation in Norwegian coastal waters within the water framework directive

Harvey, Therese[1,2]; Balfanz, Alicja[3]; Brockmann, Carsten[3]; Lebreton, Carole[3]; Philipson, Petra[4]; Saesin, Pipatthra[5]; Sørensen, Kai[6]

[1]NIVA Denmark Water Research, [2]Norwegian Institute of Water Research, [3]Brockmann Consult, [4]Brockmann Geomatics, [5]Norwegian Institute for Water Research, [6]Norwegian Institute for Water Reaserch

The Norwegian Environmental Agency (NEA) has expressed a need for a complementary dataset of water quality to the traditional monitoring programs, that could be used for deriving the water quality status classification for the EU Water Framework Directive (WFD). The ØKOSAT project started in 2023 and here we demonstrate the main results of the evaluation of Sentinel-2 and Sentinel-3 downstream products of Chl-a and Secchi depth for around 50 coastal areas and discuss the way forward for using satellite remote sensing data for water quality status assessments. The Sentinel data between 2015-2023 were processed to water quality products (e.g. Chl-a, Secchi depth, Turbidity) and different algorithms were applied. In situ data from the monitoring programme was gathered during the same period and used for evaluating the satellite products. The Secchi depth data also show a large variation with Sentinel-2 and in situ and a range of 0.5-1 m is normal for a common observation, as this parameter can have many error sources. The coastal products were in general performing well both for Chl-a, with some overestimations of Chl-a and spikey Sentinel-2 data and the Secchi depth are most often within the range of the in situ data but with high variability, but unfortunately in situ data for Secchi depth is often lacking.
Further work is currently being done for an automatic algorithm selection based on the evaluation results using the spectral signal and optical water types (OWT) as input to train a machine learning algorithm. The OWT based selection algorithm will be applied for as many water bodies as possible to provide EO based Chl-a, Turbidity and Secchi depth data to be used in status assessment for the WFD in the coming years.
Parallel and in close collaboration with the end-users an operational system for processing and deliverable of remote sensing data has been set up. The data deliverable will be as extractions of satellite data for monitoring stations and water body data on a near-daily basis together with a Viewer for visualizing the products directly to the users.

English

AquaINFRA and FAIR data: An online data infrastructure for supporting a healthy ocean, coastal, and inland waters

Özkan, Simon; Harvey, Therese; Frigstad, Helene; Balkoni, Areti

Lack of easy access to quality-assured and ready-to-use scientific data is an obstacle for many researchers and data scientists. Considerable time is often spent locating and extracting data from different sources, time that could be used more effectively for data analysis, method development, and scientific writing. To overcome this, the principles of Findable, Accessible, Interoperable, and Reusable (FAIR) data have been established within the European Union, for example, through the European Data Strategy (European Commission, 2020). The goal of the FAIR data principle is to create open access platforms that provide transparent and user-friendly data. Supported by the European Commission's Horizon Europe Research programme (AquaINFRA Home), AquaINFRA has developed the AquaINFRA Virtual Research Environment (VRE), an open-access platform that provides up-to-date high-quality data accros the full water continuum spanning inland, coastal, and marine environments.
The practice of the FAIR data principles and the AquaINFRA VRE is illustrated using the Norwegian FerryBox dataset. A FerryBox system continuously measures physical, chemical, and biological parameters from systems installed on ships-of-opportunity. These systems provide continuous, cost-effective time-series data along fixed transects that can be deployed on both coastal and offshore vessels, enabling coverage across diverse ecosystems. As an example, rapid changes during an extreme weather event will be used to showcase the AquaINFRA VRE together with the Galaxy platform developed in the project.

English

Sensing the Sea – Advancing Marine Monitoring II – Underwater Monitoring (15:30)

Modelling biofouling risk for predictive maintenance of optical water quality sensors

Elsäßer, Jannik[1]; Palmitessa, Rocco[1]; Esbjørn Kristensen, Sten[1]

[1]DHI

Online water quality sensors are crucial to continuously assess the impact of human activities at sea and meet environmental regulations. Underwater sensors are commonly affected by biofouling, the unwanted buildup of marine flora and fauna on sensor heads, which is the primary reason for the need for maintenance of water quality sensors. Optimizing maintenance has the potential to improve data coverage, reduce costs and reduce the environmental footprint from situ monitoring. We propose a method to address biofouling proactively, by predicting its likelihood and informing the maintenance schedule, instead of reacting after the incoming observations show that the sensor has been compromised.

A large marine monitoring program is in place to monitor the environment during construction of the Fehmarnbelt Fixed Link project which will connect Denmark and Germany with an 18 km long tunnel. We have used time series data as well as logs from the quality control and station service reports from 14 online water quality monitoring stations to create a 'survival analysis' dataset.

Using this comprehensive dataset and DHI's expertise, we then applied statistical survival analysis models to predict the time until a biofouling event is likely to occur, as a function of the provided covariates i.e. parameters which can influence the biofouling, e.g. location of the monitoring station, the season, the time since last service etc. Our top-performing model, a gradient-boosted Cox proportional hazards model [1], [2], displayed high predictive capabilities with concordance index of 0.984 and a cumulative dynamic AUC of 0.989.

The survival analysis model is hence promising in terms of being able to predict the time until biofouling may compromise the quality of monitoring data. Our model can be used as a decision support tool for proactive service planning. By accurately predicting the likelihood and timing of biofouling, we will test if this in the future can optimize the maintenance schedule and at the same time extend the sensor uptime.

English

Towards Climate-Resilient Shellfish Aquaculture: Early Warning and Mitigation Technologies in the CASA Project

Hermannsen, Line[1]; Thomasberger, Aris[1]; L. Maarbjerg, Kasper[1]; Trapp, Stefan[2]; V. Pérez, Borja[2]; Saurel, Camille[1]

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Coastal waters in Denmark are increasingly impacted by acute hypoxia and toxic gas emissions such as hydrogen sulphide, driven by the cumulative effects of eutrophication, slow water exchange and climate change. These extreme events impair marine organism performance, cause mortality, and pose serious challenges for shellfish farming. The CASA (Climate Adaptive Shellfish Aquaculture – EFHAF) project aims to develop proactive farm management strategies to reduce biomass losses under low-oxygen conditions and predation pressure.

To address these challenges, CASA focuses on two key innovations: an Environmental Monitoring and Early Warning System (EWS) that provides real-time alerts during extreme anoxic events to inform farmers and support adaptive farm management, and the use of Sediment Microbial Fuel Cells (SMFCs) as a passive mitigation strategy to improve benthic conditions by reducing hydrogen sulphide levels.

In summer 2025, self-powered oxygen sensors were deployed at a mussel farm in Skive Fjord, Limfjorden, an area prone to hypoxia. These sensors continuously monitored oxygen saturation and transmitted data remotely, laying the foundation for site-specific alerts. Extended hypoxic periods were recorded at the seabed during the monitoring campaign. Concurrently, a prototype platform equipped with eight SMFC units was deployed for three months (June–August 2025). Microbial activity within the SMFCs increased

markedly when oxygen concentrations at the bottom dropped below 2.5 mg/L, indicating enhanced electron transfer and potential for hydrogen sulphide reduction. Initial results demonstrate the feasibility of SMFCs as a passive, farm-integrated solution for improving benthic conditions during critical periods.

We present insights from CASA's first year, showcasing sensor technologies for early detection of hypoxia and SMFC functionality in mitigating formation of toxic compounds, and discuss the further development of climate-adaptive tools to support resilient and sustainable shellfish aquaculture.

English

The future of seafloor monitoring combines imaging, acoustics and automated image annotation

Maar, Kristian[1]

[1]DHI A/S

We present a combined imaging and acoustic approach to benthic biotic surveying based on high quality still images and correlated echograms of seabed targets such as eelgrass, macroalgae and coral reefs. Based on our experience with monitoring of coastal ecosystems we have recently developed and tested a new sensing platform and associated analyses methodology which we believe offers an improvement over the current industry practices. Conventional underwater imaging systems often rely on video and ambient light or constant artificial light sources to collect seabed images which are subsequently annotated by experts. These approaches focus on subjective assessments to identify key species or monitor the health of coastal ecosystems. We present our suggestion for 1) improving the image data by capturing high quality still images with stroboscopic illumination resulting in consistent and uniform illumination intensity and color rendering independent of depth, weather, angle of the sun etc. 2) recording echograms of key habitats such as eelgrass to provide volumetric quantification as well as an independent measurement of the target habitat. 3) reducing subjectivity and the reliance on expert annotators by developing a neural network to automate the annotation of key target habitats or species in both image and acoustic data. Furthermore, acoustic data provides improved operational performance in turbid conditions as it is less hindered by low visibility, a major obstacle in underwater imaging. Unfortunately, much of the data captured by legacy systems and stored in databases cannot be reanalyzed with novel machine learning approaches due to inferior image quality and inconsistencies, and the associated output formats are rarely transferable or display significant variation between annotators. Capturing sharp, well lit and consistently illuminated images provides a robust record of coastal habitats and offers a more generally useful foundation for future developments in analyses methodologies. We present here images, echograms and the associated neural network analyses based on the first trials of our system and share our recommendations for accurately recording coastal habitats in a world of rapidly evolving technologies.

English

Utilizing Push-Broom Fluorescence Hyperspectral Imaging for Classification of Underwater Flora and Fauna

Marc C. Allentoft-Larsen[1], Mingjun Chi[2], Mihailo Azhar[1], Karsten Dahl[1], Paul M. Petersen[2], Christian Pedersen[2], Hans Jakobsen[1]

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This study explores the application of fluorescence hyperspectral imaging (FHSI) for marine ecosystem monitoring, integrating laser-induced fluorescence (LIF) with hyperspectral imaging (HSI), an approach rarely used for ecological analysis. FHSI enables precise identification of photopigmented marine flora based on their unique fluorescence signatures. Key pigments, including chlorophyll-a, chlorophyll-b, carotenoids, and accessory pigments, emit distinct fluorescence signals when excited by specific wavelengths. This capability addresses challenges in marine ecology, such as overlapping optical properties and complex underwater conditions. Using a 450 nm blue laser and a push-broom HSI system, along with a one-dimensional convolutional neural network, we classified macroalgae, eelgrass, and blue mussels. The method demonstrates high efficiency and precision for detecting photopigment-bearing organisms while revealing limitations in low-fluorescence organisms, such as mussels. To evaluate the ecological applicability of the setup, we further conducted a beta field test in Roskilde Fjord. The laser provided sufficient excitation to resolve clear chlorophyll-a fluorescence despite sun-induced backscatter; however, assembling push-broom scans into stable hyperspectral cubes was challenged by

object motion and potential instability of the imaging system. These findings underline both the promise of FHSI for benthic habitat analysis and the need to address motion-related constraints before robust deployment in automated marine ecosystem monitoring.

English

Visual Anomaly Detection for Marine Monitoring

Bengtson, Stefan Hein[1]; Pedersen, Malte[1]

[1]Aalborg University

The use of visual monitoring systems in marine environments has increased rapidly over the past years, resulting in an exponential growth in image and video data. A majority of this data is typically redundant, depicting static environments or routine events, while only a fraction contains information of true relevance. The sheer amount of data makes it infeasible for humans to manually analyze everything. That said, over the past decade, deep learning has matured automated image and video analysis in tasks such as object detection (e.g., identifying whether a fish is present) and classification (e.g., recognizing that the fish is a cod). These advances have enabled more time-efficient and objective approaches in ecological monitoring, fisheries management, and environmental monitoring.

However, a key limitation arises when deploying cameras in new or dynamic environments; species or objects of interest may appear that were not represented in the training data of the object detection or classification models.
In such cases, these models often fail to recognize the unseen categories. To address this gap, anomaly detection algorithms can be employed. Rather than relying on predefined labels, these methods learn the distribution of normal data and highlight inputs that deviate from it, thereby flagging potentially novel events for further inspection. Additionally, integrating anomaly detection with active learning frameworks allows detected anomalies to be used iteratively to refine other models for, e.g., object detection or classification.

In fisheries monitoring, anomaly detection can be used to minimize observer effort by only highlighting rare occurrences such as bycatch. This is especially relevant for large pelagic trawlers, where manually sampling the total catch is infeasible. Similarly, in long-term underwater deployments, where cameras record hundreds or thousands of hours of potentially empty habitat, anomaly detection algorithms can isolate the short intervals where fish or other organisms enter the scene.

English

Offshore biodiversity monitoring using an automated eDNA sampler

Jacobsen, Magnus Wulff; Nielsen, Einar; Bekkevold, Dorte[1]; Arcieri, Manuel[1]

[1]DTU Aqua

Marine biodiversity is under increasing pressure due to anthropogenic impacts, environmental change, and climate warming. This has led to a growing need for monitoring and documenting existing marine biodiversity. However, there are several challenges associated with documenting marine biodiversity largely due to the high cost of traditional methods for generating biodiversity data. One emerging monitoring method is the analysis of environmental DNA (eDNA), which is defined as genetic material collected directly from the environment, outside of living hosts. eDNA can be easily collected through water filtration and it can be analyzed to detect either single species using quantitative PCR (qPCR) or analyzed for broader species communities using metabarcoding. Despite its potential, eDNA also presents several fundamental challenges, some of which are particularly relevant for remote offshore marine biodiversity monitoring. These include the need for dedicated vessel time, which significantly increases operational costs and the time lag associated with analyzing the samples.
We present data from four different field campaigns using a so-called ecogenomic sensor, the second-generation Environmental Sample Processor (2G-ESP). This instrument is a unique, autonomous and stationary eDNA sampler and analyzer that can operate at sea for several months, depending on power supply, while being remotely controlled by scientists on land. During deployment, the 2G-ESP can collect samples and analyze them using qPCR, with results accessible to scientists on land in real time. It can also store filters for subsequent analysis post-deployment, using either qPCR or metabarcoding methods, enabling the analysis of broader species communities. Hence the 2G-ESP offers a possibility to mitigate some of the limitations normally associated with marine offshore eDNA monitoring.
Here, we present the practical and analytical challenges encountered, along with results from the four deployments focusing on biodiversity assessment of a wide range of species including fish,

elasmobranchs and marine mammals. We show how the instrument can be used for real-time species detection and how temporal offshore eDNA sampling can be used to better cover full biodiversity in an area. In the end we provide an overview of the potential applications of this technology in future offshore biodiversity monitoring.

English

Jorn

Marine Biogeochemistry I - Hidden nitrogen: Internal Sources in Coastal Waters (10:40)

This session explores internal nitrogen sources in shallow coastal waters — nitrogen made available within sediments and the water column rather than from land. Presentations will highlight how these internal processes shape ecosystem productivity and nutrient dynamics.

Kvælstofpuljen i vores fjorde – hvor lang tid går der før den er reduceret tilstrækkeligt til at opnå god økologisk tilstand?

Markager, Stiig[1]

[1]Aarhus Universitet, Institut for Ecoscience

Det er velbeskrevet at eutrofieringstilstanden i vores fjorde bestemmes af den mængde kvælstof som fytoplankton har adgang til. Dette kvælstof stammer fra eksterne tilførsler – hovedsagelig fra land – og så den interne pulje, som via remineralisering bidrager med nyt uorganisk kvælstof. Det er derfor relevant at se på udviklingen i den aktive kvælstofpulje, som kan vurderes ud fra målinger af koncentrationen af total kvælstof.
De tidligste data vi har er fra ca 1980, og fra 1980 til år 2000 sker der ca en halvering af kvælstoftilførslerne fra land. I samme periode falder koncentrationen af total kvælstof, men ikke med en halvering. Efter år 2000 har tilførslerne af kvælstof fra land været konstante, mens koncentrationen af total kvælstof fortsat udviser et fald. Det er rimeligt at antage, at dette fortsatte fald, skyldes en tilpasning hen imod en ny ligevægtstand, hvor tabsprocesser, som fortynding og denitrifikation, afhænger af kvælstofpuljens størrelse, og derfor stadig er på et højt niveau.
I indlægget analyseres disse forhold. Analysen viser at kvælstofpuljen i fjordene falder med mellem 0,04 og 3,6 procent pr. år ud over de ændringer, som skyldes ændringer i tilførslerne fra land.
Ud fra estimater af den koncentration af total kvælstof, som er i overensstemmelse med god økologisk tilstand, kan man beregne, at der typisk vil gå mellem 6 og 45 år, før vi opnår god økologisk tilstand. Der er dog fjorde, hvor man ikke kan beregne en opfyldelse af målene i vandrammedirektivet, uden en betydelig større reduktion af tilførslerne, end det som er indeholdt i de nuværende vandområdeplaner. Det gælder især de indre lukkede fjorde, som Roskilde Inderfjord, Indre dele af Isefjorden og dele af Limfjorden.

Danish

The Effect of Sediment Resuspension on Pelagic Nitrogen Fixation in a Danish Fjord

Schlangen, Isabell[1]

[1]University of Southern Denmark (SDU) Odense

Sediment resuspension, driven by wind, waves, and tides, mixes benthic and pelagic environments by introducing sediment, nutrients, and microorganisms into the water column. While previous studies suggest resuspension enhances N_2 fixation, its impact remains unclear. Prior to our experiment in the microtidal fjord environment of Kærby Fed (Odense Fjord, Denmark), we experimentallyl determined the amount of resuspended material under various bed-shear-stress intensities, providing a novel approach to assessing its effects. Contrary to expectations, our data showed no significant increase in N_2 fixation rates under varying resuspension intensities. Instead, rates were influenced by geochemical dynamics, particularly phosphorus release during anoxic events. The diazotrophic community, primarily composed of Proteobacteria related to sulfate-reducing bacteria, was well-represented in the pelagic environment, likely sustaining observed N_2 fixation rates. These findings highlight the importance of environmental conditions in regulating pelagic N_2 fixation and contribute to nitrogen budget assessments for coastal systems.

English

Nitrous Oxide Dynamics in the Bay of Bengal OMZ – Microbial Drivers of Production and Consumption

Xu, Peihang[1]; Jacobsen, Mats[1]; Schlangen, Isabell[1]; Bonn, Laurenz van[2]; Bange, Hermann[2]; Löscher, Carolin[1,3]

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The Bay of Bengal (BoB) oxygen minimum zone (OMZ) is a critical, yet understudied, region for nitrous oxide (N_2O) cycling, a potent greenhouse gas and ozone-depleting agent. While OMZs are known hotspots for N_2O emissions, N_2O dynamics in the BoB are underexplored, and the mechanisms governing its production and consumption remain unclear. Unlike other OMZs, the BoB exhibits pronounced oxygen variability, ranging from hypoxia to near-anoxia in OMZ core waters, creating dynamic niches for microbial nitrogen transformations.
Here, we investigated N_2O dynamics and its microbial drivers using metagenomics, qPCR, and biogeochemical profiling in the BoB, which were sampled during the April-May 2024 pre-monsoon period, characterized by developing stratification. N_2O concentrations (5-134 nmol/kg) increased with decreasing oxygen vertically, peaking in the OMZ core, suggesting active production via nitrification and partial denitrification. However, in the near-anoxic waters of Station 32 (northwestern BoB), N_2O depletion coincided with a secondary nitrite peak and high chlorophyll *a*, indicating localized N_2O consumption. This was in line with a detected maximum in *nosZ*—a key gene for N_2O reduction. Strikingly, qPCR data revealed that atypical *nosZ*, instead of typical *nos*Z, was dominant across the BoB, suggesting its broader importance in mitigating N_2O emissions.
N_2O production was linked to both nitrifiers (ammonia-oxidizing archaea (AOA) *amoA* and AOA *nirK*) and denitrifiers (bacterial *nirK*, *nirS*, *norB*). In the southern stations of the cruise track, relative abundances of AOA *amoA* and AOA *nirK* showed a similar trend as N_2O, suggesting nitrification-associated production to be dominant. In the anoxic-suboxic OMZ core of northern stations, N_2O production is potentially primarily driven by partial denitrification, as evidenced by the co-occurrence of peak N_2O levels and elevated relative abundance of denitrifier genes (bacterial *nirK*, *nirS*, *norB*).
Our results demonstrate oxygen-mediated partitioning of N_2O cycling, with source–sink dynamics and baseline estimates for the BoB. The decoupling between widespread production and restricted consumption suggests present conditions may favor net N_2O accumulation though seasonal forcing and OMZ ventilation could also enhance consumption, especially in the northwest of the BoB. These findings highlight the need to integrate microbial and physical drivers when predicting N_2O fluxes from tropical OMZs.

English

Nitrogen fixation and Particle-Associated Diazotrophs in the Gulf of Finland

Reeder, Christian Furbo; von Friesen, Lisa W.; Lemke, Josephin; Mundil, Sarvesh; Spilling, Kristian; Farnelid, Hanna

Dinitrogen (N_2) fixation is a main way of introducing bioavailable nitrogen into the ocean. This energy-intensive process is done by specialized organisms called diazotrophs. While cyanobacterial diazotrophs have adapted to avoid oxygen irreversible inhibition of the enzyme nitrogenase, less is known about non-cyanobacterial diazotrophs (NCDs) adaptations. Increasing research suggests that low-oxygen organic particles, may be a suitable niche of diazotrophy. However, our understanding of NCDs and their interactions to marine snow remains limited.

We conducted a seasonal study (weekly, August-September 2024) in the Brackish Gulf of Finland. Diazotrophic communities and their activity were assessed using *nifH* gene amplicon sequencing and stable isotope-based N_2 fixation measurements. Samples were collected from bulk water, suspended, and sinking particles, separated into two size fractions (<3µm and >3 µm), at 5 m and 25 m depth. We saw a seasonal shift in diazotrophic community composition. Thermodesulfobacteriota dominated the >3 µm size-fraction, across all depths and sample types, suggesting their involvement in particle-associated N_2 fixation. In August, Pseudomonadota (e.g. **γ**-proteobacteria) dominated the <3 µm fraction, especially in sinking particles and bulk water. By September, a cyanobacterial bloom emerged (Pseudoanbaena dominating <3µm and

and Nodularia >3 µm size fractions), accompanied with increased N_2 fixation rates (>20 nmol N L^{-1} d^{-1}) in the <3 µm size fraction. Moderate rates (up to 15 nmol N L^{-1} d^{-1}) in the >3 µm size fraction were associated with high Thermodesulfobacteriota abundance, supporting their role in particle-associated N_2 fixation.

These findings provide insights into the seasonal succession of diazotrophs in the Baltic Sea and the importance of NCDs, particularly particle-associated groups, in supporting nitrogen input and potentially influencing primary production, carbon export and deoxygenation in brackish marine systems.

English

The legacy effect of changing nutrient inputs to Danish estuaries and coastal waters

Carstensen, Jacob

Nutrient management plans in Denmark have been successful in reducing nutrient inputs to our coastal ecosystems, but ecosystem responses have been unanticipatedly weak. This lack of recovery has been attributed to non-linear hysteresis effects, changes in climate and other factors creating a shifting baseline, and delayed responses due to legacy effects of nutrients and organic matter stored in the seabed. This presentation will primarily focus on the potential sediment legacy effect. Sediment pools of carbon (measured as Loss-on-Ignition, LoI), total nitrogen (TN) and total phosphorus (TP) sampled over 27 years in two separate periods (1999-2003 and 2017-2025) across 14 Danish estuaries and coastal ecosystems, following substantial reductions in inputs of nitrogen (>50%) and phosphorus (>80%) from land, the majority of these occurring from 1985 to 1997. Sediment pools were positively correlated with chlorophyll levels at station level, with relatively high accumulation in muddy sediments compared to sand. Consistent declines (5-15%) of LoI, TN and TP were observed for sandy sediments, whereas trends for muddy sediments were more variable, albeit no trends were significant. Variability among sediment cores was high, particularly spatial variability but also temporal variability. Given the relatively large sampling effort (~160 cores), we estimated that it is only possible to detect changes of >20% with sufficient power (probability of at least 80%). The changes in sediment pools are consistent with other studies, when considering the relative reductions in nutrient inputs. Collectively, the trends suggest that the legacy effect of nutrient reductions was small and probably not longer than a few years for sandy sediments. Importantly, the potential legacy effect of the sediments cannot explain present increasing hypoxia and chlorophyll levels, which are most likely due to other factors.

English

Biogeochemical consequences of seasonal oxygen depletion in Danish coastal waters: The impact on nitrogen cycling and N2O dynamics

Levin, Lubrina S.[1]; Bristow, Laura A.[2]; Fernandez Juarez, Victor[3]; Kraft, Beate; Thamdrup, Bo[1]

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Oxygen depletion represents one of the most severe anthropogenic impacts on marine systems, with detrimental ecological and socioeconomic effects. Oxygen concentrations in coastal waters have declined for decades, and anoxic events have increased in occurrence. In temperate waters such as the Danish seas, oxygen depletion recurs annually, with long-term impacts. However, we lack a quantitative mechanistic understanding of how emerging oxygen depletion impacts the cycling of carbon, nitrogen, and sulfur, and the accumulation of greenhouse gasses such as nitrous oxide (N_2O) and methane, and how these biogeochemical interactions feed back on oxygen consumption, driving a water mass towards anoxia.
We explored the biogeochemistry of the basins of the southern Lillebælt region, the epicentre of seasonal oxygen depletion in Danish waters, as oxygen depletion developed and receeded over summer and fall of 2023 and 2024, analyzing water column chemistry and experimentally determining rates of pelagic microbial nitrogen cycling, including the production and consumption of N_2O.

Our observations cover stages of oxygen depletion from incipient hypoxia to anoxia with accumulation of hydrogen sulfide. Even during the earliest stages, bottom waters were characterized by high ammonium concentrations, likely sourced from the sediment, which supported high rates of ammonium oxidation, implicating nitrification as a substantial oxygen sink contributing to oxygen depletion. Under these

conditions, ammonium oxidation was the main source of N_2O, but N_2O production rates were low and did not lead to substantial N_2O accumulation. Denitrification was only detected when oxygen was near depletion, but then became a major source of N_2O, which reached levels of ~10 fold atmospheric saturation in oxygen-depleted non-sulfidic waters, implicating such waters as a source of N_2O to the atmosphere, while sulfidic waters acted as a sink for N_2O.

Our results emphasize the importance of pelagic microbial processes and interactions of carbon, nitrogen, and sulfur cycling in the seasonal development of oxygen depletion and point to the importance of including these biogeochemical drivers in models for analyzing and forecasting O_2 depletion in coastal waters.

English

Marine Biogeochemistry II - It's about time: Pathways of carbon turnover and preservation in marine sediments (13:40)

This session examines how carbon is degraded and preserved in sediments, and the factors that shape benthic organic matter load and breakdown dynamics. These processes determine whether sediments act as carbon sinks, release legacy nutrient loads that fuel eutrophication, drive bottom water oxygen depletion, or liberate climate-active gases. Understanding carbon degradation is central to ongoing debates on climate and environmental management. We conclude with a discussion of future research priorities and opportunities, both within fundamental science and in relation to societal and climate challenges.

What fuels the Bay of Bengal Oxygen Minimum Zone? A Look at Carbon Fixation Rates and Microbial Ecology through the Water Column

Jacobsen, Mats[1]; Xu, Peihang[1]; Schlangen, Isabell[1]; Bange, Hermann[2]; Löscher, Carolin R.[1]

[1]Nordcee, University of Southern Denmark, [2]GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel

The Bay of Bengal (BoB) is host to an enigmatic Oxygen Minimum Zone (OMZ), rarely dropping to completely anoxic conditions. The system is highly defined by strong stratification caused by tropical heat and a high input of low salinity water from the Ganges-Brahmaputra-Meghna river-system. Riverine nutrient inputs get consumed near the shores, while mixing within the BoB is generally low, diminishing nutrient availability and thereby primary productivity within the BoB. This raises the question of how the system maintains this near-anoxic OMZ.
Samples were gathered during a South to North transect of the BoB around 88°E on cruise SO305 aboard the RV Sonne. We incubated water from 5 depths at 7 stations with ^{13}C labelled bicarbonate for 24 hours to gather data on carbon fixation rates. Samples for metagenomic analysis were gathered at 5 depths from 9 stations. The sampled depths were between the surface and 300 meters, including samples at the surface (between 2- and 6-meters depth), the deep chlorophyl max, and at 2 depths within the upper OMZ.

Surface carbon fixation rates were found to be ranging from 8.3 ± 1.1 mg C m^{-2} d^{-1} at 5°N and 10.6 ± 0.9 mg C m^{-2} d^{-1} at 7°N around the entrance of the BoB to 1.4 ± 0.1 mg C m^{-2} d^{-1} at 12°N and 4.8 ± 0.4 mg C m^{-2} d^{-1} at 15°N in the inner bay. These rates align with the lower end of measurements from previous expeditions (Löscher 2021). At all 7 incubated stations, the carbon fixation rates decreased to near 0 by 100 meters depth. Metagenomic analysis of the community composition revealed that the most likely surface primary producers at all stations were cyanobacteria - mainly *Prochlorococcus*. Signals of nitrogen fixing organisms that could introduce nutrients into the system were generally low, but a strong signal of *Trichodesmium* deep at one station points to sporadic presence of the group.
We are as of yet unsure whether these low carbon fixation rates adequately explain the perpetuation of the OMZ.

English

Macroalgae detritus accelerates degradation of refractory organic matter in coastal marine sediments

Ehrenreich, Julie Lyhne

The supply of macroalgal detritus to marine sediments may impact the degradation of pre-existing organic matter. While this "priming effect" is well described in soils and freshwater systems, its role in marine sediments remains poorly understood. To investigate this, sediment cores were sampled from a

shallow coastal estuary (Limfjorden, Denmark). Oxygen (O_2) consumption, dissolved inorganic carbon (DIC) release, and fluxes of dissolved inorganic nutrients (NO_2^-, NO_3^-, NH_4^+, and PO_4^{3-}) across the sediment–water interface were measured. We found a clear impact of macroalgal additions, with elevated carbon (C) turnover in these cores. The differences in total DIC release between unamended and macroalgae-amended cores were more than 100%, and in some cases up to 298% of the added macroalgal C. Macroalgal addition therefore accelerated the degradation of pre-existing organic matter in the sediment. Results from this experiment suggest that short-term priming (< three months) did not depend on the macroalgal species added or on the nutrient enrichment of the tissue. The modification of organic matter in marine sediments, driven by secondary production from degrading macroalgal detritus, as well as the conditions that promote this priming, remain poorly understood. These results highlight that priming can substantially influence coastal carbon cycling and should be considered when evaluating the carbon storage and climate mitigation potential of both cultivated and natural macroalgal populations.

Danish

The temporal trajectory of carbon mineralization in the seabed

Røy, Hans[1]

[1]Aarhus Universitet

The seabed stores vast quantities of organic carbon on timescales that range smoothly from days to millions of years. We will here explore how one hypothetical mol of freshly fixed organic carbon is gradually remineralized to CO2 across this vast range of temporal scales. We show that the trajectory of mineralization is systematic and predictable on time-scales larger than 1000 years, but extremely difficult to constrain on shorter time scales. More knowledge about the early stages of mineralization is critically needed to evaluate the effects carbon sequestration in the seabed on time scales that are relevant for our human society under the threat of climate change.

English

Interdisciplinary discussion and perspectives: Join the discussion on the frontiers of carbon biogeochemistry. Together we will map the knowns and unknowns, bridge water-column and sediment research, and explore how to close critical knowledge gaps – and the scientific and societal consequences of leaving these gaps unaddressed.

Marine Biogeochemistry III - New frontiers in microbiology and biogeochemistry (15:30)

This session spans microbial life forms ranging from viruses to cable bacteria, along with their diverse roles in marine biogeochemistry. Following four talks the session concludes with one-minute pitches that take you across the frontiers of microbiology and biogeochemistry, showcasing the diversity and creativity of new research in the field.

Virus-driven sulfur and nitrogen cycling in the Atacama trench sediment

Traving, Sachia J.[1,2]; Chen, Yen-Ting[1]; Schauberger, Clemens[1]; Thamdrup, Bo[1]; Glud, Ronnie N.[1,3,4]; Middelboe, Mathias[2,1]

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Viruses infecting bacteria – also known as bacteriophages – are key regulators of microbial communities, shaping both their composition and activity, and ultimately the turnover of organic matter in marine ecosystems. In hadal trench sediments both bacteria and bacteriophages are found in high numbers, sustained by the massive depositions of organic matter into the trenches. Despite their high abundances, the ecological role of viruses in hadal trenches remain largely unexplored.
In this study, we analyzed 127 metagenomic samples from the Atacama trench supported by rate measurements (sulfate reduction and denitrification) and biogeochemical profiles of the sediment cores. Our main aim was to investigate hadal virus communities and identify their potential contributions to key biogeochemical processes. The metagenomic data reveals that Atacama viruses carry a large diversity of auxiliary metabolic genes (AMGs), with several of them potentially being involved in biogeochemical cycling of sulfur and nitrogen. This was further supported by the vertical distribution of the AMGs in the

sediment cores, where the majority of sulfur and nitrogen related AMGs followed the redox zonation. Furthermore, in several of the sample sites we found significant correlations between the distribution of groups of AMGs involved in sulfate reduction and measured rates. These findings suggest that viruses may be intimately linked to elemental cycling in hadal sediments.

English

Nitrogen fixation by Rhodopseudomonas sp. BAL398 is linked to its photoheterotrophy and biofilm formation

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Non-cyanobacterial diazotrophs (NCDs) are widespread and active in marine waters. It has been suggested that the energy and low-oxygen (O_2) conditions required for their N_2 fixation are found on marine particles, but the putative role of light remains uninvestigated. Here we examined the factors governing N_2 fixation in *Rhodopseudomonas* sp. BAL398 – a phototrophic NCD isolated from estuarine surface waters. Highest growth and N_2 fixation were found at high light (250 µmol photons m^{-2} s^{-1}) and low O_2 availability (0 µM O_2), but BAL398 was only able to utilize light at high carbon levels (35 mM). According to immunofluorescence measurements, cellular nitrogenase levels increased with increasing light, decreased inorganic nitrogen availability, and high O_2. Increased light and O_2 levels stimulated biofilm formation on hydrophobic surfaces, which was accompanied by an increase in N_2 fixation and motility. Holotomography microscopy revealed the presence of distinct morphological structures (rosettes, capsules, or cysts), depending on the conditions tested, revealing a high morphological plasticity. The frequency of rosettes, which concentrate the nitrogenase toward the rosette center, increased 600-fold when cells reached maximum N_2 fixation rates. Interestingly, N_2 fixation under aerobic conditions was accompanied by increased formation of capsules and transparent exopolysaccharide particles. Our findings provide the first insights into how phototrophic marine NCDs fix N_2, revealing that they require biofilm formation to utilize light and fix N_2 under aerobic conditions.

English

Importance of resuspension for the sedimentary sulfide buffering capacity - a case study from the Limfjorden, Denmark

Mihm, Hannah Sofie[1]; Fürst Sørensen, Lisbeth[1]; Thomasberger, Aris[2]; Maarbjerg, Kasper Lenda[2]; Attard, Karl Michael[1]; Petersen, Jens Kjerulf[2]; Glud, Ronnie N.[1,3]

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Sediment resuspension is a critical yet underexplored factor for the biogeochemical function of coastal margins. This study investigated the impact of resuspension and seasonal variations in the sulfide buffering capacity (SBC) at two eutrophic sites in the Limfjorden. The sites, Skive Fjord (SF) and Venø Sund (VS), had sediment organic matter contents of 19 and 14 wt%, respectively. Both sites showed considerable sulfide (H_2S) production during all seasons but at reduced levels during winter and consistently higher values at SF. An important removal process for free H_2S is the entrapment by oxidized iron, acting as a chemical buffer. The ratio of oxidized to reduced iron (Fe^{3+}/Fe^{2+}) in surface sediments varied seasonally (January, May, September) between 3, 0.2, and <0.01 at SF and between 2.9, 0.6, and 0.1 at VS, respectively. The SBC, expressed as the period of no H_2S efflux after sediment enclosure, showed that the elevated levels of Fe^{3+} in January and May prevented H_2S release for >400 h. In contrast, September sediments exhausted the SBC after only 50 h at SF and 150 h at VS.
EROMES erosion devices simulated wave-generated sediment resuspension and were used to assess the impact for benthic solute exchange and the SBC. Under vigorous resuspension (4.4 N m^{-2}), ~6 mm of surface sediment was eroded, and sediment oxygen (O_2) uptake was enhanced by 2-, 6-, and 7-fold at VS and by 22-, 22-, and 40-fold at SF across seasons, respectively. Oxygen was used to reoxidize Fe^{2+}, and the O_2 consumption rates aligned with the Fe^{3+}/Fe^{2+}-ratios. Similar O_2 uptake during multiple

successive resuspension events in September at SF documented a large Fe^{2+} pool with negligible reoxidation occurring during each event. Full Fe^{2+} oxidation of the upper 6 mm would require ~4 h, but bottom-water O_2 would then likely be depleted after only 2 h. Thus, resuspension events must be of notable duration with sufficient supply of O_2 to enhance and maintain the SBC and mitigate the risk of H_2S emission. Such events are expected to become more frequent due to climate driven enhancement of storm surges and would benefit environmental conditions in the Limfjorden.

English

Diazotrophy in the seagrass rhizosphere - the potential role of rhizobia?

Brodersen, Kasper[1], Maria Mosshammer[2], Meriel J. Bittner[2], Lasse Riemann[2], Michael Kühl[2]

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Seagrasses can enhance nutrient mobilization in their rhizosphere via complex interactions with sediment redox conditions and microbial populations. Yet, limited knowledge exists on how rhizosphere dynamics affect nitrogen cycling. Using high-resolution chemical imaging, we show that radial O_2 loss (ROL) from rhizomes and roots leads to formation of redox gradients around below-ground tissues of seagrass (*Zostera marina*), which are co-localised with regions of high ammonium concentrations in the rhizosphere. Utilizing chemical imaging in concert with fine-scale sampling for microbial community and gene expression analyses, we showed that multiple biogeochemical pathways and microbial players contribute to the high ammonium concentration within the oxidized regions of the seagrass rhizosphere. *Bradyrhizobium* (symbiotic N_2-fixing bacteria) were particularly abundant and expressed the diazotroph functional marker gene *nifH* in rhizosphere areas with high ammonium concentrations. Such potential mutualistic association between *Z. marina* and *Bradyrhizobium* can facilitate ammonium accumulation, the preferred nitrogen source for seagrasses, enhancing seagrass productivity and performance within especially nitrogen-limited environments. ROL also caused strong gradients of sulphide at oxic/anoxic interfaces in rhizosphere areas, where we found enhanced *nifH* transcription by sulphate-reducing bacteria. ROL from below-ground tissues of seagrass thus seems crucial for ammonium production in the rhizosphere via stimulation of multiple diazotrophic associations.

English

Poster pitches: A rapid, thematically organized overview of all posters: one slide, one minute per presenter.

Øresundssalen

Marine birds in Danish waters I: distribution, trends and drivers (10:40)

Fuglelivet i de danske havområder – Oversigt, status og trusler

Frederiksen, Morten[1]

[1]Aarhus University, Department of Ecoscience

De danske havområder er nogle af de vigtigste i Europa for adskillige fuglearter. Det skyldes især de store lavvandede områder der kun sjældent fryser til om vinteren, med naturligt høj produktivitet samt den lange kystlinje, som tilsammen betinger at der er store mængder af lettilgængelig føde af mange slags. Ydermere er de indre danske farvande rige på rev, småøer og holme, hvor kolonirugende kystfugle kan yngle i fred for landrovdyr. I denne præsentation giver vi en oversigt over de vigtigste grupper af marine fugle i Danmark, hvad der betinger deres optræden i danske farvande, og de danske havområders internationale betydning. Langt de største antal fugle optræder udenfor ynglesæsonen, og omfatter især dykænder som lever af muslinger og andre bunddyr, svømmeænder og knortegæs som lever af vandplanter, og vadefugle som lever af bunddyr i tidevandszonen. I Nordsøen og de åbne dele af Kattegat optræder også store antal fiskespisende alke, lomvier, lommer, suler, mallemukker og andre arter. Blandt ynglefuglene er danske farvande især vigtige for måger, terner, skarv og ederfugl. Potentielle trusler mod marine fugle i Danmark omfatter klimaændringer, eutrofiering, fiskeri (inkl. bifangst), forstyrrelser fra jagt og rekreativ sejlads, forurening (miljøgifte og plastik), udbygning af havvind og anden infrastruktur, samt rovdyr (rotter, mink mm.) i ynglekolonierne. Vi giver et overblik over hvilke arter som er mest sårbare i forhold til de enkelte trusler.

Danish

Utilizing EO data to map aquatic vegetation coverage and dynamics in Special Protected Areas for herbivorous waterbirds in Denmark

Nielsen, Lisbeth[1]; Clausen, Preben[2]; Huber, Silvia[1]; Simonsen, Nicklas[1]; Daniel, Paul[1]; Pedersen, Claus Lunde[2]; Kanstrup, Niels[2]; Koukos, Alkiviadis[1]

[1]DHI, [2]Institut for Ecoscience, Aarhus University

Although feeding habitats and associated food availability within Special Protected Areas (SPAs) for herbivorous waterbirds remains a key variable in habitat assessments, mapping Submerged Aquatic Vegetation (SAV) and thus estimating available biomass continues to rely on costly in-situ sampling in most monitoring campaigns, reducing the spatial and temporal resolution of the datasets used to assess the suitability and quality of SPAs. Here we present an approach using satellite imagery to map SAV at large scale in the shallow coastal zone as an efficient and cost-effective complement to assessing SAV coverage in SPAs. By utilizing an ensemble of deep learning models, we analyze Copernicus Sentinel-2 images from 2016 to 2025 to derive a 10-year time series of late-season SAV coverage in five SPAs in Denmark, i.e. Ringkøbing Fjord, Nissum Fjord, Nibe-Gjøl Bredninger, the Southfunen Archipelago and Smålandsfarvandet. The models are trained on an extensive dataset of image annotations and calibrated with transect data of SAV coverage ratios. The results indicate that SAV coverage can vary significantly between years at different spatial scales, with some areas showing a consistent reduction or increase in coverage throughout the entire area, while others show a redistribution of vegetated areas within the SPA. These variations could have implications for the optimal subdivision of the SPAs to ensure that protected zones align with the optimal food supply, in addition to supporting the assessment of the SPA as a whole.

English

Almost 100 years of ups and downs for aquatic plants and associated waterbirds in Ringkøbing Fjord

Clausen, Preben[1]; Nielsen, Lisbeth Tangaa; Olesen, Birgit[2]; Huber, Silvia[3]; Kanstrup, Niels[1]; Pedersen, Claus Lunde[1]; Simonsen, Nicklas[3]; Vissing, Marie Silberling[1]; Fox, A.D. (Tony)[1]

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Background: Ringkøbing Fjord is amongst the best described brackish wetlands in Denmark, with records of water plants and birds dating back to 1900. Systematic bird counts began in 1928 at the Tipperne reserve, and a very comprehensive description of the lagoon's abiotic environment and biology was made between 1928 and 1931. In 1931 the hitherto natural, but unstable, opening to the North Sea at the southern end was replaced by an artificial channel and a regulatory sluice at Hvide Sande, which enabled options to control water levels and manipulate salinity. Like most other near-coastal wetlands in Denmark, Ringkøbing Fjord has been severely affected by eutrophication, on top of which, the protocols for operating the sluice and associated targets for maintain water levels and salinity have frequently changed. In the 1970s, the lagoon was thus maintained as almost fresh (3-6 ‰, highest in summer), but under the current regime operated since 1995, the target has been to maintain a summer salinity of 12-15 ‰.

Materials and Methods: We have reviewed and immense source of grey litterature, diary notes, and herbarium sheets with supplementary notes, to compile databases on plants and waterbirds pre-NOVANA, and use national monitoring programme (NOVANA) data from 2004 onwards. In recent years we have added large-scale mappings of submerged aquatic vegetation from satellite images to our increasingly comprehensive dataset.

Results: We show how the overall distributions, species diversity and vegetation biomass have been subject to massive changes. We also document how the associated guild of waterbirds feeding on these plants have experienced a food resource roller coaster and responded numerically. In recent years, we have seen a major recovery in vegetation (documented from transect surveys and satellite images), and many of the associated waterbirds have thrived, in numbers not seen since the 1970s.

Conclusions: Although the overall distribution of water plants may be approaching that present during 1928-1931, the restoration in a high salinity regime comes with a price-tag, i.e. a much lower diversity of water plants, where those few remaining species are more robust to tolerating the relatively high salinity in a system which remains highly eutrophic.

English

Lessons from the Danish Fjords: several coastal lagoons mirror the patterns in waterbird abundance and submerged aquatic vegetation witnessed at Ringkøbing Fjord

Fox, Anthony David; Nielsen, Lisbeth Tangaa[1]; Huber, Silvia[1]; Kanstrup, Niels[2]; Pedersen, Claus Lunde[2]; Simonsen, Nicklas[1]; Vissing, Marie S[2]; Clausen, Preben[2]

[1]DHI, [2]Dept Ecoscience, Aarhus University

Through multiple experiments with shooting-free reserves in Denmark, we have learned that the combination of a reserve and a rich food resource of Submerged Aquatic Vegetation (SAV) is key to securing a large population of herbivorous waterbirds, i.e. swans, dabbling ducks, brent geese and coots. This guild of birds is prominent in Denmark's designations of Special Protection Areas (SPAs) for birds under EU legislation. Here we combine novel satellite-based mapping with reviews of historical grey literature on estuarine SAV distribution to estimate the present and past extent of SAV in shallow waters with data on herbivorous waterbirds from four SPAs. We show that while Nissum Fjord has almost totally lost its food resource and associated waterbirds, Nibe & Gjøl Bredninger have been subject to repeated ups-and-downs in food resource abundance reflected in waterbird numbers, while the South Funen Archipelago and Smålandshavet both have maintained reasonably stable food resources and waterbird numbers. We have similar knowledge from freshwater lakes in Denmark, notably Maribo Lakes (also an SPA), where restoration of vegetation prompted a major recovery of breeding waterbird populations. Past and present absences of SAV can generally be attributed to local problems associated with eutrophication. Maintaining the quality of wetlands in SPAs designated for herbivorous waterbirds under the EU Birds Directive through appropriate management fits well with the requirements under the EU Water Framework Directive and its associated River Basin Management Plans, which aim to restore water quality and the ecological status of water bodies throughout the catchments to the sea.

English

100 years with Large Decadal Changes in Seabird Populations at Ertholmene

Mosbech, Anders; Abrahamsen, Lars; Castenschiold, Johan H Funder; Frederiksen, Morten; Johansen, Kasper L.; Merkel, Flemming

Large decadal changes in seabird populations at Ertholmene reflects changes in marine ecosystems, as well as other factors. What can we infer from the data, and what can be learned for management.

Seabirds forage at sea, and especially during breeding, when they collect food for the chicks within a limited foraging radius, abundance and phenology of appropriate food items are critical for reproduction and population development. Ertholmene is a group of three small islands 18 km northeast of Bornholm, and one of the islands, Græsholmen, was strictly protected 100 years ago. Since then, numerous seabird studies have taken place on the islands, now having more than 25.000 pairs of breeding seabirds. Here we discuss how the marine environment and other factors have influenced the development of breeding populations, potential future population trajectories and research needs. Estimates of population development are available for six seabird species for the last hundred years. Two species (razorbill and common guillemot) have shown nearly continuous population increases, reflecting the protected breeding site and abundant forage fish (predominantly sprat). Three species (common eider, lesser black-backed gull and herring gull) have more complex population histories with large population increases followed by declines in recent decades. One species (common gull) has declined throughout the period. Main factors in the population trajectories are food availability, not only at the breeding sites but also in the non-breeding areas, and availability of safe nesting sites. Ertholmene has no mammalian predators, but avian predators and interspecific competition for nest sites as well as human disturbance all contribute to the development of the breeding populations.

English

Are Danish waters increasingly important staging and foraging grounds for Northern gannets (Morus bassanus)?

Jeglinski, Jana W.E.[1]; Lane, Jude V[2]; Franklin, Kirsty A.; Garthe, Stefan[3]; Hamer, Keith C.[4]; Sheddan, Maggie[5]; Schwemmer, Henriette[6]; Matthiopoulos, Jason[7]

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Centre, [6]Research and Technology Center FTZ, University of Kiel, Germany, [7]School of Biodiversity, One Health and Veterinary Medicine, University of Glasgow

Northern gannets (*Morus bassanus*) are not traditionally associated with Danish waters: the largest European seabird breeds in high-density colonies distributed from Northern Norway to Northern France with the bulk of the metapopulation in Scotland, and gannets migrate annually to various wintering regions including the southern North Sea, the Iberian Peninsula and the Atlantic coast off West Africa. However, in the last decade, gannet sightings in the Danish North Sea, Kattegat, Skagerrak and western Baltic Sea have increased. Recent geolocator (gls) tracking of gannets from the nearest breeding colony Helgoland showed the first observation of a gannet overwintering in the western Baltic Sea (Garthe et al. 2024), but gls data temporal and spatial resolution is low, and it is unclear if gannets from other colonies use Danish waters as well.
Here, we use a unique fine-scale GPS tracking dataset from breeding adult and non-breeding immature gannets at the world's largest colony Bass Rock, Scotland and at Helgoland, Germany. Spanning more than a decade (2014– 2025), these data allow us to explore the role of Danish waters as foraging and staging habitat for gannets tracked at both sides of the North Sea.
We investigate whether use of Danish waters is associated with age, specific individuals, or a distinct period of the breeding cycle, and whether any changes in space use can be detected over the decade covered by the data. We discuss hypotheses for possible changes in marine conditions (e. g. water temperature, pelagic fish community) that may increasingly benefit gannets and highlight avenues for future research.
Finally, we conclude with applied considerations regarding assessments and apportioning of offshore windfarm impacts for species such as Northern gannets that range across multi-national jurisdiction.

English

Marine birds in Danish waters II: threats and impacts (13:40)

Havfugles følsomhed overfor havvindmølleparker. Strategisk planlægning af udbygningen i danske farvande.

Petersen, Ib Krag

Udbygning af havvind startede i Danmark i år 2000. Undersøgelser af miljømæssige konsekvenser er sket i forbindelse med miljøkonsekvensvurderinger af de enkelte projekter. I år 2022 ivværksatte Energistyrelsen et stort projekt, der tilgår problemstillingen fra en strategisk vinkel, der skal hjælpe til at kvalificere placeringen af fremtidige havvindmølleparker. I den sammenhæng blev der udarbejdet følsomhedskort for havfugle overfor havvindmølleparker. Formålet var at klassificere alle danske farvande efter graden af følsomhed for havfugle i en høj geografisk opløsning (grid celler på 1x1 km).

Arbejdet har taget udgangspunkt i vores kendskab til fuglenes fordeling og antal i tid og rum, deres reaktion overfor havvindmøller, deres habitat-krav samt deres beskyttelses-niveau. Analyserne blev gennemført for 17 arter eller artsgrupper, der repræsenterer forskellige funktionelle grupper, for hvilke der blev etableret fordelings- og tætheds-kort for alle danske farvande. Arts-specifikke følsomheds-niveauer blev identificeret, kombinerende effekten af ændringer i deres fordeling og potentielle kollisionsrisici.

Et generelt følsomhedskort for havfugle kunne derefter udarbejdes som en kombination af data fra de artsspecifikke kort. Data skal anvendes i den administrative planlægning af fremtidig udbygning af havvind i danske farvande. Metoden og resultaterne vil desuden være direkte anvendelige i analyser af kumulative effekter og vil kunne udvides til at omfatte større geografiske områder (fx Nordsøen og Østersøen).

Lignende analyser er gennemført for havpattedyr, flagermus, bunddyr og for oceanografien.

Danish

The perception and reaction of marine birds to aerial and underwater noise

Wahlberg, Magnus; Abildtrup Nielsen, Nicoline[1]; Anderson Hansen, Kirstin[2]; Christensen-Dalsgaard, Jakob[1]; Fjordside, Kasper[1]; Frahnert, Sylke[3]; Næsbye Larsen, Ole; Mooney, Aran; Röβler, Helen[4]; Smith, Adam[1]; Sørensen, Kenneth[5]; Dähne, Michael[4]

[1]University of Southern Denmark, [2]Odense Zoo, [3]Musem für Naturkunde, [4]Ocean Museum Germany, [5]University of Rostock

With increasing human activities in and around our oceans, there are concerns about how noise from oil exploration, naval sonars, shipping and green energy installations affect marine birds. Little is known about hearing of marine birds and their reaction is to sound in both media. We measured aerial hearing abilities of great cormorants, Humboldt penguins and common murres. All species had in-air audiograms shaped comparable to similar-sized terrestrial birds, except for a surprisingly low-frequency sensitivity found in penguins. Both psychophysiological as well as testing the hearing using the auditory brainstem response were conducted successfully. Underwater hearing thresholds measured in cormorants show that the shape of their underwater audiograms resembles the in-air ones, and that they can hear some types of anthropogenic noise at considerable distances. 3D-scans of the inner ear structures in penguins showed surprisingly little morphological adaptation to the underwater environment. Preliminary underwater hearing thresholds on murres indicate they are less sensitive to underwater sound. Playback experiments with underwater noise bursts at a received level of 130 dB re 1 µPa resulted in no reactions in eider ducks, weak reactions in common murres, and strong aversive reactions in gentoo penguins. We also showed that gentoo penguins can be conditioned to underwater sounds, showing that they can associate sounds with food and also take adequate decision based on underwater sound cues. All in all, our studies strongly indicate that underwater sounds may be important cues for diving marine birds, and that some species may be vulnerable to both in-air and underwater human-induced noise sources.

English

Factors of bycatch of birds and mammals in Danish gillnets

Gildas Glemarec, David Lusseau, Lotte Kindt-Larsen, Anne-Mette Kroner, Casper Berg, Mollie Brooks

Incidental captures (bycatch) in fishing gears exert an important pressure on some fragile populations of megafauna species worldwide. Solutions to reduce or mitigate bycatches of endangered, threatened, and protected species (ETP) exist but are not widely applicable across species and across fisheries. Because of the inadequate monitoring effort in many fisheries, a precise knowledge of the ecological and operational drivers of bycatch is often missing. Here, we exploit 15 years of electronic monitoring (EM) data from the Danish gillnet fishery to dig out the most influential determinants of ETP species bycatch for several species of marine mammals and seabirds subjected to bycatch in our seas. We use a generalised linear mixed model (GLMM) to improve our understanding of the mechanistic relations that exist between observed bycatch rates, and operational and ecological factors in gillnet fisheries. Within the parameters considered in our analysis, we show that some factors are more influential than others to explain species-specific bycatch rates. These results are important for fisheries and conservation managers to design effective and appropriate mitigation measures and ensure the sustainability of the ETP species populations affected by bycatch in gillnets.

English

How bycatch rates of ETP species vary spatiotemporally and with covariates

Brooks, Mollie, Lotte Kindt-Larsen, Gildas Glemarec, Casper W. Berg and David Lusseau

Since 2010, in Denmark, electronic monitoring (EM) has been routinely done in gillnet fisheries to collect data on bycatch of endangered, threatened and protected (ETP) species. The EM data is collected at a fine spatial and temporal scale, including time, position, and effort of each fishing operation, whether or not there was a bycatch event. Effort is in the form of net-length and soak-time. The EM data allowed us to model bycatch per unit effort and how it changed with location, time, and different aspects of the fishery. Separately, standard national logbook data gives us an overall approximation of the total effort in the Danish gillnet fisheries. These data were then used to extrapolate estimates of annual total bycatch of ETP species. Annual total bycatch is a nonlinear function of the model parameters including a spatio-temporal random effect. Recent statistical developments have shown that, in this case, estimates can be improved using a bias correction method that was recently implemented in glmmTMB. Here, we present these statistical models and the resulting estimates of annual bycatch of cormorants, common eiders, and alcides in Danish gillnet fisheries.

English

How much of the Western Baltic cod stock is eaten by cormorants?

Varlund Strange, Markus

Birds are an integral part of marine ecosystems. In Danish waters, cormorants (*Phalacrocorax carbo carbo*) are among the most important, where they shape the food web as top predators. Cormorants feed almost exclusively on fish, which has made them subject to one of the most pronounced human-wildlife

conflicts in Denmark, because they pressure a coastal fishery that is already struggling with depleting fish resources.
The coastal fishers have essentially two complaints: 1) depredation on active fishing gears reduces their revenue, and 2) predation is a driver for the poor state of some commercial fish stocks. A key challenge in this conflict is the polarized debate, where fishers and conservationists argue in opposite directions, without much willingness to find common ground. Therefore, there is a strong need for evidence-based management advice, with quantitative measure of the impact cormorants have on the coastal fishery. In this project, we investigate the impacts of cormorants on commercial fish stocks in inner Danish waters. We use the Western Baltic cod (*Gadus morhua*) as a case study, and quantify the annual cormorant consumption of this stock. Our analysis is based on a time-series of the population size of cormorants feeding in the Western Baltic, and a large dataset of fish otoliths found in pellets over the past five decades. We use the otolith data to estimate a continuous time-series of cormorant diets, predicted from the relative availability of key prey species. We estimate cormorant consumption of Western Baltic cod back in time and compare it with other major fish removers, i.e., seals and the fishing industry.
This study is the first to look at stock level impacts of cormorant predation on fish over a wide span of years in Danish waters. It thus contributes to developing ecosystem based management advice, that acknowledges the current concerns of the coastal fishers.

English

MuslingeVagt

Lyngsgaard, Maren; Tjørnløv, Rune; Kristensen, Louise; Jensen, Kjeld

Projektet MuslingeVagt har til formål at sikre fremtidig produktion af bæredygtige lavtrofiske arter som blåmuslinger i både fjorde og offshore-områder. I flere kystregioner, både i Danmark og internationalt, udgør ederfugle en væsentlig trussel mod muslingeopdræt, da muslinger er en foretrukken fødekilde for trækkende og rastende fugle. Selvom de danske farvande er ideelle til muslingeproduktion på grund af eutrofiering og rigelige mængder føde, begrænses mulighederne af ederfuglenes prædationstryk (Tjørnløv, Holbach & Timmermann, 2023). Der er derfor behov for skånsomme løsninger, der beskytter muslingeopdræt uden skade på fuglene.

I projekt MuslingeVagt udvikles et skånsomt redskab til bortskræmning af ederfugle bestående af en selvsejlende enhed/drone. Enheden udvikles således, at der kan gennemføres online overvågning af opdrætsanlæg i fjorde såvel som anlæg offshore i realtid. Enheden er baseret på batteridrift, og kan således sejle på vedvarende energiformer og med autonom opladning vha. en flydeenhed på vandet. Enheden udvikles på baggrund af et tidligere pilotstudie, som indikerer at MuslingeVagt effektivt skræmmer ederfuglene væk fra muslingeanlæggene.

MuslingeVagt er udviklet med fokus på minimal drift og økonomi. Den er 1,5 meter lang og vejer ca. 40 kg. Fremdriften sker ved elmotorer, og den kan sejle med normal hastighed på 5-8 km/t og samt korte boosts på 20-30 km/t. Den er bygget af glasfiber, der gør den let og energibesparende. Ved normal hastighed er driftstiden ca. 2 timer. Den kommunikerer med fjernoperatøren via 5G og har et uafhængigt sikkerhedssystem baseret på geofencing og satellitforbindelse, så motorer stoppes hvis den kommer for langt fra muslingefarmen, og operatøren alarmeres.
Projektet vil udover at udvikle og teste en brugervenlig enhed og infrastruktur omkring redskabet MuslingeVagt, udarbejde en risikovurdering i forbindelse med kommerciel drift med sparring fra Søfartsstyrelsen. Der laves desuden undersøgelse og dokumentation på ederfuglenes responsadfærd ved gentagne autonome missioner, da ederfugle kan vise habituering eller tilvænning til den type af forstyrrelse, som MuslingeVagt forårsager.

MuslingeVagt kan blive et brugbart redskab til at åbne op for regenerativ fødevareproduktion samt mere effektiv næringsstof fjernelse i de danske farvande.
Projektet er et samarbejde mellem Syddansk Universitet, Skylevel, Kerteminde Seafarm, WSP og Wittrup Seafood, og medfinansieret af Den Europæiske Union

Danish

Marine Mammals in a Changing Seascape (15:30)

Status of Marine Mammals in Danish waters – Trends, Threats, and Future

Jonas Teilmann, Signe Sveegaard and Anders Galatius

Marine Mammal Science, Department of Ecoscience, Aarhus University, Frederiksborgvej 399, 4000 Roskilde

Six marine mammal species thrive in Danish waters, while several other species are occasional visitors. The two seal species; harbour seals and grey seals are now widely distributed after severe depletion or extinction due to hunting, until their protection in 1976 and 1967. While harbour seals seem to have reached carrying capacity in most areas, grey seals, which were hunted to extinction about 100 years ago, are now slowly returning with about 20 pups born and a few thousand visitors every year. The four cetacean species living in Danish waters harbour porpoise, white-beaked dolphin, bottlenose dolphin and minke whale are distributed unevenly. While the harbour porpoise live in all waters although rarely in Limfjorden and around Bornholm, white-beaked dolphins and minke whales are mainly seen in the offshore waters of the North Sea and Skagerrak. Bottlenose dolphins are rare, but a small group has settled in the opening between the North Sea and Limfjorden. Five of the six species are found year-round in Danish waters, in contrast to the minke whale that migrates to warmer waters in the southern Atlantic during winter. While the North Sea seems to sustain viable populations of both seals and cetaceans, the inner waters suffer from oxygen depletion, habitat destruction, bycatch in fishery and depleted fish stocks. This has resulted in significant declines in genetically isolated populations of harbour porpoises and harbour seals in the inner Danish waters in recent years. If habitats are restored, and populations are protected by effective management, history shows that it is possible to successfully reestablish populations of large predators, but it is also clear that human interactions and disturbance may be limiting factors that require adaptive adjustments in wildlife management.

Genomic insights on the history, health and local adaptations of Danish marine mammals

Morten Tange Olsen

Section for Molecular Ecology and Evolution, Globe Institute, University of Copenhagen, Denmark

Denmark and the wider Baltic Sea region is home to several marine mammals, including seals and porpoises, which each seem to be genetically distinct from neighboring populations in the North Sea and North Atlantic. On behalf of a long list of coauthors, I here present the main findings of recent population genomic studies to shed light on the evolutionary and demographic history of Danish marine mammals, their genomic health and vulnerability, as well as putative adaptations to local environmental conditions, including salinity and temperature. The results provide new insights on the possible fate of each species in the context of the ongoing climate and biodiversity crisis.

Integrating drones in monitoring of harbour porpoise body condition and demographics in Danish waters

Christiansen, Fredrik; Sveegaard, Signe[1]; Galatius, Anders; Teilmann, Jonas

[1]Aarhus University, Department of Ecoscience, Marine Mammal Research

Reliable data on demographics and body condition are critical for monitoring marine mammal populations, yet current assessments in Danish waters rely largely on stranded or bycaught harbour porpoises (*Phocoena phocoena*), which often represent biased samples of inexperienced or unhealthy animals. This study evaluates the feasibility of using unmanned aerial vehicle (UAV) photogrammetry to measure morphometrics of free-ranging porpoises, providing insights into both population structure and nutritional status. Between May 2024 and March 2025, morphometric measurements (body length and widths at 5% increments) were obtained from 100 harbour porpoises along the Danish coast. Sampled reproductive classes included calves (n = 14), juveniles (n = 26), adults (n = 34), pregnant females (n = 10), and lactating females (n = 16). Body volume was estimated using a segmented elliptical model, and body condition was derived from the standardized residual of the log-linear relationship between body volume and body length. Body lengths ranged from 0.74 to 1.83 m, while body condition values ranged from –0.26 to 0.51. Pregnant females exhibited significantly higher body condition than other classes, demonstrating that pregnancy can be detected from UAV data. Seasonal variation in adult body condition was captured using a generalized additive model, reflecting intra-seasonal fattening in response to environmental variability (i.e. water temperature). Calves grew in relative length at a mean rate of 0.06% of maternal length per day, while lactating females replenished condition more slowly than other adults in autumn, reflecting the energetic cost of lactation. These results demonstrate that UAV photogrammetry can accurately capture demographic structure and seasonal dynamics in porpoise body condition and should be integrated into future health monitoring of marine mammals in Danish waters.

English

How much is too much? Defining bycatch reference points for harbour porpoises in a European context

Lusseau, David[1]; Lusseau, David[1]; Glemarec, Gildas[1]; Kindt-Larsen, Lotte[1]

[1]Technical University of Denmark

Incidental catches in fisheries (bycatch) continue to present a conservation threat for many marine top predator species globally. Over the past 30 years, several countries have introduced the notion of reference points to manage this threat. Those points define bycatch levels that cannot be sustained by management units or populations of sensitive species. Reaching a reference point is supposed to trigger clearly defined management actions aiming to reduce bycatch to sustainable levels. Reference points are defined precisely and are underpinned by rigorous technical approaches to estimate them. The regulatory context is complex in European waters with both national and EU level objectives, as well as additional multilateral commitments, which do not always align. Here, we use a well-studied management unit of harbour porpoise (*Phocoena phocoena*) in the Western Baltic to assess how the different objectives that apply to define bycatch reference points in our seas might become conflicting. At first, we define a range of scenarios for bycatch management based on these multiple objectives. To estimate these scenarios, we use a procedure developed as an extension of the Catch Limit Algorithm from the International Whaling Commission. Specifically, we use an aggregated population model to estimate the current population depletion rate based on time series of abundance and bycatch estimates for 2010-2022. We then apply an age-class demographic model to estimate the likely current age-sex structure of the population subjected to bycatch. We finally use this tuned age-class demographic model, based on the current depletion rate, to forecast the behaviour of the population subjected to bycatch over the time horizon(s) specified by the management scenario(s) and estimate the corresponding value of each reference point. This procedure relies on a series of assumptions made about bycatch estimation and demography. We test the sensitivity of outcomes, as well as the goodness-of-fit of the forecasting models to these assumptions. We use this large set of simulations to show that both bycatch estimation procedures and demographic assumptions have a large effect on outcomes and that both must be improved to retrieve precise bycatch reference points for this population.

English

How much of the Western Baltic cod stock is eaten by seals?

Varlund Strange, Markus

Mammels are an integral part of marine ecosystems. In Danish waters, seals (*Halichoerus grypus* and *Phoca vitulina*) are among the most important, where they shape the food web as top predators. Seals feed almost exclusively on fish, which has made them subject to one of the most pronounced human-wildlife conflicts in Denmark, because they pressure a coastal fishery that is already struggling with depleting fish resources.
The coastal fishers have essentially two complaints: 1) depredation on active fishing gears reduces their revenue, and 2) predation is a driver for the poor state of some commercial fish stocks. A key challenge in this conflict is the polarized debate, where fishers and conservationists argue in opposite directions, without much willingness to find common ground. Therefore, there is a strong need for evidence-based management advice, with quantitative measures of the impact seals have on the coastal fishery. In this project, we investigate the impacts of seals on commercial fish stocks in inner Danish waters. We use the Western Baltic cod (*Gadus morhua*) as a case study, and quantify the annual seal consumption of this stock. Our analysis is based on time-series of the population sizes of seals feeding in the Western Baltic, and a large dataset of fish otoliths found in scats over the past two decades. We use the otolith data to estimate continuous time-series of seal diets, predicted from the relative availability of key prey species. We estimate seal consumption of Western Baltic cod back in time and compare it with other major fish removers, i.e., cormorants and the fishing industry.
This study is the first to look at stock level impacts of seal predation on fish over a wide span of years in Danish waters. It thus contributes to developing ecosystem based management advice, that acknowledges the current concerns of the coastal fishers.

English

Electromagnetic sensing and potential disturbance in harbor porpoises

Adam B. Smith[1], Peter Sigray[2], Laia Rojano Donate[3], Joanna Sarnocinska-Kot[4], Matthieu Povidis-Delefosse[4], Peter T. Madsen[3], Jacob Nabe-Nielsen[3], Jonas Teilmann[3], Magnus Wahlberg[1].

1Department of Biology, University of Southern Denmark, Denmark

2KTH Royal Institute of Technology, Sweden
3Aarhus University, Denmark
4Vattenfall, Denmark

Experimental evidence shows that some cetaceans possess passive electroreception. Cetacean exposure to electromagnetic (EM) fields via subsea power cables thus constitutes a source of potential anthropogenic disturbance. The harbor porpoise (*Phocoena phocoena*) is of particular concern given its sensitivity to disturbance, ecological importance, and widespread presence across northern European waters which overlap significantly with current and planned offshore wind development. Here, we examined potential EM reception and disturbance in porpoises using data from both trained and wild individuals. With trained porpoises, we tested for passive electroreception by observing behavioral responses to DC electrical field stimuli. Our results indicate that porpoises can detect these fields, likely through a passive electroreception sense similar to that described in bottlenose dolphins. We also analyzed biologging tag data from 10 wild porpoises in Danish coastal waters to explore if (i) porpoise proximity to subsea power cables was detectable in tag sensor data, and (ii) if porpoises exhibit behavioral patterns or changes around such cables. We found that proximity to a buried DC power cable was clearly identifiable through anomalies in magnetometer data, and in-situ measurements of the cable's EM fields closely matched modeled EM field outputs. Moreover, harbor porpoises exhibited variable behavioral patterns in the presence of the cable, which included following and foraging the cable for up to 2 km. Although we cannot determine if this behavior resulted from detection and tracking of EM fields or from other environmental features, porpoises may be attracted to subsea infrastructure and consequently experience elevated EM exposure. Our findings suggest the need for further experimental and field studies of porpoise biology and behavior in relation to EM exposure from offshore wind energy infrastructure

Onsdag 21.1

Damgaardssalen

Coastal Fish and their Habitats in Denmark I (9:00)

Havets spisekammer: Marine fødevarer på Nørre Vosborg, 1830erne–2025

Poulsen, Bo[1]

[1]Aalborg University

Denne undersøgelse analyserer forbruget af marine fødevarer ved herregården Nørre Vosborg i Vestjylland over en periode på 170 år. Med udgangspunkt i detaljerede husholdningsregnskaber fra perioden 1855–1867 og dagbogsnotater fra 1925–1926, samt nutidige observationer af menuer og fiskebestande, afdækkes markante forandringer i både artssammensætning og forbrugsmønstre.
I midten af 1800-tallet blev der registreret et bredt udvalg af lokalt fangede fiskearter, herunder **stør, helleflynder og skade** – arter som i dag er uddøde eller ekstremt sjældne i Nissum Fjord og langs den jyske vestkyst.
Sammenligning af artssammensætningen over tid viser et skifte fra ferskvands-, brakvands- og anadrome arter i midten af 1800-tallet til primært saltvandsfisk i starten af 1900-tallet. Denne udvikling falder sammen med etableringen af nye fiskerihavne ved Vestkysten og intensiveret kommercielt fiskeri, samt ødelæggelse af lokale habitater i fjorde og åløb. I 1920'erne blev fisk serveret på ca. 1 ud af 5 dage, med en tydelig præference for friske frem for saltede eller konserverede produkter. Mandag fremstod som en fast "fiskedag", hvilket afspejler både kulturelle og logistiske mønstre i datidens husholdning. I dag er der stort set intet kommercielt fiskeri i Nissum Fjord, og den restaurant, der i dag holder til på Nørre Vosborg serverer marine produkter fra nutidens globale fødevaremarked.
Studiet demonstrerer, hvordan historiske husholdningsdata kan anvendes som kilde til marine miljøhistorie og bevaringsforskning. Det bidrager til forståelsen af, hvordan samfundsmæssige, teknologiske og økologiske faktorer har formet forbruget af marine ressourcer – og hvordan fortidens spisevaner kan kaste lys over nutidens biodiversitetskrise.
Marine biodiversitet og forbrug er indlejret i skiftende epistemiske regimer: fra lokal, erfaringsbaseret viden til moderne infrastrukturel og globaliseret tilgang til marine fødevarer. Samtidig peger undersøgelsen på en "shifting baseline"-problematik, hvor tabet af arter og habitater ikke nødvendigvis registreres som videnstab, men som normalisering.

Danish

Danish Reef Fish Diversity: SCUBA, BRUV and eDNA

Robinson, Ben[1]

[1]Aarhus University, Department of Ecoscience

Danish reef fish biodiversity and community structure are a key component of the marine ecosystem yet challangeing to assess and of increasing importance within marine frameworks such as Marine Strategy Framework Directive (MSFD), Regional Seas Conventions (RSC) like the Oslo-Paris Convention (OSPAR). Sampling methods for reef fish are heterogenous with some traditional methods such as nets, trawls and pots are destructive and cause fish mortality impacting sensitive habitats. Hence the demand for non-invasive and widely adoptable methods for fish monitoring and provide ecological assessments. In this study we develop and combine two tranditional protocols Underwater Visual Census (UVC) and Baited Remote Underwater Video (BRUV), along with a novel complementary method, metabarcoding on environmental DNA (eDNA), with the aim of validating the methodolgical framework across three sampling methods. Reef fish survey was was conducted on 24 reefs across Danish water in August 2024, from the North Sea to the Baltic, vary with depth, topography and enviromental conditions, providing a snapshot of Danish reef fish diverisity across all three methods. This data will provide instruction on how to optimise and harmonise sampling designs for reef fish across mulitple conditions and regions, particularly when combined with matched surveys from our European partners in the EUROCKFISH project. The results of which will produce methodological guidelines for long-term reef fish monitoring strategy in Europe and greater insight into previous reported reef fish data.

English

Evaluating a Novel Approach to Remote Underwater Video Systems (RUVs) for Assessing Fish Assemblages in a Danish Fjord

Rooth, Daniel[1]; Henriksen, Ole[2]; Steinfurth, Rune[3]; Schiønning, Mette[4]; Nielsen, Benjamin[5]; Skov, Christian[6]; van Deurs, Mikael[1]

[1]National Institute of Aquatic Resources, Technical University of Denmark, Kemitorvet, building 202, 2800 Kgs. Lyngby, Denmark, [2]DTU aqua - Section for Ecosystem based Marine Management, [3]Department of Biology, University of Southern Denmark, 5230 Odense M, Denmark, [4]Technical University of Denmark, National Institute of Aquatic Resources, Kgs. Lyngby, Denmark, [5]Department of Biology, University of Southern Denmark, Odense M, Denmark, [6]National Institute of Aquatic Resources, Technical University of Denmark

Non-invasive alternative methods for assessing fish assemblages have gained increasing attention compared to traditional fishing techniques. Approaches such as Baited Remote Underwater Video systems (BRUVs), Autonomous Underwater Vehicles (AUVs) equipped with cameras, and environmental DNA (eDNA) sampling have seen substantial growth over the past decade. Despite their advantages, these methods also present specific trade-offs that must be considered in monitoring design and interpretation. Baited Remote Underwater Video systems (BRUVs) are cost-effective, versatile, and provide high reproducibility but can face limitations such as reduced utility in low underwater visibility and challenges related to their weight and cumbersome deployment (Langlois et al., 2010). Additionally, the use of bait to attract fish may bias sampling outcomes, particularly when studying spatiotemporal patterns within small-scale fish assemblages (Oruç, 2025). In this study, we propose an alternative approach using Non-baited Remote Underwater Video systems (RUVs) deployed in a shallow mixed-habitat coastal zone in Vejle Fjord, Denmark. Up to seven RUV units were simultaneously deployed at random, at fifteen selected underwater sites representing diverse habitats, including transplanted eelgrass mosaics, natural eelgrass patches, artificial boulder reefs, and barren sand flats. Each deployment recorded up to 10 hours during daytime and 5 hours at night. We will compare data obtained from Non-baited Remote Underwater Video systems (RUVs) with traditional seine net catches and environmental DNA (eDNA) samples to evaluate the performance and complementarity of extended-duration RUV deployments in assessing fish assemblages. Our study aims to identify potential species biases driven by species-specific ecological traits across these different monitoring approaches. Additionally, we will explore temporal trends in species composition and relative abundance over the duration of RUV deployments.

English

Modiolus modiolus beds are biodiversity hotspots and may function as essential fish habitats in Danish marine waters

Dinesen, Grete Elisabeth[1]; Jeppesen, Jens Peder[2]; Henriksen, Ole[1]; Kroner, Anne-Mette[1]; Pedersen, Eva Maria[1]; Svendsen, Jon Christian[1]; Seehusen Kruchov van Deurs, Mikael[1]

[1]Technical University of Denmark, National Institute of Aquatic Resources (DTU Aqua), [2]The Øresund Aquarium, Department of Biology, University of Copenhagen

The large-bodied, filter-feeding northern horse mussel, *Modiolus modiolus* (Linnaeus, 1758), forms aggregations on soft and mixed substrates between 0-200 meters depth. The longevity of the individual mussel and the horse mussel beds may exceed 45 and 100 years, respectively. Horse mussel beds are currently protected under the EU Habitats Directive habitat type "1170 Reefs". Across its pan-boreal distribution, international sea conventions have documented declines caused by bottom trawling. Both the species and its biogenic habitats are considered threatened and in need of further protection and restoration throughout Danish and European seas. While these habitats are well known to creating local biodiversity hotspots of benthic invertebrates, knowledge of their functioning as fish habitats are remarkably limited. We conducted an experimental field study of the fish and invertebrate epifauna associated with a *M. modiolus* habitat in Danish waters. Historically, the biodiversity associated with *M. modiolus* habitats was first reported upon from the Sound and Kattegat as part of the *Modiola*-community (e.g., Petersen, 1913). Several recent *M. modiolus* habitat studies in the Atlantic and adjacent seas have recorded high diversities of associated invertebrate fauna and macroalgae species and documented these habitats as being local biodiversity hotspots in different biozones. Other studies have linked variation in habitat structure and complexity to different functioning as substrate for sessile organisms and nursery grounds for mobile invertebrates, such as welks and decapods, and other common prey for fish. Our field study showed several fish and invertebrates species were associated with the *M. modiolus* habitat. The initial results from our experimental study suggest that *M. modiolus* habitats are essential habitats not only for epifaunal invertebrates but also for several fish species. Studies that integrate habitat-forming species, invertebrates, fish and their interactions may add great value to habitat protection and restoration actions and support ecosystem-based management solutions. This study was supported by the research projects, MarHab (Horizon Europe 2024-2027) and ECOSPACE (European Maritime, Fisheries and Aquaculture Fund 2023-2027).

English

Baltic Cod reshaped by mild hypoxia – subtle oxygen decline triggers profound physiological changes

Husen, Magnus Højen, Niels g. Andersen, Kim Birnie-Gauvin, Sune R. Sørensen, Mikael van Deurs & Jane W. Behrens

[1]DTU Aqua

Oxygen depletion is expanding worldwide and not at least in the semi-enclosed Baltic Sea. Naturally, fish seek to find optimal oxygen conditions, yet the increasing spatial and temporal extent of hypoxia-affected areas may at times present certain tradeoffs. Especially during summer and autumn months, where fish must roam sub-optimal and non-lethal oxygen conditions, to forage or avoid predation. One example is the demersal Baltic cod (*Gadus morhua*). Cod feeds extensively on benthic prey and must avoid predators like seals and cormorants by seeking deep waters which are often characterized by suboptimal oxygen conditions for extended periods. Yet, the consequences of long-term exposure to mild hypoxia for Baltic cod remain poorly understood. Here we present experimental results that reveal that even a subtle decrease in the water oxygen content, has propound effects on the physiology and performance of Baltic cod. More specifically, we show that exposure of Baltic cod to mild hypoxia (4–6 mg O_2 L^{-1}) over six weeks resulted in significant negative effects on key fitness-related traits, although the fish also revealed some adaptive response to reduced oxygen, to mitigate the negative impact of these suboptimal conditions.

Our study demonstrates that exposure to persistent mild hypoxia can produce cascading impacts on individual performance. This may – at least partly - explain the historical decline in Baltic cod growth and condition, revealing population-level consequence. This work highlights the importance of considering the ecological significance of persistent subtle decreases in oxygen levels on fish in our waters.

English

Living on the edge: behavioural response of three-spined stickleback (Gasterosteus aculeatus) to the trade-off between progressive hypoxia and refuge

Broegaard-Iversen, Amalie; Heide Andreasen, Magnus; Behrens, Jane; Christian Svendsen, Jon; Seehusen Kruchov van Deurs, Mikael

Seagrass meadows such as eelgrass habitats, are vital to coastal ecosystems, among other things as they serve as habitat for various marine species. A decrease in the eelgrass abundance has been reported globally caused by several factors including eutrophication, climate change, shoreline development and the wasting disease. At the same time, periods of hypoxia (dissolved oxygen < 2 mg/L) have become more frequent in Danish waters, disrupting species distribution and ecosystem functioning. The decline in eelgrass abundance, combined with more frequent hypoxia events, may compel fish to the trade-off between structurally complex habitats with low oxygen and oxygen-rich areas lacking eelgrass. We aimed to investigate this trade-off in the three-spined stickleback (*Gasterosteus aculeatus*), a highly adaptable small teleost fish that plays a crucial role in temperate freshwater and marine ecosystems, using a two-current choice chamber. Using the setup of the two-current choice chamber sticklebacks could freely choose between an area with 9.6 mg O_2 L^{-1} (100% air saturation) and no vegetation and an area with slowly decreasing oxygen levels 9.6-1.0 mg O_2 L^{-1} (100-10% air saturation) with vegetation. The results of the experiments indicate that sticklebacks are willing to tolerate moderate hypoxia when vegetation, and thus refuge, is present.

English

Coastal Fish and their Habitats in Denmark II (10:50)

Explaining early-stage distribution of larval fishes in the Kattegat Sea by combining field observations and mechanistic modelling tools.

Neuheimer, Anna[1]; Bering, Line; Jørgensen, Kris-Emil

[1]Aarhus University

The Kattegat Sea is an important nursery area for several fished species including sandeel (*Ammodytes* spp.), Atlantic cod (*Gadus morhua*), common dab (*Limanda limanda*) and plaice (*Pleuronectes platessa*). As a transition area between the North and Baltic Seas, the Kattegat Sea hosts both resident fish populations and larvae from surrounding regions. Recruitment for these populations depends on the success of their early life stages (e.g. yolk-sac larvae). This success is shaped by how the physical environment interacts with biological traits of the different groups.

Here we describe how the larval distribution of several fish species varies over time and space in the Kattegat. We develop and use statistical and mechanistic models to explain this distribution with respect to both biological traits (e.g. total vs. batch and pelagic vs. benthic spawners) and the physical environment. The mechanistic modelling tools are agent- (or individual-) based, linking the physical environment to the individual's biological processes. This includes transport via high-resolution, four-dimensional hydrodynamic advection. In addition, we use species-specific thermal time as a physiologically relevant time-scale that allows us to estimate developmental timing and, along with the advection estimates, approximate spawning locations and times.

Results link our observations to trait-based variability among the fish species as well as highlighting the strong and seasonally varying influence of North Sea inflow on the Kattegat ichthyoplankton community. The modelling tools developed here can be used to explain functional, and genetic diversity as well as connectivity among fish populations in the Kattegat and surrounding seas. Moreover, these mechanistic modelling tools can be used to make predictions of how changing physical conditions will affect fish production in the area, informing ecosystem-based management and spatial planning.

English

Lost and Found: the story of a fish and its fisheries

Henriksen, Ole

The lumpsucker (Cyclopterus lumpus) has supported a seasonal, coastal and valuable fishery in Denmark for decades. Yet, it has received little scientific or managerial attention. With no quotas, no monitoring framework, and no targeted research, it has remained outside the scope of both the EU Data Collection Framework (DCF) and advice efforts. As a result, data have been sparse, fragmented, and inconsistent

reflecting a broader challenge in coastal fish management where prioritization follows funding more than ecological urgency.
In recent years, signs of a dramatic population decline have emerged. Survey data and commercial landings point to a potential collapse, though the uncertainty surrounding the available data is so large that we are effectively starting from scratch. No historical baselines exist, CPUE estimates are unreliable, and biological sampling has been minimal. Despite this, the lumpsucker has become a symbol for the deteriorating state of marine environments in Denmark and drawing political and public attention.
In 2025, the fishery was fully closed. A management decision taken under scientific uncertainty, driven by precaution and public concern. This closure has triggered attempts to rebuild the knowledge base, including experimental fisheries, improved biological sampling, and efforts to digitalize historical logbooks.
This presentation uses the lumpsucker case to highlight what can happen when a species falls outside of science-based management. It illustrates the risk of neglect in coastal systems and the long-term consequences of insufficient baseline data, poor habitat knowledge, and fragmented monitoring. The story underscores the urgent need for a national coastal fish monitoring program, integration of overlooked species into advice frameworks.

Danish

Danish Marine Fish Atlas - a new baseline

Møller, Peter Rask; Carl, Henrik

In 2009 a Danish National Marine Fish Atlas was initiated, as an extension of the Danish Freshwater Fish Atlas. The project is a collaboration with KU/NHMD and DTU Aqua and was presented at "Dansk Havforskermøde 2009". The new Atlas book is now done, with a new baseline for the distribution for all 214 Danish marine fishes. Hereof 202 naturel and 12 non-indigenous species. Ca. 109 are considered spawning in Danish waters, whereas 105 are guests spawning elsewhere.
Here we attempt to provide an estimate of whether individual species are increasing, declining, or stable. To make such an estimate, we have divided the records into those before the year 2000 and those from 2000–2025. Species are considered stable if the number of records from 2000 onwards makes up between 30% and 70% of the total. If the proportion of new records is less than 30% of the total, the species is regarded as declining, and if it exceeds 70%, it is generally considered to be increasing. Using these criteria 44 species have declined, 66 are stable, and 105 have increased. How can we see increases, when we hear so much about fishless waters, oxygen depletion, and overfishing? Some changes are clearly due to increased effort in the registration, whereas others are a result of climate change, reduced predation due to collapse in cod populations. Twenty-five species have been recorded for the first time in Denmark since the turn of the millennium – nine of these are non-native, presumed to have arrived with human assistance, whether intentional or unintentional. The most recent newcomer is the Atlantic butterfish. Overall, as many as 12 species have been recorded only once, 40 species have been recorded no more than five times, and no fewer than 100 species have been recorded a maximum of 100 times. The return of the Atlantic tuna to Danish waters is perhaps the most positive event of the Atlas period, while the decline of cod and the fishing ban—even for recreational anglers—in the inner waters represent a corresponding low.

English

Monitoring coastal fish and fisheries through an electronic angler citizen science platform: Opportunities and challenges

Skov, Christian; Skov, Christian; van Deurs, Mikael; Olesen, Hans Jakob; Gundelund, Casper

Knowledge of coastal fish populations and their interactions with recreational fisheries remains limited. Citizen science, facilitated by digital platforms such as smartphone applications, offers a promising approach to enhance data collection and support research. In Denmark, the electronic citizen science platform *Fangstjournalen*, developed by DTU Aqua and launched in 2016, has engaged approximately 18,000 recreational anglers who have reported around 100,000 fishing trips. In this study, we utilize data from *Fangstjournalen* to explore the spatial and temporal distribution of selected coastal fish species and to assess trends in catch per unit effort (CPUE) and fish length distributions over time. These metrics provide valuable insights for fisheries management and can increase the general knowledge of coastal fish population. Furthermore, we discuss key challenges associated with citizen science, including challenges with participant retention and the limited representativeness of participants across the broader angling community. Despite these limitations, data quality assessments indicate that, when sample sizes are sufficient, citizen science data can be comparable to those obtained through traditional scientific surveys. We advocate for the integration of citizen science into fisheries management

frameworks, not only to enhance scientific understanding but also to promote public engagement, education, and trust in science.

English

State of the Danish recreational sea trout and cod fisheries: insights from 15 years of recall surveys and 10 years of citizen science

Gundelund, Casper[1,2]; Olesen, Hans Jakob[1]; van Deurs, Mikael[1]; Skov, Christian[2]

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Recreational fisheries are most important fisheries in most inland and many coastal areas, with recreational anglers being the sole or dominant users of many fish stocks. However, in the absence of a national coastal fish monitoring program, and given the challenges of tracking a large and diverse population of recreational anglers, very little is known about recreational fisheries and the status of the targeted, often coastal, fish stocks.In Denmark, coastal angling for sea trout (*Salmo trutta*) and Atlantic cod (*gadus morhua*) are among the most important fisheries with substantial socio-economic benefits. Yet, information about the state of these fisheries is largely lacking or anecdotal at best. In this study, we present 15 years of national recall survey data and 10 years of electronic citizen science contributions to the Fangstjournalen platform to describe temporal and spatial patterns in rod and reel caught sea trout and Atlantic cod. By comparing recall and citizen science datasets, we highlight the strengths and limitations of each approach, including coverage, reporting biases, and complementarities. Together, these findings demonstrate the importance of collecting data from recreational fisheries to inform management and support that integration of citizen science data has strong potential.

English

Citizen science network reveals unique insights into coastal eel abundances over the past 20 years.

Sørensen, Sune Riis

The European eel holds a central position in discussions of historical population changes among European fish species. Since the late 1970s, the species has suffered a dramatic decline and is described as critically endangered by the IUCN Red List of Threatened Species. Assessing stock trends however remains highly challenging, as eels occupy a wide range of freshwater, estuarine, and marine habitats, which complicates the collection data and the evaluation of population fluctuations.
In Denmark, coastal fish abundances have been monitored since 2002 through the Citizen Science network "Nøglefiskere" (*Key Fishermen*), where volunteer recreational fishers collaborate with DTU Aqua and fisheries organizations to collect standardized catch data from Danish coastal waters. The most recent Nøglefisker report, among other findings, summarizes 20 years of catch per unit effort data on eel, revealing significant temporal and spatial changes.
In this presentation we elaborate on catch results of eels and present regional differences. Overall, the catch data from 2002 until approximately 2015–2017 show stable relatively low catches. Thereafter, however a marked increase has been documented nationally. This increase is mainly driven by catches in eastern Danish fjords and coastal regions such as Roskilde Fjord, Øresund, Køge Bugt, Storstrømmen, Fakse Bugt, Hjelm Bugt, and the Fehmarn Belt, which outmatch a decline recorded in areas including the South Funen Archipelago, Als, and Lillebælt. No clear explanation is available for this increase, but positive management actions are outlined. Furthermore, eels' general linkage to lunar phases was also visible in catch rates as these were found to vary with lunar phases, being higher around new moon than full moon.
These spatial and temporal patterns emphasize the complexity of eel stock dynamics and underscore the need for continued long-term monitoring through standardized coastal fishery surveys such as the Nøglefisker network.

English

Marine virkemidler som driver for et godt havmiljø (13:40)

Genopretning af havnaturen – en strategisk og teknologisk helhedsplan

Birkeland, Mads Joakim

Marine virkemidler som driver for et godt havmiljø

Genopretning af havnaturen – en strategisk og teknologisk helhedsplan
Mads Joakim Birkeland. Senior Biolog, DHI.
Genopretning af marine økosystemer i danske farvande er en kompleks og langsigtet opgave. Generationers intensiv udnyttelse har medført omfattende tab af biodiversitet og levesteder i store områder.
Vandområdeplanernes mål for reduktion af kvælstof og fosfor er det helt afgørende skridt mod bedre økologisk tilstand og gunstig bevaringsstatus. Men fremskridtene er langsomme – og spørgsmålet er, om vi har tid til at vente?
Samtidig accelerer klimaændringerne. Selv under moderate scenarier (SSP2-4.5) forventes betydelige ændringer i afstrømningsmønstre, havtemperaturer og vandstande frem mod 2100.
Det stiller krav om, at genopretningen ikke blot fokuserer på restaurering, men også på **resiliens** – strukturel og funktionel robusthed og integritet, der kan understøtte biodiversitet og levesteder – også på lang sigt.
Det vil være en enorm opgave at udplante ålegræs langs hele Danmarks 8.750 km kystlinje eller udlægge 55 km^2 stenrev. Skal vi lykkes, kræver det derfor en strategisk tilgang, hvor eksisterende viden og avanceret teknologi anvendes til at optimere indsatsen og supplere effekten af Vandområdeplanerne.
Eksempler på relevante teknologier inkluderer:

Satellitbaseret overvågning og fjernmåling, som muliggør præcis kortlægning af havbundens tilstand og udvikling over tid

Autonome undervandsdroner (AUVs) til dataindsamling, habitatkortlægning og inspektion af genoprettede områder

eDNA-analyse, der gør det muligt at overvåge biodiversitet uden fysisk indsamling

Modellering af økosystemer og hydrodynamik for at planlægge, optimere og forudsige effekten af genopretningsindsatser og klimaforandringer

Revstrukturer som stabiliserer havbunden og understøtter biodiversitet.

Integrerede dataplatforme og beslutningsstøttesystemer, der samler information fra nationale overvågningsprogrammer og lokale projekter.

Denne præsentation vil give et bud på, hvordan marine virkemidler og naturgenopretning kan integreres med teknologiske løsninger og nationale overvågningsprogrammer i én samlet og ambitiøs plan for genopretning af havnaturen.

Danish

Statusrapport for arbejdet i Kystvandrådet for Nissum Fjord. Kan ændringer i slusedriften forbedre miljøtilstanden?

Nielsen, Morten Holtegaard[1]; Erichsen, Anders Chr.[2]; Larsen, Trine Cecilie[2]; Christensen, Jesper Philip Aagaard[3]; Hansen, Jens Würgler[3]; Gertz, Flemming[4]; Nedergaard, Mads[5]; Mølgaard, Torben[5]; Grooss, Jane[6]

[1]Marine Science & Consulting ApS, [2]DHI A/S, [3]Institut for Ecoscience, Aarhus Universitet, [4]SEGES Innovation P/S, [5]Holstebro Kommune, [6]Lemvig Kommune

Som en del af den politiske aftale om Den Grønne Trepart er der etableret en lang række kystvandråd med deltagelse af lokale parter samt bidrag fra eksterne eksperter. Kystvandrådenes opgave er at rådgive og bidrage med viden om lokale virkemidler og analyser, der kan understøtte den lokale indsats for et sundere havmiljø. I Kystvandrådet for Nissum Fjord, som ledes i samarbejde mellem Holstebro og Lemvig Kommuner, har man at gøre med særlige udfordringer, idet fjorden er relativ lille (ca. 70 km^2) og lavvandet (ca. 1 m i middeldybde) og modtager afstrømning af ferskvand og næringssalte fra et relativt stort opland (1615 km^2), som primært sker via Storå. Endvidere er udvekslingen med Nordsøen styret af en sluse i Thorsminde, hvilket gør Nissum Fjord til et stærk modificeret vandområde. Fjorden består af tre bassiner med relativt store forskelle i saltholdighed. På trods af den lave dybde er fjorden stort set uden bundvegetation, hvilket betyder bl.a. manglende leve- og opholdssteder for fisk og smådyr, store sandvandringer og konkurrencefordel for planteplankton og epifytter. I præsentationen giver vi en status for arbejdet med at belyse og forstå de fysiske og biologiske forhold i Nissum Fjord, og hvordan

økosystemet fungerer i dag. Dette arbejde omfatter både analyse af eksisterende data og opstilling af nogle mekanistiske modeller til beskrivelse af udvekslingen gennem slusen og de fysiske og biologiske forhold i fjorden. Da Nissum Fjord er et stærkt modificeret vandområde, er et af de mulige virkemidler til forbedring af vandmiljøet at ændre på slusepraksis. Derved kan saltholdigheden, lagdelingen og vandstanden i fjorden påvirkes. En af de væsentligste opgaver i arbejdet med Nissum Fjord er at bruge modellerne til at belyse, på hvilken måde en ændring af slusepraksis vil kunne påvirke miljøtilstanden i systemet.

Danish

BlueOFS: Boosting Blue Carbon in Denmark's Odense Fjord

Canal-Vergés, Paula; K Lees, Mikkel; Barnewitz, Anders; K. Lücking, Søren; H Hansen, Frederik; Svane, Niels; H Petersen, Anders; Kragh, Theis; Kuusemaee, Kadri[1]; Murray, Alexandra[1]; Huber, Silvia[1]; Cecilie Larsen, Trine[1]; B Hansen, Lars; Chr. Erichsen, Anders[1]; R Flindt, Mogens

[1]DHI

This project explored the potential to enhance blue carbon storage in Denmark through a pilot initiative in Odense Fjord (OF) and the Egensedybet sub-catchment. The focus was to design and implement a holistic plan using Nature-based Solutions (NBS) in the catchment to improve marine carbon sequestration.

A literature review identified six NBS options for the catchment and three for the marine area, with eelgrass beds and coastal wetlands as the main blue carbon contributors. However, large variability in carbon, nitrogen, and phosphorus retention highlighted the need for site-specific monitoring and long-term data.

OF is highly eutrophic, with persistent nutrient pollution and eelgrass decline from 44% coverage in the 1960s to less than 1% today. Sediment instability, low light, and high organic content further hinder recovery. Eelgrass transplantation at 17 sites showed poor survival—only one persisted through winter—due to hypoxia, unsuitable sediments, and macroalgal competition. Coastal meadows have largely been lost to reclamation, while remaining wetlands face coastal squeeze, desalinization, and fragmentation.

Mechanistic and GIS models simulated nutrient reduction (30% N and P). Nitrogen reduction was more promising, particularly in the inner fjord, shifting production from phytoplankton to benthic species. Yet natural eelgrass recovery is unlikely without transplantation. A GIS-based suitability model was created but requires refinement, including salinity and substrate data.

Blue carbon modeling showed eelgrass accounts for ~20% of OF's stored carbon, most locked in deep sediments. Simulations indicated that even an 84% nutrient reduction only increased blue carbon by 5% in the outer fjord due to low current eelgrass biomass.

To address nutrient inputs, a new hotspot-mapping method was tested in Egensedybet. Combining GIS modeling, citizen-science monitoring, and hydrological modeling revealed diffuse agricultural sources as dominant contributors. A 334 ha wetland in the catchment could reduce nitrogen loads by up to 80%, supporting eelgrass survival and carbon recovery.

The project concludes that enhancing blue carbon in OF requires integrated measures: large-scale nutrient reduction, targeted NBS, and strategically supported eelgrass transplantation.

English

Cultivation of sugar kelp as a marine measure for mitigating eutrophication: Production in large-scale, nutrient removal efficiency, environmental impacts, and economy

Bruhn, Annette[1]

[1]Aarhus University, Ecoscience

The cultivation of sugar kelp has emerged as a marine mitigation measure for uptake and removal of nutrients from the marine environment. In 2022-2023, sugar kelp was cultivated in the Limfjorden in a 12-hectare experimental facility to document biomass yields, uptake of nitrogen, phosphorus and carbon and effects on the environment by large-scale cultivation. Results show that sugar kelp production can remove up to 23 g N m^{-1} line $year^{-1}$, corresponding to an annual nutrient removal potential of 23 kg N ha^{-1} and 0.8 kg P ha^{-1} in a standard system with 1000 m cultivation line ha^{-1}. Removal efficiency varies across Danish waters, with highest yields in areas of high salinity and nutrient availability. The lowest cost

of nitrogen removal was DKK 2805 per kg N. Modelling scenarios indicate that significant upscaling of sugar kelp cultivation is required to achieve any effect on key environmental indicators for Good Ecological Status (GES): summer chlorophyll-a and light attenuation. At high biomass densities, environmental effects include negligible reduction of light to the seabed, altered water flow, reduced sedimentation rates, and limited periodic increases in pH and oxygen concentration under, in and near the cultivation site. Harvesting in April reduces carbon loss from the seaweed to the marine environment, and it is unlikely that seaweed cultivation contributes to carbon sequestration in inner Danish waters. Cultivation and harvest of sugar kelp enables the capture of nutrients from the marine environment, returning them to the food system on land, supporting the circular blue bioeconomy. The effect, however, remains a supplement to reducing emissions from land to accelerate the process towards GES. The need remains for large-scale and long-term studies of the efficiency and environmental effects of sugar kelp cultivation addressing persisting fundamental knowledge gaps, in particular: 1) implementing more area-intensive production systems; 2) lowering production costs; 3) assessing the extent of seaweed-mediated C production (including emissions of climate-relevant VOCs) and C burial/sequestration – to minimize negative impact on the marine carbon cycle and climate; 4) evaluating the effects on biodiversity. This requires cooperation with the industry or strategic infrastructure investments to ensure relevance and reduce costs.

English

Evaluating the potential for sea-based Ulva cultivation: combined effects of salinity and nutrient availability.

Larsen-Ledet, Kristoffer[1,2]; Boderskov, Teis[1]; Olesen, Birgit[3]; Christensen, Esben[4]; Bruhn, Annette

[1]Department of Ecoscience, Aarhus University, [2]Center for Circular Bioeconomy, Aarhus University, [3]Department of Biology, Aarhus University, [4]Pure Algae Denmark

Seaweed cultivation can play an active role in removing and recycling nutrients from the marine environment. This has been demonstrated through the cultivation of sugar kelp (*Saccharina latissima*) in various European countries. With the growing political interest in offshore wind energy and the "multi-use" concept, the opportunities for seaweed farming are expanding. However, the Danish marine environment poses several challenges for kelp cultivation including the low salinity levels in the Baltic Sea, seasonal water stratification, and fluctuating nutrient concentrations. As a result, the fast-growing and resilient green macroalgae sea lettuce (*Ulva*) has been proposed as an alternative candidate for seaweed cultivation.
This study presents a series of laboratory experiments investigating *Ulva*'s salinity tolerance (ranging from 5 to 25) under varying nutrient concentrations. Additionally, the study showcase field trials using longline cultivation of *Ulva* at five different locations across Danish fjords, coastal areas, and offshore sites. *Ulva* exhibited a wide salinity tolerance and could grow across all tested salinity levels — provided that nutrient concentrations were high (7.5 – 18.8% day^{-1}). However, this salinity tolerance decreased significantly under low nutrient conditions and this effect was most pronounced in brackish water (salinity 5), where growth rates were the lowest (1.9 - 4.7% day^{-1}). The field trials revealed strong seasonal and geographical variations with the highest biomass yields recorded in the Kattegat region (225.9 – 317.3 g fresh weight m^{-1} cultivation line), where both salinity and nutrient levels were relatively high. In contrast, the lowest yields occurred in the Baltic Sea (1.1 – 34.7 g FW m^{-1} cultivation line), where salinity consistently remained below 10. Furthermore, *Ulva*'s nitrogen uptake potential was estimated as 1.92 – 4.8 kg N ha^{-1} $year^{-1}$ in Kattegat and 0.02 – 0.5 kg N ha^{-1} $year^{-1}$ in the Baltic Sea. These findings offer valuable insights into *Ulva*'s physiological responses and can aid in future marine spatial planning and modelling. Importantly, the results highlight that *Ulva* cultivation is not a quick-fix solution to anthropogenic eutrophication and careful consideration of local conditions is essential for successful implementation.

English

Kystbeskyttende stenrev

Kaufmann, Stina[1]; Svendsen, Jon[2]

[1]Dalgas A/S, [2]DTU Aqua

Kystbeskyttende stenrev repræsenterer en tilgang til en bæredygtig kystforvaltning, hvor tekniske og økologiske hensyn integreres i økosystembaseret kystbeskyttelse. I modsætning til traditionelle løsninger

som høfder, diger mv., testes der muligheder, hvor stenrev både dæmper bølgeenergi og reducerer kysterosion – samtidig med at de skaber levesteder for marine organismer som fisk, tang og skaldyr.

Netop denne kombination af funktioner gør revtilgangen særligt interessant i en tid, hvor samfundet efterspørger løsninger, der både beskytter og genopretter.

Ved at designe rev med udgangspunkt i både hydrodynamik og økologisk funktionalitet, arbejder man på at opnå større resiliens i kystzonerne og samtidig understøtte biodiversitet og økosystemtjenester.

Flerfunktionelle stenrev peger dermed frem mod en ny generation af kystbeskyttelse, hvor klimatilpasning og havmiljø ikke står i modsætning – men i samspil.

Danish

Non-indigenous marine species – dispersal, effects, monitoring and mitigation. (15:30)

A new tool for accessing the risk of natural dispersal of non-indigenous species to comply with the Ballast Water Management Convention

Hansen, Flemming

The introduction of Marine Non-Indigenous Species (NIS) poses a significant threat to global marine biodiversity and ecosystems. To mitigate this risk, the Ballast Water Management Convention (BWMC) was adopted by the UN International Maritime Organization (IMO), setting strict criteria for discharges of ballast water. However, the BWMC permits exemptions for individual shipping routes or for shipping routes operating within a geographical area, known as a Same-Risk-Area (SRA). Assigning an SRA requires a risk assessment (RA) that can conclude that the spread of NIS via ballast water is low relative to the predicted natural dispersal. Despite the BWMC's requirement for RAs to be based on modelling of the natural dispersal of NIS, no standard procedures have been established. A recent study proposed a methodology utilizing biophysical modelling and marine connectivity analyses to support both the RA of the dispersal of NIS between individual ports, and the SRA RA and delineation. While these types of analysis typically require highly specialized competences and costs in terms of person hours to carry out tailored marine connectivity studies, this presentation wiil demonstrate and discuss a new web based tool for rapid assessment of the risk of natural dispersal of marine NIS in the transboundary marine waters of Denmark, Sweden and Germany. The tool is build on a Marine Connectivity Database which constitutes a large number of biophysical simulation results and calculated connectivity matrices. This approach proposes a new standard for conducting marine connectivity studies specifally for accessing the risk of the natural disperal of marine NIS, and has the potential for other types of applications including optimization of monitoring networks, site selection of habitat restoration and conservation efforts, fisheries management, etc.

Danish

Green Energy as Blue Corridors: Are offshore wind farms stepping-stones for marine invaders into Danish waters?

Clubley, Charlotte[1]; Dahl, Karsten[1]; Mohn, Christian[1]; Buur, Helle[1]; Larsen, Janus[1]; Koziol, Adam[1]; Stæhr, Peter[1]; Maar, Marie[1]

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The global number of non-indigenous species (NIS) is projected to rise substantially by 2050, with >800 NIS already established in European waters. Only 130 of these are currently recorded in Danish seas, suggesting a potential six-fold increase in coming decades. To date, the dispersal of hard-substrate NIS to Danish waters has been limited through separation by distance and a scarcity of natural rocky habitats in Danish coastal areas. However, recent and projected future expansion of offshore wind farms (OWF) is fundamentally altering the North Sea seascape, introducing artificial hard substrates that have the potential to act as 'stepping-stones' for NIS, creating 'Blue Corridors' for larval transport to previously isolated hard-substrate areas. Despite the ecological significance of Danish boulder reefs as habitat and as a donor region of larvae to the Baltic Sea, studies on the effects of OWF on larval transport of NIS to date have predominantly omitted Danish coastal areas. Here, we combine species distribution models, a high-resolution hydrodynamic model, agent-based modelling and graph network theory to assess the potential multi-generational spread of three model NIS from the North Sea into Danish waters under both

current and future (2030) offshore wind scenarios. The effects of individual OWF monopiles on hydrodynamics, and therefore larval dispersal, are incorporated into the models. We compare the ecological network of resulting dispersal pathways to a reference scenario containing no OWF to determine the relative impact of these artificial hard substrates, and identify the 'worst offenders' for contributing to the stepping-stone effect, on NIS spread.

English

Unravelling the impact of artificial structures on marine invasions with network theory

Pastor Rollan, Ane[1]; Thorbjorn Hansen, Flemming; Birchenough, Silvana; Stuer-Lauridsen, Frank; Timmermann, Karen

[1]DTU Aqua

In a changing climate and human-modified environment, understanding the spread and persistence of invasive marine species is crucial. The rapid expansion of offshore renewable energy, alongside the decommissioning of Oil & Gas platforms and wind farms, will significantly alter marine ecosystems over the next 30–40 years. The long-term ecological consequences of both man-made structures (MMS) installation and removal remains unclear[1]. These MMS can act as stepping-stones, facilitating the spread of both native and invasive species by enhancing ecological connectivity and gene flow. While MMS can serve as artificial reefs, supporting biodiversity and fisheries, they may also accelerate biological invasions, threatening native ecosystems. To understand these complex interactions, biophysical models coupled with field observations in combination with network theory, is a strong tool to quantify potential connectivity across the seascape[2]. Networks can represent structures or habitat patches, connected by the movement of organisms between them. Network analyses can then identify biodiversity hotspots, stepping-stones, and critical structures that either aid or hinder the spread of invasive species. This study will reveal ecological implications of offshore MMS on connectivity and metapopulation dynamics of invasive species in the North Sea by assessing 1) how artificial platforms contribute to the stepping stone effect and connectivity and 2) how decommissioning or building of new structures will facilitate or reduce the spread. This knowledge will help inform management decisions, balancing the benefits of artificial habitats with the risks of facilitating invasions, ultimately supporting biodiversity conservation in a rapidly changing seascape.

English

Seasonal fates of marine non-indigenous species at an offshore-wind platform in the North Sea

Koziol, Adam; Stæhr, Peter; Montesanto, Federica; Dahl, Karsten; Sapkota, Rumakanta; Winding, Anne; Andersen, Karolina; Wilms, Tim

Offshore windfarms have taken centre stage as critical infrastructure in revolutionizing the energy transition towards renewable energies. In the North Sea, developments of offshore windfarms have outpaced that of any other sea, with projections of sea-space projected to increase by 129% by 2030. Despite the benefits towards the increasing access to renewable energies, the location of these windfarms offshore have altered the sea-scape, increasing the footprint of hard-substrates that historically have not occupied these areas. While there is optimism about the attraction of native species towards these hard-substrates, these do not reflect the life-history traits of these species and have been proposed to prefer invasive species capable of occupying this novel niche. Here we investigated the utilization of environmental DNA in the detection of windfarm biodiversity across two seasons at Horns Rev 1 in the North sea and utilize the methodology to detect invasive species and determine whether these represent hot-spots for marine invasive species.

English

Towards a national monitoring program for Non-Indigenous Marine Species in Norway

Husa, Vivian[1]

[1]Institute of Marine Research Norway

Vivian Husa, Frode Fossøy

During the last five years we have been working on testing out the efficiency of different methods to detect NIMS along the coast. As biofouling on vessels is considered to be the most important vector into the Norwegian coast, we performed an analysis of 155 000 port calls for one year. This analysis revealed

that the coasts along the Oslofjord and the western part of the country has the highest risk of new introductions by boat traffic. Identification material for established and door knocker species were developed. Field methods were basically in line with the HELCOM procedures, but with more extensive use of genetic methods. We here present the results from 2 pilot studies from the east and west coast of southern Norway. The national programme will be financed from 2026.

English

Prey preferences of the Invasive Japanese Oyster Drill in the Limfjord: Native Bivalves Favored Over Introduced Pacific Oyster

Herz, Laura Marie

Introduced species often arrive in clusters. A current example is the Pacific oyster (*Magallana gigas*), originally introduced in the early 1900s as a fast-growing aquaculture resource, which subsequently spread from aquaculture facilities into the wild. Several marine species were unintentionally co-introduced, including the predatory Japanese oyster drill (*Ocinebrellus inornatus*). In recent years, populations of both Pacific oysters and Japanese oyster drills have expanded rapidly in Denmark's largest fjord, the Limfjord.

In its native range, the Japanese oyster drill feeds on a range of bivalves, including Pacific oysters. In the Limfjord, it preys not only on the introduced Pacific oyster but also on native bivalves. The seven-week field study presented in this talk demonstrates that the drill not only consumes native bivalves — specifically European flat oysters (*Ostrea edulis*) and blue mussels (*Mytilus edulis*) — but also shows a marked preference for the native bivalves over the introduced oyster. Such selective predation may have significant long-term ecological consequences for the Limfjord ecosystem, as well as for the mussel fishery in the region.

English

Jorn

Oceanografiske ekstremer og impacts (9:00)

Seamless Storm Surge Forecast with LSTM Networks: Bridging Early Warnings and Climate Impact Assessments

Mik-Meyer, Villy

In this project, a machine learning framework is developed, calibrated, and verified to predict storm surge levels in the North Sea and Baltic Sea. The model is based on 58 years of spatially distributed wind data and uses a Long Short-Term Memory (LSTM) architecture to capture the temporal dynamics driving water level variability. Compared to traditional physically based hydrodynamic models, the machine learning approach requires only a fraction of the computational resources, enabling rapid forecasts across large domains and extended time periods. This efficiency allows the model to be applied to long climate simulations, facilitating advanced analyses such as the projection of extreme water levels and the determination of their statistical distributions under future climate scenarios.

English

Design data for engineering projects in Danish waters

Drønen, Nils; Jensen, Palle M.; Jacobsen, Niels Gjoel

Reliable design data for new infrastructure and coastal protection schemes are always in high demand in coastal engineering projects. In the context of the rising risk of damaging extreme – related to storm surge and sea level rise – this demand challenges such projects and calls for careful consideration on how climate change is best represented in the design data.
Fortunately methodologies developed within the field of meteorological forecasting, climate projection and reanalysis have been building momentum over the last decades (e.g. ERA5 and SEAS5, cf. ECMWF) and have now reached a level where data quality and availability make the application of results from climate science in engineering project realistic adding value to projects and ensure optimal design of new infrastructure and mitigation measures against anticipated negative impacts in terms of flooding and erosion.
In this presentation DHI will give an overview of DHI's most recent studies on how to update a best practice for local design data from state-of-the-art meteorological and climate reanalysis hindcast data -

and climate change future projected data. The study is based on the application of DHI's existing regional scale models for Danish Waters including the North Sea and the Baltic Sea.
The work has been based on application of most recent reanalysis data and climate projection model data selected with support from DMI. The project also draws inspiration from DHIs modelling done in connection with most recent large scale infrastructure projects like Lynetteholmen and work related to the coming Fehmern connection. We have furthermore taken inspiration in current research done in the Dutch sector (research associated with TU Delft and KNMI), where the application of reanalysis data is currently being developed and tested as a mean to increase accuracy on the estimation of 10.000 year events which typically forms the basis for Dutch national storm surge flood protection.
The project has been developed as a part of DHI's core research which is part of the GTS program funded by the Danish Ministry of Higher Education and Science.

English

Re-examine Current Monitoring and Forecasting Capacities and Practices for Enhancing Coastal Resilience in Extreme Events: a Case Study on Storm Babet

She, Jun

Early warning of extreme events and rapid assessment of post-event impacts are essential to improve short-term coastal resilience. Although operational met-ocean monitoring and forecasting systems have been developed for decades, it is still an open question that in which extent the current met-ocean services fit for the purposes of community needs on preparedness before the event, emergency response during the event, impact/damage assessment and making efficient recovery measures after the event. Using Storm Babet as a testbed, we re-examine current monitoring and forecasting capacities to identify gaps on science, technology, and infrastructure and workflow management. Based on such re-examination, joint research have been carried out among partners in Denmark, Germany, Sweden and Finland to fill some of these gaps. Scientific questions considered include: i) What are the mechanisms leading to this event? ii) What are the impacts of the storm on the ocean? iii) Did monitoring systems provide adequate, timely and quality-assured observations? what are the gaps? iv) Do current national forecasting services provide forecasts on all key parameters together with uncertainties and risks? v) How good are the forecasts? vi) How are error sources attributed: weather forcing, model physics, initial field (pre-conditioning), numerics and system configurations (boundary condition, resolution and bathymetry)? vii) What are major gaps in current practices of forecast validation, data assimilation and forecasting technology? viii) what are impacts of waves on storm surge forecast? ix) What are compound impacts of storm surge and waves on coastal morphology? x) How much is the storm surge attributed to climate change (sea level rise)?
Storm Babet is featured with a preface of westerlies for several days followed by 36h prevailing easterlies up to 22m/s in the western Baltic Sea. The storm brought exceptional storm surges, high waves, widespread flooding, coastal erosion and dike breaking to Danish and German waters and coasts in October 2023. In Danish and German coasts in western Baltic Sea, water levels rose more than 2 m above normal, with many stations recording their highest levels in over a century. Homes and infrastructure in coastal towns were inundated, leading to mass evacuations and over a thousand insurance claims, while transport was heavily disrupted.

English

Reconstructing historical storm surges levels with models and machine learning

Su, Jian[1]; Nielsen, Jacob Woge[1]; Madsen, Kristine Skovgaard[1]; Larsen, Morten Andreas Dahl[1]

[1]Danish Meteorological Institute

Coastal sea-level extremes are essential in risk assessments, but historical sea-level records are often biased, have missing data, or hold inaccuracies. By combining machine learning, hydrodynamic modelling, and statistical tools, we here present a solid framework for extending, correcting, and reconstructing storm surge events.

First, a block-median approach and benchmarked statistical techniques are used to identify and correct for station-specific biases in the observational records. The historical catalogue is then expanded using a hybrid approach, in which a machine learning model (such as Random Forest) is trained to reconstruct the complete time series of previous storms, for which only model data is available, and where hydrodynamic simulations are instead used to identify extreme events that are absent from the record.

In the study, more than 50 tide gauge stations along the Danish coasts are used with the framework. The result is a high-quality, validated dataset of reconstructed extreme events and bias-corrected observations for higher end events (~24h before and after the peak) for the period of 1961-2024 along the Danish coastline, to help direct assessments of coastal risk for climate adaptation.

English

Forudsigelse af stormhændelser igennem marine vådområder

Niels G. Jacobsen (DHI, DK), Vincent Vuik (HKZ, NL), Jim Chen (Northeastern Uni., USA)

Introduktion
Naturbaserede løsninger tiltrækker sig stor interesse i forhold til klimatilpasning som supplement til hårde konstruktioner. Der er dog en væsentlig usikkerhed i forhold til nøjagtigheden af vores state-of-the-art beregningsværktøjer, da de i høj grad har behov for empiriske data til kalibrering. Denne præsentation giver indblik i DHIs udvikling af forbedrede beregningsværktøjer, der fjerner en markant usikkerhed i forudsigelserne fra et ingeniørmæssigt perspektiv.

Metode
En ny matematisk metode til beregning af bølgehenfald er for nyligt udviklet (Jacobsen, under review), og den tager højde for, i hvor høj grad vegetationen interagerer med bølgerne. Dette er en nyskabelse i forhold til eksisterende metoder, der alle antager, at bølgerne vandrer uforstyrret igennem vegetationen. Ved at tage højde for en forbedret fysisk procesbeskrivelse, har DHI kunnet benytte lukningskoefficienter, som ikke varierer i tid og rum, hvilket ellers er påkrævet i eksisterende metoder. Metoden er på implementeringsstadiet i DHIs spektrale bølgetransformationsmodel MIKE SW.

Resultater
Den nye metode er valideret op imod to datasæt fra felten, som blev målt i forbindelse med stormflod hen over marine vådområder. Det ene datasæt er fra landgang af den tropiske storm Lee på Louisianas kyst i 2011, og det andet datasæt er fra en stormhændelse i det hollandske vadehav i 2015. Bølgehenfald blev målt på tværs af vådområderne, og vegetationens egenskaber (dimensioner og bevoksningstæthed) blev indhentet inden stormen. Ved at benytte de målte konditioner længst søværts som randbetingelse, var det muligt at beregne bølgehenfaldet med stor nøjagtighed, dog med en større usikkerhed i det hollandske tilfælde, da vegetationen knækkende under stormen. Beskadigelsen på vegetationen rejser relevante spørgsmål omkring kumulerede effekter på oversvømmelsessikring fra naturbaserede løsninger, specielt i forbindelse med design af kystsikringsanlæg, da flere storme kan optræde inden for samme sæson.

Konklusion
Validering af DHIs nye, robuste metode for bølgehenfald igennem marine vådområder giver en markant forbedret sikkerhed i forudsigelserne. Fordelen er, at den udførende modellør ikke skal gætte sig til lukningskoefficienter i modelopsætningen, da en stor del af procesbeskrivelsen (interaktion mellem bølger og vegetation) nu er en integreret del af beregningsmetoden.

Danish

A Novel Framework for Tracking Impact-Driven Extratropical Cyclones and Compound Flood Events in Northern Europe

Larsen, Morten Andreas Dahl; Agertoft, Niels; Ringgaard, Ida Margrethe; Su, Jian; Pedersen, Jonas Wied

Extratropical cyclones (ETCs) are key drivers of extreme weather in the Nordic region, often associated with storm surges, heavy precipitation, and high winds that result in significant socio-economic and environmental impacts. Critically, ETCs frequently generate *compound events*, such as the co-occurrence of storm surges with pluvial and fluvial flooding, amplifying risk. However, conventional cyclone tracking methods emphasize large-scale atmospheric dynamics and often lack direct linkage to regionally specific impacts. This study introduces a novel cyclone tracking framework designed to identify and follow ETCs with explicit consideration of their hydrometeorological impacts—namely storm surges and precipitation-driven flooding.
The framework incorporates several methodological innovations: global optimization for the correspondence problem, BLOB analysis techniques to address track fragmentation over complex terrain, and automated calibration of post-processing parameters. Applied to the Copernicus CERRA reanalysis dataset, with a regional focus on the Nordic countries, the framework demonstrated robust performance in reconstructing ETC tracks under challenging conditions, including rapid cyclone development and

complex orography. Compared to standard tracking methods, the framework reduced suboptimal track linkages by up to one-third, with negligible additional computational cost.
Building upon the tracking framework, the second component of the study analyzed historical peak storm surge events over a 30-year period across the Nordic and Baltic Sea countries (Denmark, Norway, Sweden, Finland, Estonia, Latvia, Lithuania, Poland, and Germany). Using K-means clustering, regional surge patterns were identified and linked to specific storm types via the tracking algorithm. Finally, to explore compound risk, each storm surge cluster was evaluated for coinciding precipitation characteristics based on varying accumulation periods, enabling assessment of co-occurring flood drivers.
This integrated approach offers a scalable methodology for impact-oriented cyclone tracking and a foundation for improved risk assessment of compound weather extremes in Northern Europe.

English

Development of Digital Twin of Ocean (DTO) (10:50)

Decade of Ocean Science: Predictions and management scenarios using Digital Twins of the Ocean for Greenland, Faroe Islands and Denmark

Marie Maar[1], Jun She[2], Till Rasmussen[2], Asbjørn Christensen[3], Anders Erichsen[4], Janus Larsen[1], Sissal V Erenbjerg[5], Christian Thellufsen[6], Lars Troldborg[7], Per Berg[8]

1) Aarhus University, 2) DMI, 3) DTU Aqua, 4) DHI, 5) Firum, 6) Geodatastyrelsen, 7) GEUS, 8) GeoMETOC

The UN has dedicated this decade 2021-2030 to particularly focusing on the world's ocean areas. Research and cooperation are to contribute to sustainable community development and support the UN's Sustainable Development Goal No. 14, which objective is to conserve and ensure sustainable use of the oceans and their resources. To effectively manage acute events such as marine pollution, storm surges, and maritime safety incidents, as well as the long-term governance of marine ecosystems ("what-if" scenarios), on-demand and timely ocean information services are required. Although there is currently capacity to generate some of the necessary information products, the process is slow and lacks coordination between institutions.
The theme group "Predictions and management scenarios of coastal marine systems" established by the Decade of Ocean Science committee have members from several institutes to collaborate on the development of a 'Digital Twin of the Ocean' (DTO) covering Denmark, the Faroe Islands, and Greenland. **The Digital Twin is a virtual representation of the ocean** that integrates real-time and historical data with advanced modelling, artificial intelligence, and simulation tools. It is designed to mirror the physical, chemical, biological, and socio-economic dynamics of marine environments, enabling users to understand, predict, and manage ocean-related processes more effectively. The theme group develops and applies models and observations for e.g., storm surge warnings, climate change predictions, assessment of significant events, and management scenarios such as offshore wind expansion, nature restoration, marine pollution, and climate adaptation. We will give examples of existing DTOs and those under development by the theme group members. The long-term vision is to develop a hybrid model platform that will be on-demand, portable, and interactive, with integrated model data for coastal marine physical, biogeochemical, and biological systems.

English

Building up sub-regional Digital Twin Ocean for Offshore Wind Energy

Murawski, Jens; She, Jun

The European offshore wind energy (OWE) production is growing at an accelerated rate; according to EMODnet, more than 300 wind farms are planned for EU waters in the coming decade. With more and larger wind turbines in a single wind farm and clustering of wind farms, it becomes evident that existing knowledge about wind farms interactions with the marine environment needs reconsideration to make OWE expansion sustainable. To this end, Digital Twin of the Ocean (DTO) for the comprehensive impact of OWE production on the marine environment in a sub-regional scale forms essential digital solutions. The question is how to co-design and co-develop these DTOs with stakeholders from the OWE sector.

This presentation will introduce private-public partnerships in ocean observing and maritime service in the Baltic-North Sea region. Based on such interactions, needs on marine data, digital technology and decision supporting tools are identified. A project DTO4OWE (Digital Twin Ocean for Offshore Wind Energy) has been funded in the framework of SBEP (Sustainable Blue Economy Partnership). Planned

work for developing sub-regional DTO for OWE in the Baltic-North Sea, including multi-scale digital presentations, impact-resolving models, data-driven models for forecast optimization, downscaling and reconstructions of marine state history will be introduced.

English

Advancing Ocean Modelling with the European Digital Twin Ocean

Lavelle, John[1]; She, Jun; Frisfelds, Vilnis; Murawski, Jens

[1]Danmarks Meteorologiske Institut

The European Digital Twin Ocean (EDITO) provides cloud infrastructure for ocean modelling and environmental decision-making, supporting the EU Mission Ocean & Waters' objectives: protecting biodiversity, reducing marine pollution, and developing a sustainable blue economy [1].

EDITO's cloud-native platform facilitates the development of applications that deliver model outputs and visualisations through accessible web interfaces, while also enabling direct data access, interoperability, and efficient use of computational resources. The Danish Meteorological Institute's Ocean group has utilised the platform's capabilities with microplastic-distribution applications (covering the Baltic Sea), and an On-Demand Modelling service for configurable regional simulations [2]. Also, a validation toolkit had been developed for the platform, which enables efficient and reproducible validation of ocean models outputs against observations.

By converting complex oceanographic model outputs into accessible insights, EDITO connects scientific data with practical applications for both research and environmental governance.

English

Machine-Guided Derivation of Atlantic Meridional Overturning Circulation Strength

Wu, Qi-fan[1]; Häfner, Dion[2]; Nuterman, Roman[1]; Vettoretti, Guido[1]; Jochum, Markus[1]

[1]Niels Bohr Institute, University of Copenhagen, [2]Pasteur Labs

We combine neural networks and symbolic regression to analyze 100,000 years of fully coupled CESM simulations. This combination allows us to derive a set of interpretable coupled SDEs that emulate the co-evolution of the AMOC, sea-ice and density. We evaluate the statistical properties of our learned set of SDEs and find it more realistic than traditionally used sets of SDEs like Van-der- Pol or the FitzHugh-Nagumo models. We then use our SDEs to analyze the AMOC transitions found in CESM, and that cause Dansgaard-Oeschger events. We find that D.O. events are noise driven and not the result of internal oscillations.

English

Advancing Marine Ecosystem Management: Implementing digital twins approaches for the integrated ecosystem assessment of the Atlantic Ocean

Mariani, Patrizio

The future implementation of Digital Twins of the Ocean (DTOs) offers a transformative framework for mapping, monitoring, understanding, and managing marine ecosystems across diverse coastal and open-ocean regions. Within the EU-funded MISSION ATLANTIC project, long-term observations are combined with autonomous data collection, advanced processing techniques, numerical modelling, and interactive visualization to capture key physical, chemical, and biological ocean variables and their interconnections in support of the integrated ecosystem assessments (IEAs) for the Atlantic Ocean.
A network of autonomous observing platforms including underwater gliders, surface vehicles, and sensor arrays, has delivered near real-time data streams across several Atlantic regions. These heterogeneous datasets are processed and fused using machine-learning as well as process-based models and methods, enabling the detection of critical ecosystem indicators and drivers of change. This initial DTO framework provides interactive simulation environments, allowing stakeholders to explore alternative management strategies and climate scenarios, assess cumulative pressures, and evaluate the resilience, risks, and vulnerabilities of marine ecosystems. Findings from MISSION ATLANTIC demonstrate significant advances in the operational application of DTOs, offering decision-makers actionable, science-based tools to guide sustainable development and conservation efforts for the Atlantic Ocean.

English

Towards digital twins of the Arctic

Hestnes, Arne Johan

The EU Horizon-funded High Arctic Ocean Observation Systems (HiAOOS) and SBEP-funded ARCFISH projects are pioneering efforts to modernize ocean data acquisition and processing in the Arctic. Both project aims to progress the development of digital twins. Central to both initiatives is the deployment of Kongsberg Discovery's Blue Insight platform, a modular digital infrastructure originally designed for uncrewed systems, now extended to support climate research, critical infrastructure, ocean observation, and fisheries management

HiAOOS focuses on deploying multipurpose moorings equipped with acoustic sensors to collect high-resolution data on ocean, ice, and marine life in ice-covered regions. This data is ingested into Blue Insight, enabling visualization, acoustic thermometry, geo-positioning, and marine mammal detection. The solution also looks into the automation of dataprocessing steps to increase reusability, and ultimatly the ability to share dataprocessing steps.

Building on HiAOOS, ARCFISH develops a pilot Digital Twin of the Ocean tailored to Arctic fisheries. It integrates data from research vessels, autonomous platforms, and operational models to co-design ecosystem indices and decision-support tools with stakeholders. The platform ingests fisheries-dependent data, environmental forecasts, and reference datasets to support sustainable resource management

Together, these projects operationalize Arctic digital twins by combining in situ observations, AI-driven analytics, and stakeholder-driven design. They deliver scalable, interoperable platforms that support science, policy, and industry, fostering resilient stewardship of Arctic marine ecosystems

In thesession we will go through data integrations, data processing (and automation), visualizations and considerations done when implementing such a system, aimed both at users and developers of Digital Twins. We will discuss different approaches to interfaces and standardizations as implemented by the projects.

English

Ocean prediction and coastal modelling (13:40)

Building a digital twin of the Danish marine waters in support of European directives

Erichsen, Anders Christian[1]; Kronborg, Mai-Britt[1]; Fenger-Nielsen, Rasmus[2]; Lange, Troels[2]; Wong, Xin Huei[1]

[1]DHI A/S, [2]Styrelsen for Grøn Arealomlægning og Vandmiljø

Today, Danish marine environmental monitoring primarily relies on ship-based collection of environmental data, characterized by relatively limited temporal and spatial resolution. This type of monitoring is costly and does not necessarily provide the most accurate mapping of ecological status.

In recent decades, technologies such as satellite Earth Observation (EO), aerial drone imagery, sensors mounted on buoy systems, ferry boxes and underwater drones have emerged as powerful data sources to complement or, in some cases, replace conventional monitoring approaches. However, the integration of these tools into national monitoring programs – particularly to support EU directives such as the Water Framework Directive, remains limited.

The Danish Agency for Green Transition and Aquatic Environment (SGAV) is addressing this gap by developing a cost-effective, scalable and holistic solution for the monitoring of Danish marine waters by collecting and enhancing marine environmental data in support of European directives. The overall solution, called "Integrated Marine Monitoring (IMM)", builds on a combination of marine biogeochemical models and integration with traditional ship-based measurements, EO data and buoy-data through data assimilation (DA) supplemented by mapping of submerged aquatic vegetation (SAV) based on EO imagery.

The use of both EO and buoy data introduces a higher spatial and temporal frequency of important parameters such as chlorophyll-a (fluorescence), light conditions, SAV and oxygen. Satellites and buoys complement each other, as satellites can provide systematic information of the water surface for large areas, while buoys provide e.g., frequent water quality data like salinity, temperature, chlorophyll-a and oxygen.

In parallel, IMM partners with Copernicus Marine Service National Collaboration Programme, with their real time in-situ platform providing model results and sharing monitored data from various sources, complementing the data-sources beyond national data from NOVANA.

The long-term ambition of IMM-solution is to develop a digital online platform where monitoring data, marine ecosystem models and new routines based on machine learning (ML) and DA are used to continuously generate precise and geographically comprehensive assessments of the current state of the marine environment. The IMM-solution will provide detailed insight into the current and potentially future environmental state of the ocean and thus constitute a digital twin of Danish marine waters.

Danish

Dispersal and bioaccumulation modelling of PFOS and Cadmium in Smålandsfarvandet

Lopez de Gamiz-Zearra, Ane[1]; Mørk Larsen, Martin[1]; Strand, Jacob[1]; Schourup-Kristensen, Vibe[1]; Larsen, Janus[1]; Tairova, Zhanna[1]; Maar, Marie[1]

[1]Aarush University

This presentation provides the dispersal patterns of the hazardous substances (HS), PFOS and Cadmium (Cd), in Smålandsfarvandet as well as their content in mussels.

Environmentally HS are released to coastal waters from point sources such as wastewater treatment plants, industries, precipitation-related overflow, or fire drills. Pollution with HS can have toxic effects on marine organisms. Further, bioaccumulation of HS in the food web poses risk to humans consuming seafood, potentially impairing human reproduction, development, the immune system, the hormone balance, vital organs, and even causing cancer (Strain et al., 2022). In particular, in recent years, environmental concerns on the previous use of poly-fluorinated compounds (particularly in the form of PFOS) in firefighting training sites has been a major public safety concern, the first of which centred around Korsør Nor. Additionally, the latest EU Water Framework Directive analysis of the fjords around Smålandsfarvandet and the Great Belt shows non-compliance with good chemical status for 2021-2027, mainly due to lead and mercury exceedances in biota, as well as Cd in some areas.

This study develops a model where different tools are integrated to give a more holistic assessment of the status, impacts, risks, and fate of PFOS and Cd in Smålandsfarvandet. Field data from water and industrial treatment plants was used to force, calibrate and validate the dispersal model developed in the FlexSem model system (Larsen et al., 2020). The bioaccumulation model was then coupled with the dispersal model using field data from mussel cage deployments. The first results showed that there are some areas along the coast with high PFOS and Cd concentrations, which are in line with observed field data. The modelling process also showed that there are some uncertainties in data and threshold values to determine “good environmental status”, and still limited knowledge on the HS that makes it difficult to assess the impact of the HS and if they pose a risk to marine life. The presented model is a step forward within dispersal and bioaccumulation modelling that will help us move towards determining the main sources of pollutants and developing management scenarios aimed at achieving a clean sea.

English

Upcoming enhancements of the DMI operational storm surge model

Lindberg, Ole[1]; Woge Nielsen, Jacob[1]

[1]Danish Meteorological Institute (DMI)

This presentation outlines recent and upcoming enhancements to the Danish storm surge model (DKSS), which plays a central role in operational storm surge forecasting by Danish Meteorological Institute (DMI).

At its core, DKSS computes sea surface elevation using the ocean circulation model High Resolution Model for the Baltic Sea - Baltic Operational Oceanography System (HBM) (Dick et al., 2001). In recent years, we have improved HBM by optimizing its parallel computing performance and refining its turbulence modelling. These upgrades are planned for implementation within the operational DKSS system for the 2026–2027 storm surge season. For the current season, we have enhanced the DKSS ensemble prediction system by increasing the number of ensemble members from 18 to 30, which enables our forecasters to better quantify uncertainties in storm surge warnings.

While HBM performs well at most water level observation stations, it continues to face challenges in

complex areas such as narrow fjords and straits like Lillebælt and in tidal-dominated regions like the Wadden Sea. To address these difficulties, we are continuously working to increase both the computational performance of DKSS and its temporal and spatial resolution.

In parallel with these operational improvements, we are working towards a potential longer-term transition from HBM to the more modern ocean circulation model Nucleus for European Modelling of the Ocean (NEMO) (Madec et al., 2024). NEMO is developed by a European consortium with a large and active community and is widely used for global and regional ocean circulation modelling. At DMI, NEMO is now being further developed for application to coastal waters, including the inner Danish waters and the Wadden Sea. At this meeting, we present comparisons between two versions of HBM and NEMO for several major storm surge events in Danish waters.

Finally, the use of DKSS is expanding beyond traditional storm surge forecasting. As marine areas are increasingly utilized for offshore wind energy production, aquaculture, and other activities, the demand for accurate predictions of salinity, temperature, and currents is growing. This broader use further underscores the importance of ongoing improvements to the model system.

English

Developments of ocean dynamics in the NemoNordic configuration of North Sea and Baltic Sea : two-way nesting and wetting and drying

Hilt, Margaux[1]

[1]Danmarks Meteorologiske Institut

State-of-the-art numerical regional ocean models are being continuously improved by new sub-grid parametrizations, more accurate and computationally efficient time integration and advection numerical schemes, and the integration of missing real-world processes. Moreover, a numerical model's accurate representation of a given area's real-world processes remains tied to its horizontal and vertical resolution.

We present some developments currently underway in the physical ocean component of the NEMO based NemoNordic configuration that covers the southern North Sea and the whole Baltic sea. Firstly, two-way nesting using the AGRIF module (Debreu et al., 2008) to improve the representation of the Baltic–North Sea water exchange and sea level in the danish straits, and secondly, a 'flooding and drying' scheme developped by Warner et al. (2013) to better capture tides and sea level variability in shallow coastal areas such as the Wadden Sea. We focus on the model's performance for key-processes such as Major Baltic Inflows (MBI), using for reference the MBI of december 2015, as well as storm surges that have affected the south-eastern North Sea and western Baltic Sea in December 2013 and October 2023.

These areas of development are being pursued within the framework of two EU projects : Copernicus Marine's Baltic MFC (Monitoring Forcasting Center) for use in operational ocean forecast and reanalysis, and the EU Horizon Europe project MOIRAI (Multiscale Ocean models and Information for climate Risk Assessment and Impact mitigation) for regional–coastal climate modelling.

English

Investigating Shelf-Fjord Processes in the Faroe Islands on the Faroe Shelf in the Northeast Atlantic Ocean with a Nested Version of FarCoast version 2 (ROMS) from 2 km to 130 m

Erenbjjerg, Sissal Vágsheyg

The Faroe Islands is an archipelago located in the Northeast Atlantic Ocean. This area is included in an adaption of the Norwegian NorKyst (Lien et al, 2013) model, a Regional Ocean Model System (ROMS), called FarCoast (Erenbjerg et al, 2020). This second version of FarCoast is forced with GLORYS12V1 and Operational Mercator on the lateral boundaries along TOPEX for tides and atmospheric forcing from ERA (29km). As the Faroese archipelago is located on a shelf with steep bathymetry at all four open boundaries, special care must be taken to reduce implications for the setup of a local model domain, as depth varies from almost 3 km to 5 meters in this rather small domain. The model domain in all nested domains contains four open lateral boundaries. The FarCoast version 1 model setup has been validated for the year 2013 (Erenbjerg et al, 2020). This year has clarified the importance of tides in water exchange in the fjords as well as estuarine forcing. Furthermore the Faroe shelf is subjected to influence of semi-diurnal, diurnal and long-period tides due to the location in an amphidromic region (Erenbjerg et al, 2021). The long-period tides also determine the exchange between the on-shelf water masses and the fjords. These shelf-fjord processes are investigated through a 20 year hind-cast library of FarCoast2km

data as well as a nested 2 year highly resolved FarCoast130m data library with focus on the coastal region, that when used as forcing for an individual based model (IBM) clarifies the most important pathways into and out of the Faroese strait-like fjord Sundalagið Norður, as well as Sundalagið Suður and adjacent fjords (Tangafjord, Kaldbakfjord, Kollafjord and Skálafjord). This model study is compared to a high-intensity period of observations in the same area with ADCPs, CTDs, VPR, water sampling and trawls during the same period. The high productivity in Faroese fjords and on the shelf appears to be linked to this balance between the long-period tidal forces, the residual currents and the estuarine forcing, that again influences the pelagic productivity within the fjords and the coastal region.

Danish

Advances in marine dynamic modelling and residence time estimation in Roskilde Fjord

Larsen, Janus; Schourup-Kristensen, Vibe; Pacifique Ishimwe, Ange; Grieco, Gaia; Lopez de Gamiz Zearra, Ane; Maar, Marie

Ocean prediction and coastal modelling

This presentation provides an overview of recent developments within the marine dynamic modelling group at EcoScience, Aarhus University. New setups for the Inner Danish Waters, North Sea, Kriegers Flak have been calibrated and validated and other setups have been enhanced. Key technical improvements to the FlexSem model system include implementation of a higher-order advection-diffusion scheme, enhanced wind drag parameterization, and improved diffusion handling in the agent-based model (ABM). These advancements have been integrated into a new hydrodynamic model setup for Roskilde Fjord, which has been calibrated and validated against observational data. The model was run continuously for four years and applied to estimate spatially resolved residence times throughout the fjord by simulating the monthly half-concentration dilution time in each computational cell over the first three years. This method provides spatially and temporally resolved estimates of residence time, revealing significant variability across different periods and regions of the fjord. The results provide support to both the NewSea project assessing effects hazardous substances and to the mussel restoration efforts in the ROMUS project.

English

Beskyttede havområder - Effektive værktøjer til at genoprette havet eller streger på et søkort? (15:30)

Effektivt beskyttede havområder – erfaringer fra udlandet og anbefalinger til Danmark

Christoffersen, Mads; Jacobsen, Pernille; Mandøe Andreasen, Ditte

Beskyttede havområder er et centralt redskab i EU's biodiversitetsstrategi, som fastsætter et mål om 30 % beskyttede havområder, heraf 10 % strengt beskyttede, i 2030. International forskning dokumenterer, at beskyttede områder kan øge biodiversitet, styrke fiskebestande og forbedre økosystemers modstandskraft, hvis områderne beskyttes effektivt.
Der skal en kombination af tiltag til – som forbud mod bundtrawl, begrænsning af råstofindvinding, stop for anlægsaktiviteter og konsekvent håndhævelse – før der kan skabes markante positive effekter for både natur og miljø inde i og udenfor beskyttede områder. Omvendt peger eksempler også på, at såkaldte marine naturudpegninger, eller *paper parks* – altså områder der kun er beskyttet på papiret – ikke leverer de ønskede resultater.
Oplægget vil præsentere centrale internationale cases, fremhæve forskellene mellem effektiv og ineffektiv beskyttelse samt pege på, hvordan Danmark kan omsætte erfaringerne til praksis. Afslutningsvis gives anbefalinger til, hvordan Danmark kan sikre, at marine beskyttede områder, lever op til deres potentiale og bidrager til opfyldelse af de fastsatte mål.

Danish

Sandheden om Danmarks beskyttede havområder

Jacobsen, Pernille Schou[1]; Andreasen, Ditte Mandøe[1]; Christoffersen, Mads[1]; Lund, Henrik[2]; Kallenbach, Emilie[3]

[1]Tænketanken Hav, [2]Danmarks Fiskeriforening Producent Organisation, [3]Danmarks Naturfredningsforening

EU-mål har fastsat et mål om at 30 % havet skal være beskyttet hvoraf 10 % af havet skal være strengt beskyttede i 2030.
Ifølge myndighederne har Danmark allerede nået dette mål, da 31,7 % af Danmarks havareal i dag "beskyttede havområder". Denne opgørelse er dog foretaget ved blot at samle alle marine naturudpegninger under ét uden at skelne mellem hvad områderne er udpeget til at beskytte, og hvad der egentlig er tilladt eller forbudt.

Før 2023 var der ikke et overblik over det samlede forbud mod fiskeri med bundslæbende redskaber i Danmark, men derimod var de forskellige forbud for hvert redskab eller område spredt ud over et hav af forskellige bekendtgørelser og love. I et forsøg på at skabe dette overblik, gik de tre organisationer Danmarks Fiskeriforening Producent Organisation, Danmarks Naturfredningsforening og Tænketanken Hav sammen for at gennemgået den danske fiskeriregulering.
Oplægget vil belyse dette overblik, og dermed komme tættere på at finde ud af hvor stor en andel af de 31,7 % der reelt er beskyttet i Danmark i dag og i fremtiden.

Danish

Recovery of crustacean populations in protected areas

Moland, Even

Crustaceans are targeted in fisheries worldwide. Although populations have shown remarkable resilience in the face of centuries of exploitation, they often exist in depleted states. Clawed and spiny lobsters have thus been the focus of long-term monitoring and scientific study aiming to gain a firm understanding of the effects of harvesting and conservation on populations. In Marine Protected Areas (MPAs), areas where fishing pressure has been eliminated or reduced, population effects have been unequivocally demonstrated. This review provides an overview of conservation efforts and studies that have contributed to increased understanding of such effects. Three well-studied species and conservation cases are showcased, namely those of *Jasus edwardsii* (New Zealand), *Panulirus elephas* (Mallorca) and *Homarus gammarus* (Norway). In these cases, long-term scientific monitoring and fisheries data have provided information for evaluation of the effects of MPAs and pointed to caveats regarding their design and integration with other fisheries management regulations. The talk focuses on commercially exploited, large-bodied decapod crustacean species to highlight the relevance of protected areas as harvest refugia, and functional hotspots that sustain resources for adjacent fishing grounds. Appropriately scaled applications of MPAs throughout the marine realm are now deemed essential supplements to traditional fisheries management to achieve sustainability in global fisheries and reach sustainable development goals.

English

Marine Protected Areas as tools in ecosystem-based fisheries management: Existing compatibility, objective misalignment, and potential for future shared objectives.

Brown, Elliot[1]; van der Reijden, Karin[2,1]; Schiønning, Mette[3]; Van Hoey, Gert[4]; Feary, David[5,6]; Mangi Chai, Stephen[7]; Wakeford, Robert[5]

[1]National Institute of Aquatic Resources, The Technical University of Denmark, [2]International Council for the Exploration of the Seas, [3]National Institute of Aquatic Resources, Technical University of Denmark, [4]Flanders Institute for Agriculture, Fisheries, and Food, [5]MRAG, United Kingdom, [6]NEOM Nature Reserves, [7]MRAG, The United Kingdom

Fisheries management in Europe requires ecosystem considerations in the regulation of fishing activities (European Commission, 2023/103). Europe also has other conservation objectives, focussed on protecting marine habitats and vulnerable species (Directive 2008/56/EC). Furthermore, a desire to prevent biodiversity loss has been expressed in pledges to protect and restore marine habitats (Regulation 2024/1991). In the context of these many objectives and legislative mechanisms, how are marine protected areas (MPAs) in Denmark and around Europe currently interacting with fisheries, how do the various fisheries regulations they impose align with their stated conservation objectives, and in what contexts might future MPAs be designed to incorporate fisheries objectives? These three questions are addressed using empirical data from an augmented, European wide database of MPAs, a comprehensive data call on fishing activities in MPAs, a specific case study of a Danish MPA in the Western Baltic Sea, the application of a systematic literature review on the impacts of different fishing activities, and a novel systematic review of spillover from MPAs. Findings show that currently, European MPAs are focussed on specific conservation goals, but the evidence that these objectives are ever achieved or improved upon is lacking. These MPAs are not established as fisheries management tools

but often impose regulations on fishing activities. Even where fisheries regulations are in place, they often lead to no change in fishing behaviour, because of their implementation where there is low or no conflict with fisheries. Furthermore, while empirical studies of spillover from MPAs is sparse, we find that there are conditions under which spillover from MPAs could be a feasible objective. Such conditions include the MPA's age, position relative to the coast, and relationship to an MPA network; as well as the life-histories and traits of the organisms of interest (e.g. broadcast spawning vs brooding, walking vs swimming). We conclude that the integration of conservation and Ecosystem Based Fisheries Management objectives in the planning and design of MPAs will both improve their efficacy and their acceptance as a management tool.

English

Biologisk kortlægning af havbunden i beskyttede havstrategiområder

Kjellerup, Sanne

Projektet " Kortlægning af havbunden i beskyttede havstrategiområder i 2024-2026" omfatter habitatkortlægning af havbunden i ni kortlægningsområder, fordelt i Øresund, Lillebælt, Kattegat, Skagerrak og Nordsøen for Miljøstyrelsen. Projektet bliver gennemført ved et samarbejde mellem GEUS og WSP. Den biologiske kortlægning blev baseret på i alt 316 ROV-dyk samt 558 bundfaunaprøver (42x14). Områderne er kortlagt i henhold til substrattyper og overordnede habitattyper, og artssammensætningen og -diversiteten af flora og fauna knyttet til de forskellige bundtyper er kortlagt og beskrevet. Artdiversiteten for flora og epifauna samt infauna var meget varierende både indenfor de kortlagte områder samt mellem områderne styret af områdernes varierede substrat-, dybde-, salinitet-, iltforhold mm. Kortlægningen fungerer som baseline for de ni beskyttede havstrategiområder, der fremover enten vil være helt eller delvist beskyttet mod fysiske forstyrrelser af havbunden m.m. Datagrundlaget gør det muligt i fremtiden at overvåge og sammenligne, hvordan økosystemerne udvikler sig i de danske farvande, både som følge af naturlige forhold og menneskelig påvirkning. Projektets resultater bidrager til en bedre forståelse og beskyttelse af havmiljøet og understøtter den nationale havstrategi. Man forventer, at beskyttelsen vil føre til større biodiversitet og skabe bedre økologiske forhold i de danske farvande.

Danish

Geofysisk kortlægning af havbundens landskaber og levesteder i beskyttede havstrategiområder

Ernstsen, Verner Brandbyge[1]; Hansen, Lars Øbro[1]; Andersen, Mikkel Skovgaard[1]; Larsen, Isak Ring[1]; Nielsen, Nina Lei Juul[1]; Blok, Carlette Neline[1]; Al-Hamdani, Zyad[1]

[1]GEUS

GEUS og WSP udfører i partnerskab for Miljøstyrelsen projektet "*Kortlægning af havbunden i beskyttede havstrategiområder i 2024-2026*". Projektet omfatter kortlægning af havbunden i 9 havstrategiområder fordelt i Øresund, Lillebælt, Kattegat, Skagerrak og Nordsøen. Den geofysiske kortlægning er baseret på multibeam, sidescan sonar og sub-bottom profiler data langs ca. 4.000 linje-km i kombination med ROV-videoer og bundprøver, suppleret med ortofotos og satellitbilleder i de lavvandede (<2 m) områder. Den geofysiske kortlægning omfatter kortlægning af batymetri og af havbundens morfologi, substrattyper og naturtyper (jf. habitatdirektivet) samt menneskelig påvirkning af havbunden. Desuden omfatter kortlægningen modellering af havbundens overordnede habitattyper (jf. havstrategidirektivet). Havstrategiområderne skal bidrage til at opfylde forpligtelserne i EU's havstrategidirektiv og bidrage til at opnå EU's samlede biodiversitetsmål. De udpegede områder vil også bidrage til at opfylde Danmarks forpligtelser i henhold til biodiversitetskonventionen og FN's verdensmål 14 om livet i havet, samt bidrage til forpligtelser i regi af de regionale havkonventioner, OSPAR i Nordsøen/Skagerrak og HELCOM i Østersøen.
Fremadrettet skaber kortlægningen grundlag ("baseline") for undersøgelser i udvalgte interesseområder/moniteringsområder med henblik på estimering og vurdering af havbundens naturlige dynamiske forhold, naturlige variabilitet og menneskelige påvirkninger. Dermed udgør kortlægningen et vigtigt skridt mod at kunne estimere og vurdere tab og forstyrrelse af havbunden – specifikt i forhold til havbundens morfologi, substrattyper, naturtyper og overordnede habitattyper. Endelig udgør kortlægningen et grundlag for fremtidige undersøgelser af effekten af klimaforandringer, herunder effekten af havspejlsstigninger.

Danish

Marine protected areas under pressure: Do they reduce cumulative human impacts in the Skagerrak?

Ramon, Paula[1]; Frigstad, Helene; Andersen, Jesper; Stock, Andy; Aarflot, Johanna; Hemraj, Ashley; Moland, Even; Bekkby, Trine; Murray, Ciarán

[1]NIVA Denmark

Marine ecosystems rarely face single threats in isolation; rather, they are exposed to a web of anthropogenic pressures that interact in complex ways. Over the last decade, cumulative impact assessment (CIA) methods, initiated by Halpern et al. (2008), have advanced from static mapping tools to powerful approaches for exploring how multiple stressors overlap with vulnerable ecosystem components.

The Synthesis Working Group *MultiStress Skagerrak* aims to deliver the first systematic baseline of cumulative impacts in this area. We also evaluated the capacity of current management measures, particularly marine protected areas (MPAs), to alleviate stressor intensity in the Skagerrak, a regional sea under increasing anthropogenic pressure and with high economic importance, shared by Norway, Sweden and Denmark.

Two core questions guide our work. First, where are the spatial "hotspots" and "coldspots" of cumulative human impact in the open Skagerrak? By compiling spatial data on human activities and ecosystem components, we developed a cumulative impact map that highlights areas of concentrated pressure. Second, to what extent do existing MPAs reduce these impacts? Specifically, we compared cumulative pressures inside versus outside protected boundaries to assess whether MPAs act as effective buffers or remain symbolic demarcations.
Our findings reveal stark spatial differences in human pressure across the region, with hotspots often overlapping with ecologically important habitats. While some MPAs appear to provide relative relief from cumulative stressors, others show limited effect, with human impacts persisting at levels comparable to surrounding waters.

This work provides both a regional overview and a management-relevant assessment of how cumulative pressures align or conflict with existing conservation designations. By integrating stressor mapping with policy evaluation, our study offers a science-based foundation for adaptive management in the Skagerrak and enlightens broader debates on the role of MPAs as effective tools for restoring the sea versus lines on a nautical chart.

English

Øresundssalen

Increasing gender equality in marine research and fostering alternative problem-solving approaches: Building networks for women and gender diverse people (9:00)

Welcome: Building Inclusive Networks in Marine Science

Johannesen, Ellen

Gender equality is integral to the sustainability agenda and must be systematically embedded within ocean science and governance. This contribution will open the session by setting the rules of engagement, aiming to establishing a safe space to discuss and address persistent gender inequalities in ocean science, where women and gender diverse researchers remain structurally underrepresented. Creating such spaces is critical for recognising and challenging barriers to participation, visibility, and career progression, while also enabling the exchange of experiences that are often marginalised in mainstream professional settings. By situating gender equality as both an equity imperative and a driver of epistemic diversity, the session underscores the value of inclusive networks in fostering alternative approaches to marine research. This framing sets the foundation for dialogue, knowledge-sharing, and the co-creation of a sustainable professional community for women and gender diverse people.

English

Karen Ellemann Gender equality in the Nordic blue economy – in a time of global backlash

Navigating gender equality in a male-dominated field: a reflection on how perspectives change over career stages

Melli, Valentina[1]

[1]DTU Aqua

This contribution will provide a personal account of the experiences of navigating professional development as a female Early Career Scientist entering the male-dominated field of fisheries science. Drawing on personal experiences, it explores how institutional structures, social expectations, and gendered 'protective' measures can simultaneously constrain and shape the trajectories of women in research. Early career experiences illustrate the frustration of being treated differently from male colleagues—whether through restrictions justified by safety concerns or through selective opportunities offered on the basis of gender rather than scientific merit. Over time, such practices revealed that striving for "gender-blindness" is not a solution in contexts where unequal conditions persist. The address will illustrate that careers in science are often profoundly influenced by the kinds of opportunities made available, withheld, or differently framed for researchers of different genders. It will further highlight how these personal experiences have shaped understanding of the ethical responsibility of project leaders to recognize and address these asymmetries, ensuring that safety requirements, logistical arrangements, and personal considerations do not inadvertently limit participation. Structural reforms are needed to help ensure that as a community we move beyond individual resilience and toward equitable access to fieldwork and fostering an inclusive working culture as a cornerstone of scientific practice.

English

The value of research networks for Early-Career Researchers

Ekstedt, Josefin[1]

[1]Centre for Blue Governance, Aalborg University

Building and maintaining a strong research network in the academic field in which one works is crucial for any science discipline, as is the case for working in an interdisciplinary field such as marine social science. In this presentation, I will briefly introduce my academic background and current research, which focuses on the governance of marine areas and marine resources. I will reflect on how formal and informal research networks have supported and shaped my academic journey – from securing my first research internship to co-authoring journal articles, participating in informal peer groups, and receiving mentorship. While interdisciplinarity offers a wide knowledge base, it can also present challenges, such as difficulties in reaching specific stakeholder groups or navigating legitimacy across disciplines. Research networks can address these challenges by providing an avenue to connect with relevant stakeholders, providing legitimacy through association or collaboration, and offering analytical assistance. Through this presentation, I aim to raise awareness of the benefits of participating in a research network and encourage other emerging or early-career researchers to actively engage in research communities and contribute to collaborative research networks.

English

The Value of Early-Career Networks for an Inclusive Research Environment

Rist, Sinja

Early career researchers (ECRs) play a vital role in shaping a more diverse, inclusive, and forward-thinking marine research landscape. Their fresh perspectives and interdisciplinary approaches are essential for tackling complex environmental challenges. However, many ECRs, particularly those of underrepresented groups, encounter systemic barriers that hinder their full participation and visibility within the scientific community. These barriers often manifest as implicit biases, exclusionary practices, and a lack of access to mentorship and decision-making spaces.
Early career networks can be pivotal for cultivating belonging, mutual support, and professional growth. These networks do not only empower individuals but also amplify collective voices, enabling ECRs to influence institutional culture and research agendas more effectively.
Here, I want to share experiences as a member of the Strategic Initiative on Integration of Early Career Scientist (SIIECS) within ICES (International Council for the Exploration of the Sea). I will discuss the

challenges of ECRs and share insights into how collaborative spaces and inclusive networks can create a marine research environment that values diverse contributions.

English

Engagement with the audience: Building Inclusive Networks in Marine Science

Ramírez-Monsalve, Paulina[1]

[1]Independent Researcher – NIVA DK affiliated

Informal, community-driven research networks can play a transformative role in creating a more inclusive and equitable research environment. These networks not only support career development and mentorship but also provide space to address systemic challenges and share resources.

To shape a network that reflects our collective values and ambitions, and to help build a more inclusive future for marine science, we need input from researchers across all marine science disciplines, career stages, and institutions

This session will be interactive and participatory, marking the first steps towards co-creating a supportive and collaborative community that extends beyond Havforskermøde 2026

Attendees will be invited to contribute ideas through a live survey (accessible via QR code), exploring questions such as:

What platform should host our year-round collaboration?
What themed working groups should we establish?
Beyond funding, what factors influence your participation in annual meet-ups?
How could this network fail—and how can we prevent that?

We will also gather input on mentoring and matchmaking needs and invite open feedback to guide future network development. A word cloud and live discussion will help visualize shared concerns and aspirations

English

Co-existence at sea – opportunities and challenges (10:50)

Offshore Wind Energy Infrastructure in Danish Waters: Coexistence, environmental impacts, knowledge gaps and risks of the unknown

Brown, Elliot[1]; Thomassen, Jasmin; Galparsoro, Ibon[2]; Henriksen, Ole; Mildenberger, Tobias; Clausen, Niels-Erik[3]; Riisager-Simonsen, Christian; van Deurs, Mikael

[1]National Institute of Aquatic Resources, The Technical University of Denmark, [2]AZTI, Marine Research Division, Basque Research and Technology Alliance, [3]Institute for Wind and Energy Systems, The Technical University of Denmark

Under increasing competition for marine space, one industry is expanding rapidly, both globally, but especially in the North-East Atlantic, including Denmark: Offshore wind energy (OWE). This raises a key question: what does "coexistence" between OWE and the marine environment actually mean, and what do we know about the interactions between OWE and different components of the ecosystem?
We begin by defining coexistence in this context, using a systematic review of definitions from primary literature, combined with a survey of international and domestic experts. This forms the basis for a working definition of coexistence between OWE and the environment.
Next, we synthesise existing knowledge on the interactions between OWE and the marine ecosystem. While political will and technological innovation have accelerated the growth of offshore wind, understanding its environmental impacts takes time. Now, with ~20 years of deployment, monitoring, and study, we can begin to consolidate and learn from the accumulated scientific evidence on the impacts of OWE on the marine environment.
Through a systematic literature review (up to September 2025), we conducted a meta-analysis to identify where impacts across OWE activities, the pressures they impose, and the ecosystem components affected, have been investigated. Our findings show that some environmental impacts are generalisable across contexts (e.g. location, infrastructure design, species, and habitats), while others are highly context dependent (e.g. benthopelagic fish). We also highlight areas where significant scientific knowledge gaps remain.

Based on a workshop with Danish experts, we rank the environmental risks associated with these knowledge gaps. Our syntheses create accessible knowledge to aid in the reduction and minimisation of environmental impact from OWE. To achieve this, our analysis and results are presented in formats to support decision-makers and practitioners in site identification and selection, technology choice, and impact assessment design. Meanwhile, our definition of coexistence and the prioritised unknowns offer a roadmap for future research on the interactions between offshore wind and the marine environment.

English

Multi-use eller sameksistens: Energiproduktion og lavtrofisk akvakultur

Kjerulf Petersen, Jens; Nielsen, Mette Møller; Schmedes, Peter Søndergaard; Fischel, Andrea; Taylor, Daniel

Med de store havarealer, der allerede er lagt beslag på til energiproduktion på havet og som kun bliver til endnu mere i fremtiden, er det relevant at diskutere om hele arealet af f.eks. en marin vindmøllepark alene skal reserveres møllerne, eller om arealet mellem møllerne kan bruges til andre formål som produktion af bæredygtige fødevarer som muslinger og tang.

Mens det er oplagt at bruge arealerne mellem møllerne til andre formål, er det ikke nødvendigvis ensbetydende med, at områder egnet til at producere energi også er egnede til fødevareproduktion. I ULTFARMS projektet har vi studeret produktion af muslinger og tangarterne søl og sukkertang i vindmølleparkerne ved Anholt og syd for Samsø (kun muslinger). Et særligt formål med projektet var også at undersøge muligheder og udfordringer for samarbejdet mellem forskellige industrier og om der er muligheder for reelt samarbejde.

Her præsenteres nogle af de første resultater med fokus på produktionspotentialet. Generelt var udbyttet af tangproduktionen lavt sammenlignet med produktionsområder tættere på land, mens der umiddelbart er potentiale i produktionen af muslinger.

Generelt er akvakultur-operationer af en anderledes karakter end servicering af vindmøller, og erfaringerne fra projektet viser, at der mere er tale om multi-use af arealer end om sameksistens

Danish

Sharing the Space at Sea – integrating low trophic aquaculture, nature restoration and marine monitoring in an off-shore wind farm

Bruhn, Annette[1]; Wilms, Tim[2]; Dahl, Karsten[1]; Svendsen, Jon Christian[3]; Andersen, Lars Emil Juel[4]; Taylor, Daniel[4]; Hecter, Mads[5]; Boderskov, Teis[1]; Schnmedes, Peter[4]; Andersen, Per[1]; Maar, Marie[1]; Clubley, Charlotte Hannah[1]; Budhathoki, Mausam[6]; Thomsen, Marianne[6]; Christiansen, Sofie Laage[7]; Mouritsen, Lone Thybo[7]

[1]Aarhus University, Ecoscience, [2]Vattenfall, [3]DTU Aqua, [4]DTU-Aqua, [5]Kerteminde Seafarm, [6]University of Copenhagen, [7]Kattegatcentret

The competition for space at sea is increasing, and the need for intelligent solutions for sharing space at sea is pertinent[1]. The concept of marine multi-use is emerging as one such solution. With marine multi-use, actors at sea share space and time, services, data, infrastructure and logistics[2]. This concentrates human activities in confined areas, leaving other areas free for Marine Protected Areas, and also allows for synergistic activities, reducing the overall energy use, emissions, labour and increasing safety of operations.

In the WIN@sea project, the project partners have created a marine multi-use prototype in the Danish Kriegers Flak (DKF) offshore windfarm in the Baltic Sea. Here, the partners combine off-shore production of fossilfree electricity with low trophic aquaculture (LTA) of seaweed and mussels, restoration of marine ecosystems through nutrient extraction, and data production for the national marine monitoring program.

While the low salinity of the Baltic waters (<10 ppt) limits the yields of seaweeds and blue mussels, the multi-use prototype at DKF has generated valuable outcomes for future multi-use operations: Primarily, the project has demonstrated integration of activities between partners, allowing for reduced fuel use, emissions and labour – as wind farm Crew Transfer Vessels have monitored the aquaculture site on a regular basis, and costly maintenance and repair activities have been combined. Safety in LTA operations has been increased through joint risk assessment procedures and through the wind farm Marine Coordination Centre overseeing all operations in the wind farm 24/7. In the windfarm, technological

innovation for marine monitoring with Autonomous Underwater Vehicles has been tested to automatise future monitoring operations.

Site selection tools have been developed to secure optimal positioning of LTA in windfarms for maximal harvest yields and nutrient extraction, and Life Cycle Assessment will further quantify the benefits in saved emissions and identify the emission hot spots for future optimisation of multi-use concepts.

Optimising future Marine multi-use operations calls for integration of the concept in the earliest planning phase of future offshore wind farms, aligning Marine Spatial Planning Frameworks across EU and regulating across food, environmental and climate policy sectors.

English

Is Ocean Space Shared a Problem Halved? Assessing Multi-Use Potential of Offshore Wind with Low-Trophic Aquaculture

Clubley, Charlotte[1]; Larsen, Janus[1]; Agüera, Antonio[2]; Boderskov, Teis[1,3]; Søndergaard Schmedes, Peter[4]; Taylor, Daniel[4]; Holst, Niels[5]; Bruhn, Annette[1,3]; Hecter, Mads[6]; Maar, Marie[1]

[1]Department of Ecoscience, Aarhus University, [2]Institute of Marine Research, [3]Centre for Circular Bioeconomy (CBIO), Aarhus University, [4]Technical University of Denmark, National Institute of Aquatic Resources, Section for Coastal Ecology, [5]Department of Agroecology, Aarhus University, [6]Kerteminde Seafarm Aps

In just five years' time global demand for seafood will exceed supply by 40 million metric tonnes, yet production in Europe is constrained by competition for marine space. Therefore, maximising spatial efficiency across competing Blue Economy sectors is critical to meet future aquaculture needs. In Europe, offshore wind farms (OWF) dominate ocean space and present an ideal candidate for 'multi-use' with aquaculture. However, the open ocean remains largely untapped as a farming resource and consequently production potential within OWFs remains an unknown. Here, we use a 3D coupled hydrodynamic-biogeochemical model, combined with growth models for two key low-trophic aquaculture species – *Mytilus edulis* and *Saccharina latissima* – to assess harvest potential within an OWF in the Southern Baltic Sea. We explore several scenarios to determine both the maximum biomass yield and the maximum carrying capacity for aquaculture farms within the OWF area. Our results demonstrate a framework for farm location selection within OWFs, aiming to maximise sustainable seafood production. This work represents a significant advancement in spatial planning for OWF-aquaculture multi-use, providing a framework that can be applied globally to support the design and development of sustainable offshore aquaculture and balance the growing demands of the Blue Economy with the urgent need to protect and restore marine ecosystems.

English

Beyond Biodiversity: Securing Sustainability in Marine Eco-Engineering Practices

Wolfgang Kunther[1], Joseph W. Parkinson[1,2], Jon C. Svendsen[3], Martin Macnaughton[2], Ana T. Lima[1]

[1] DTU Sustain

[2] Sund og Bælt

[3] National Institute of Aquatic Resources Sund

Interest in sustainable eco-engineering in marine infrastructure construction (MIC) is rising, particularly with increasing coastal urbanization and climate adaptation. However, current eco-engineering efforts, through concrete modifications that support marine biodiversity, often lack comprehensive sustainability assessments that integrate environmental, social, and economic dimensions.

Summarizing previous projects along the three sustainability dimensions, we develop a sustainability framework for eco-engineering practices. The previous projects spanned across small-scale MSc studies to large-scale projects like the Circle Reef in Køge Bay Marine Park, Denmark, and the Living Ports in Vigo, Spain.

While these projects demonstrate ecological innovation and stakeholder collaboration, they also reveal gaps in sustainability planning. Particularly concerning are the planning gaps relating to economic cost, social, and long-term ecological impacts and the degree of long-term monitoring (often lacking entirely).

Our framework is designed to guide MIC projects toward multifunctional, resilient, and societally beneficial outcomes. Our framework emphasizes early stakeholder engagement, quantitative goal definition, and integration of life cycle sustainability assessments in planning. We advocate for adaptable monitoring protocols tailored to quantitative project objectives and environmental conditions, including biotic and abiotic factors.

The framework highlights the importance of considering planetary boundaries through resource use and societal acceptance through ocean literacy efforts and public outreach. Achieving sustainability in eco-engineering requires balancing ecological benefits with economic feasibility and societal value. Using our framework, stakeholders can complete integrated approaches that align project design with broader sustainability goals.

English

Pollution effects, assessment, and monitoring in the context of multiple stressors in the marine environment (13:40)

New concept for integrated assessment of pollution effects in the sea (NEWSEA project)

Tairova, Zhanna[1]; P. A. Christensen, Jesper[1]; Gustavson1, Kim[1]; Lopez de Gamiz Zearra, Ane[1]; Bossi, Rossana[2]; M. Larsen, Martin[1]; Strand, Jakob[1]; Turja, Raisa[3]; Lehtonen, Kari[3]; Tonteri, Ossi[3]; Stankeviciute, Milda[4]; Maar, Marie[1]

1- Department of Ecoscience, Aarhus University
2- Department of Environmental Science, Aarhus University
3- Marine and freshwater solutions unit, Finnish Environment Institute (SYKE)
4- State Scientific Research Institute, Nature Research Centre, Lithuania

Environmentally hazardous substances (**HS**) are released into coastal waters from numerous point sources, including wastewater treatment plants (WWTPs), industries, and harbors. Despite increasing awareness of HS in the marine environment, knowledge about their levels, origin, and biological effects in the marine environment is still limited, hindering assessment of risks to marine life and the development of effective mitigation strategies.

The ***NewSea* project** aims to develop a new concept with integrated tools for assessing both the distribution and biological impacts of HS discharged from point sources to coastal waters. The case study area is the south-eastern Great Belt and Smålandsfarvandet, a region characterized by a high density of point sources and currently classified as "failed to achieve good chemical status".

To investigate **the biological effects** of HS exposure in the study area, we conducted ***in situ* "cage studies"** with blue mussels deployed near effluents from point sources. In addition, locally occurring species were sampled and analyzed for physiological and biochemical effect indicators to complement the assessment. Significant biological responses (antioxidant, genotoxic, lysosomal) were observed in caged mussels, alongside other effect indicators in local fish, amphipods, and gastropods (e.g. biliary PAH metabolites, reproductive success), altogether providing evidence of biological stress.

Chemical analyses supported the biological findings. Passive samplers deployed alongside the caged mussels provided information on contaminant exposure, while dispersal modeling (FlexSem) was applied using hypothetical passive tracer compounds, validated against empirical chemical measurements. The bioaccumulation model was integrated with the dispersal model derived from mussel cage studies, and this coupling provided insights into the spatial extent and variability of HS dispersal and bioavailability.

This combined approach demonstrated that point sources can create localized, biologically relevant exposure scenarios, which are not always captured by traditional monitoring strategies.

The study highlights the effectiveness of combining mussel caging with passive samplers and modeling to identify realistic environmental exposure levels of HS and their effects at point source sites. Together, these methods offer **a promising framework** for improving our understanding of HS biological impacts in coastal waters and for developing more targeted strategies to mitigate ecological risks and achieve regulatory goals.

English

Abalone larvae in a multi-stressor ocean

Rist, Sinja

Survival and fitness of meroplanktonic larvae determine population dynamics of benthic invertebrates. With increasing anthropogenic stressors affecting the world's oceans, it is crucial to understand how combined pressures can affect these sensitive early life stages. Here, we investigated the impacts of different types of chemical pollution in combination with a simulated marine heatwave on early and late larval stages of the abalone *Haliotis tuberculate coccinea*. Larvae were exposed to a range of concentrations of crude oil, leachates of car tire particles, or leachates of beached microplastics for two days. Exposure experiments were performed with larvae that were less than one day old as well as with competent larvae three days after fertilization. In early larvae, we analyzed effects on development and survival, while potential effects on metamorphosis were studied in late larvae. Early larvae were sensitive to all tested pollutants as shown by increased mortality. However, leachates of car tire particles induced the strongest effects as all surviving larvae showed signs of abnormal development. This was rarely observed for the other pollutants. The heatwave treatment had a significant negative effect on survival. In late larvae, the heatwave markedly reduced metamorphosis. In contrast, this process was only slightly affected by pollution, though in different directions (indicating reduced as well as enhanced metamorphosis). The results indicate different sensitivities of larvae depending on their age and the combination of stressors.

English

Combined effects of climate change and crude oil pollution on the larval development of blue mussels (Mytilus spp.) from Denmark and Greenland

Rodrigo González, Carla; Nielsen, Torkel G.[1]; Rist, Sinja

[1]DTU-Aqua

Coastal marine ecosystems are increasingly exposed to multiple stressors due to climate change and human activities. Blue mussels (e.g. *Mytilus* sp.) are key species performing important ecosystem functions. This study evaluated the individual and combined effects of temperature (17, 19 and 21.5°C for the Danish population and 2, 3.5 and 5.3°C for the Greenlandic population), salinity (24 and 33 psu) and oil exposure (0, 1, 10 µL L^{-1}) on early developmental stages of *Mytilus edulis* from Denmark and *Mytilus sp.* from Greenland. Fertilization, larval development and growth were assessed. Results showed that high temperature and oil exposure negatively affected fertilization and development, while low salinity sometimes mitigated these effects. The Greenlandic population showed greater resilience during fertilization and early survival than the Danish population, suggesting local adaptation. However, larval development failed under laboratory conditions for the Greenlandic population. The D-shaped stage in the Danish population was particularly sensitive to the combination of high temperature and oil. Stress during early life stages can reduce recruitment and result in smaller adult populations. A reduction of *Mytilus* abundance may affect key ecosystem functions such as the bentho pelagic coupling and the production of the higher trophic levels. These findings highlight the vulnerability of *Mytilus* larvae to multiple environmental stressors and the importance of understanding how multiple stressors affect larval stages to predict future impacts on populations and the ecosystem.

English

Sublethal Effects and Species-Specific Sensitivity to Produced Water of North Sea Organisms

Bonciani, Neri[1]; Ugwu, Kevin[2]; Rist, Sinja[3]; Kuehr, Sebastian[4]; Brooks, Steven[5]; Feilberg, Karen[1]

[1]DTU Offshore, [2]RUC, [3]DTU Aqua, [4]IME, [5]NIVA

The oil and gas industry remains essential for producing a wide range of goods. However, offshore subsurface extraction can be a serious pressure factor for marine organisms due to the large volumes of wastewater, called produced water (PW), generated during production. In the North East Atlantic alone, approximately 287 million m³ of PW are discharged each year, with Danish offshore operations contributing more than 18 million m³ annually (OSPAR 2023). This saline wastewater is a complex mixture of hydrocarbons, gases, ions, suspended solids, and production additives. Despite this complexity, the only parameter that is continuously monitored at the discharge point is oil-in-water, which must remain below 30 mg/L. Since 2012, this limit has been applied alongside risk-based assessments to evaluate potential impacts on marine ecosystems, using acute toxicity results of standard organisms (bacteria, algae,

crustaceans).
Yet, while dispersed oil is a major concern, less abundant compounds such as suspended/dissolved metals, metalloids, PAHs, and phenols can also harm marine life. These substances may persist in the environment for extended periods and exert negative effects even at very low concentrations. Additionally, current regulations and risk-based approaches often overlook acute and sublethal effects on a wider variety of species inhabiting the North Sea. To address this, the present study investigated the sublethal effects of PW on oyster embryos (M. gigas) and examined the acute sensitivity of two copepod species (T. battagliai and T. longicornis).
The results showed that concentrations as low as 1% of PW inhibit oyster larval growth, and T. battagliai is less sensitive to most of the tested PWs than T. longicornis (lowest LC50 = 2.4% PW). Importantly, all bioassays demonstrated substantial variability among PW samples from different discharge points and suggested that suspended solids may play an adverse role. These findings highlight the need to integrate compositional data with site-specific and chronic toxicity assessments in order to guide effective management strategies and advance the industry's goal of "zero harmful discharge" by 2050. Furthermore, incorporating a wider range of taxa allows for the identification of the most sensitive and vulnerable species, which can be prioritized for protection.

English

Effects of ammonia on North and Baltic Sea key copepod species.

Konstantinopoulos, Themistoklis[1]; Rist, Sinja[1]; Vestergaard Kilian, Mai; Bruni, Lucia; Koski, Marja[1]

[1]DTU Aqua

The shipping industry, in line with the International Maritime Organisation's strategy to reduce greenhouse gas emissions, is introducing carbon-free engines powered by ammonia. Commercial deployment of such vessels is expected to begin globally from mid-2026. With a growing ammonia-fuelled fleet, the probability of accidental releases during operations, maintenance, or maritime accidents will increase. Thus, it is critical to assess the effects of ammonia spills in marine environments, especially in ecosystems that are already under heavy anthropogenic stress, such as the Baltic Sea and the North Sea.
Copepods, which constitute a key link in marine food webs, are particularly relevant for risk assessment. Known impacts of ammonia exposure include cellular osmotic stress, as well as reduced growth, reproduction, and survival. However, existing studies have largely focused on species and conditions that do not apply to complex natural systems.
We present the results of laboratory and ship-board experiments exposing different Baltic and North Sea copepod species to a range of ammonia concentrations and measuring mortality (LC_{50}), feeding, egestion and juvenile development. Our results demonstrate that the environment and organismal condition play a role in copepod responses, like the LC_{50} of *E. affinis* being 0.64 and 1.06 mg L^{-1} NH_3-N in the Finnish Gulf and Bothnian Sea, respectively. In addition, we observed significant sub-lethal effects of ammonia on feeding activity and fecal pellet production both in Baltic and North Sea key copepod species above concentrations of 0.5 mg L^{-1} NH_3-N, although the response differed between feeding strategies.
These findings highlight the vulnerability of Baltic copepods to ammonia exposure and underline the importance of incorporating ecological complexity into spill impact assessments as ammonia emerges as a marine fuel. Our findings provide critical evidence to support risk assessments, regulatory frameworks, and spill-response strategies related to ammonia use in shipping.

English

Potential ecological impacts of ammonia fuel spills: A mesocosm study on coastal plankton

Svensgaard, Julie[1]; Fritt-Rasmussen, Janne[1]; Gustavson, Kim[1]; Juncher Jørgensen, Christian[1]; Jakobsen, Hans[1]; Sønderby Rask, Sofie Amalie[1]

[1]Aarhus University | Department of Ecoscience

The shipping industry's transition from fossil fuels to alternative 'green' fuels such as ammonia and methanol offers promising benefits for the climate. By 2050, ammonia is anticipated to become the predominant green marine fuel for shipping accounting for up to one third of total global fuel consumption in the maritime industry. As ammonia is a well-characterized inorganic nitrogen compound, known to be toxic to fish, large scale implementation of ammonia may introduce potential environmental risks if these fuels are accidentally released into the marine environment. This study investigates the biological effects of ammonia exposure on lower trophic levels in a Danish coastal fjord system across a

wide concentration gradient to explore the broader ecological impacts at relevant spill concentrations.

To simulate realistic spill concentrations under near-natural environmental conditions, a 14-day mesocosm experiment was conducted using 1000 L polyethylene containers submerged in seawater during spring 2025. Natural coastal plankton communities (<250 µm) where exposed to increasing ammonia concentrations ranging from 2 to 200 mg/L. Changes in community structure, biomass, and growth of bacteria, phytoplankton and microzooplankton was determined using flow cytometry, alongside measurements of ecosystem production, respiration, and nutrient dynamics. The experiment also captured the temporal development of ammonia speciation, which is strongly influenced by pH fluctuations driven by biological activity.

This field-based ecotoxicological study provides new insights into the potential environmental consequences of ammonia spills in coastal marine ecosystems. It enhances our understanding of ammonia toxicity in lower trophic marine organisms and supports the development of improved environmental risk assessments for its future use as a marine fuel.

Disclaimer: The research project is supported by Dampskibsselskabet NORDEN A/S.

English

Miljøfarlige stoffer og Plastik i Havmiljøet (15:30)

Overvågningen af marint affald på strande i Danmark og grønland afslører et generelt fald i affaldsmængderne siden 2015

Strand, Jakob[1]

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Overvågning af marint affald på strande udgør et centralt redskab til at dokumentere forureningsniveauer, kilder og udviklingstendenser i både Danmark og Grønland. I Danmark omfatter den nationale overvågning otte strande, heraf seks referencestrande og to nyere peri-urbane strande. Dataindsamlingen gennemføres kvartalsvist på de samme 100 m strækninger efter internationale retningslinjer med fokus på at registrere mængder og sammensætning af det marine affald. Fx I 2023 blev der registreret i alt 8245 genstande fordelt på 32 surveys. Mængderne varierede markant mellem farvandsområder, med de højeste medianværdier i Nordsøen/Skagerrak (360 genstande/100 m) og de laveste i Østersøen (50 genstande/100 m). Plastik udgjorde i gennemsnit 91 % af affaldet, hvor genstande karakteriseret som engangsplastik (SUP), udgjorde 11–27 % af de registrerede genstande. På især strandene ved Nordsøen/Skagerrak udgjorde fiskerirelateret affald med 25 % også en væsentlig andel). De peri-urbane strande adskilte sig med et større indslag af lokalt genereret affald, såsom cigaretskod og metalkapsler.
Tidsserier fra 2015 og frem dokumenterer et generelt fald på mere end 40 % i affaldsmængder på både nationalt og regionalt niveau, også som også afspejler et generelt faldende niveau som er fundet i affald på strande i store dele af EU. Mængderne på de danske strande overstiger dog fortsat EU's tærskelværdi på 20 genstande/100 m.
I Grønland er der siden 2016 gennemført næsten 140 overvågningssurveys på mere end 11 km kyststrækning under SUMAG-projektet. Her anvendes en modificeret OSPAR-metodik tilpasset arktiske forhold. Resultaterne viser store geografiske forskelle, også mellem lokalt beliggende strande: Vestgrønland med samlet medianværdi på 65 genstande/100m præges af SUP og landbaseret plast, mens fiskerirelateret affald dominerer i Østgrønland, dog kun med en medianværdi på 1 genstand per 100m. Tendensanalyser peger på faldende mængder i visse områder af Vestgrønland, hvilket sandsynligvis kan tilskrives lokale tiltag for bedre affaldshåndtering og stigende offentlig bevidsthed. Samlet fremhæver resultaterne både de store udfordringer med plastforurening i de danske og grønlandske kystområder og samtidig tegn på, at målrettede indsatser kan have en positiv effekt på at reducere marint affald.

Danish

Korsør Nor - hvordan står det til med PFAS og anden forurening i Storebælt og Smålandsfarvandet?

Larsen, Martin M[1]; Sølvbjerg, Nanna K.[2]

[1]AU Ecoscience, [2]AU Ecoscience Roskilde

I forbindelse med NewSea projektet med Velux fonden har vi set på hovedkilderne til forurening i området Smålandsfarvandet og Storebælt.

Der er både udtaget vandprøver, udlagt passive samplere (DGT'er) og indsamlet fisk og muslinger for at kortlægge niveauerne af metaller og PFAS, ligesom der kigges efter biologiske effekter og modelleres spredning fra renseanlæg og andre kendte punktkilder. Den største punktkilde for PFOS i området er brandskolen i Korsør, og den har indgået i et laborant projekt hvor der blev set på PFAS'er i jord, vand og muslinger som en del af projektet. På basis af en nylig rapport udarbejdet for Region Sjælland er der et estimat for afstørmningen fra hoved grøften der modtager PFAS forurenet vand fra brandskolen, med målte PFOS resultater der stemmer godt overens med vores projekt data. Den beregnede mængde udledt PFOS til Korsør Nor er på sammen niveau som den samlede udledning af PFOS fra renseanlæg i Danmark (Larsen, 2024) og ca 13% af de forventede tilførsler fra vandløb i hele Danmark til det marine område!

Der vil blive præsenteret resultater fra både Korsør Nor og hele området omrking Storebælt og Smålandsfarvandet, og teorien bag anvendelse af DGT (diffusion gradients in thin films) vil blive diskuteret og sammenholdt med andre passive sampler systemer til måling af PFAS*er i vandmiljøet. Korsør brandskole er nu et nationalt testcenter for PFAS forurening (Region Sjælland, 2023), og udsivningen af PFAS fra brandskolen til Korsør Nor vil blive diskuteret med baggrund i egne data og region Sjællands seneste rapport (udkast fra juni 2025) fra WSP om forureningen.

Danish

Råstofindvinding på havet er vigtig for forsyningssikkerheden i Danmark, men hvad sker der egentlig, når vi forstyrrer havbundens øverste lag?

Elkjær, Cecilie Kjer[1]

[1]WSP

Råstofindvinding på havet er vigtig i forhold til at sikre industrien, private og byggeriets behov for materialer i Danmark og foregår primært ved to metoder: slæbesugning og stiksugning. Ved begge metoder anvendes vand som transportmedium, der returneres til havet efter at råstofferne er suget op på skibet, så lasten hovedsageligt består af råstoffer. Under denne proces føres de fineste partikler med overløbsvandet ud over skibssiden, hvilket resulterer i et sedimentspild på generelt ca. 5 -10 % af råstofvolumet, afhængigt af fartøjstype, råstofressource og materialets indhold af fine partikler, som normalt er lavt for råstoffer indvundet på havet (TOC < 1-3%).
Når havbundens øverste lag forstyrres under indvinding, frigives ikke kun sediment, men potentielt også næringsstoffer og miljøfarlige stoffer (MFS), der gennem årtier er akkumuleret i de øvre lag. Viden om frigivelse og koncentrationer af MFS i forbindelse med råstofindvinding er dog imidlertid begrænset. Det er derfor væsentligt at undersøge, om MFS frigives i koncentrationer, der kan overskride gældende miljøkvalitetskrav for vand, sediment og biota.

Projektet, som er udbudt af Miljøstyrelsen og vundet af WSP Danmark A/S, præsenterer for første gang feltdata fra danske indvindingsområder, hvor overløbsvand og sedimentspild analyseres på enkeltstofniveau.
Tre centrale spørgsmål belyses:

Hvilke koncentrationer af MFS findes i overløbsvandet og i sedimentspildet?
Overskrides de fastsatte sediment- og vandkvalitetskrav?
Hvilke implikationer har resultaterne for fremtidig råstofindvinding?

Resultaterne skal ikke erstatte konkrete miljøvurderinger i forbindelse med ansøgninger, men bidrage med ny viden til en bredere faglig forståelse af, om råstofindvinding i danske farvande kan forringe den kemiske tilstand på vandområdeniveau. Projektet er dermed et vigtigt skridt mod at afklare problemets omfang og sikre at der i forbindelse med råstofindvinding tages de nødvendige at der tages hensyn til havmiljøets sårbarhed.

Danish

Miljøfarlige stoffer i forbindelse med marine anlægsprojekter – vurdering, databehov og forskningsperspektiver

Christensen, Anne Munch; Finnich, Heidi Louise[1]

[1]Energinet

Etablering af kabler og rørledninger i dansk havbund er en central del af den grønne omstilling og sikring af en stabil energiinfrastruktur mellem landsdele, samt internationale forbindelser. Anlægning af kabler medfører fysiske forstyrrelser af havbunden, hvor ophvirvling af sediment kan resultere i mobilisering og spredning af miljøfarlige stoffer (MFS) i vandsøjlen, der er blevet ophobet i sedimentet over en længere årrække.

Administrationspraksis på området har de seneste år været under løbende udvikling, og nye klagenævnsafgørelser og vejledninger stiller øgede krav til dokumentation og vurdering. Samtidig er der et øget behov for at kende den reelle miljøpåvirkning, som kan understøtte en smidig godkendelsesproces.

I forbindelse med vurdering af anlægsprojekternes miljøpåvirkning udføres der omfattende undersøgelser af sedimentkvalitet. Der opnås viden om indhold af MFS i overfladesediment, baseret på kemiske analyser og i enkelte tilfælde er der ligeledes foretaget analyser af borekerner. Disse data bidrager ikke kun til projektgodkendelse, men også til en bredere forståelse af fordeling af MFS i havbundens dybde som følge af antropogen påvirkning samt naturlige baggrundsniveauer i danske havområder. I enkelte områder af den danske havbund, er der foretaget sådanne undersøgelser, men hvor stor forskel der er i fordelingen af MFS fra område til område, og hvor stor betydning sedimentdynamikken har for tykkelsen af den antropogene zone og den mere upåvirkede zone vides ikke?

Aktuelle udfordringer i forbindelse med anlægsprojekter som fører til ophvirvling af sediment, såsom de tilknyttede beregninger og opdaterede myndighedsvurdering, belyses. Derudover peges der på viden- og forskningsbehov, som vil styrke de komplekse miljøvurderinger.

Danish

Miljørisikovurdering af skibsfartens brug af 'grønne' brændstoffer

Fritt-Rasmussen, Janne

Internationalt er der en målsætning om at gøre skibsfarten klimaneutral i 2050. Ved COP-mødet 2021 i Glasgow tiltrådte Danmark en erklæring om netop at støtte IMO´s arbejdet med at gøre skibsfarten klimaneutral. Klimaneutral skibsfart søges opnået ved implementering af nye teknologier, herunder udskiftning af fossile brændstoffer med 'grønne' brændstoffer bl.a. fremstillet via Power-to-X (PtX) teknologien. Mens implementering af disse teknologier har en åbenlys gevinst for at reducere udledning af CO2 til atmosfæren fra skibsindustrien, er de afledte miljøeffekter og mulige miljøgevinster uafklarede. Vi vil her præsentere en omfattende miljørisikovurdering af de mulige miljøproblemer, der kan opstå i forbindelse med skibsindustriens udskiftning af fossile brændstoffer med 'grønne' brændstoffer. Vi vil præsentere mulige miljøpåvirkninger og effekter i havmiljøet ud fra analyser af de 'grønne' brændstoffer kemiske egenskaber samt simuleringer af koncentrationer i havmiljøet og luften ved uheld/spild af 'grønne' brændstoffer.

Projektdeltagere: Janne Fritt-Rasmussen, Sofie Amalie Sønderby Rask, Julie Svensgaard, Anne Sofie Lansø, Ane Lopez de Gamiz Zearra, Christian Juncher Jørgensen, Kim Gustavson

Projektet er støttet af Velux Fonden og Dampskibsselskabet Norden A/S

Danish

Persistence-Directed Testing Combined with Non-Targeted Analysis Reveals Discharge of Persistent Chemicals from Offshore Oil Platforms

Møller, Mette T.[1]; Birch, Heidi[1]; Papazian, Stefano[2,3]; Wennberg, Aina C.[4]; Bonnefille, Bénilde[2,3]; Kronsbein, Pia[1]; Kelland, Malcolm A.[5]; Martin, Jonathan W.[2,3]; Mayer, Philipp[1]

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Persistent chemicals discharged to the sea can pose long-term irreversible risks. New approaches are needed to elucidate the number and type of persistent chemicals, particularly in complex mixtures and

high-volume discharges. We introduce a novel "Persistence-Directed Testing" approach that combines environmentally relevant biodegradation tests with non-target analytical methods. Complex produced waters from two offshore oil platforms in the North Sea served as case studies. In the biodegradation tests, produced waters were diluted 1:200 with seawater from the site of discharge (inoculum)[1]. Biotic test systems and abiotic controls were incubated at 9°C. On day 60 non-target analyses were performed by Solid Phase Microextraction coupled to GC-MS and Solid Phase Extraction coupled to LC-HRMS. Primary biodegradation and persistence were determined based on biotic/abiotic peak area ratios. Over 600 chemicals passed the quality control filtering criteria, and the persistent fraction of chemicals discovered by GC-MS was 4% and by LC-HRMS 32-44%[2]. Spectral library matches and computational modeling of the LC-HRMS data annotated several persistent chemicals as N-substituted aromatic ring structures. These findings demonstrate the value of a persistence-directed approach in uncovering the hidden burden of unidentified persistent chemicals in environmental discharges and highlight the urgent need for enhanced treatment of produced water discharges. The presentation will place the findings of the study in a wider context, emphasizing the relevance to the field of marine pollution.

Please note that this work, including the above abstract, was published in a peer-reviewed international journal in October 2025: https://pubs.acs.org/doi/10.1021/acs.est.5c08802

English

Torsdag 22.1

Damgaardssalen

Marine restoration in a Danish context I (9:20)

Danmarks første naturgenopretningsplan – den marine del

Pedersen, Anna-Grethe Underlien

Miljøstyrelsen udarbejder den første naturgenopretningsplan for marine naturtyper og levesteder for havpattedyr. I planen skal der foretages en opgørelse af areal og tilstand for grupperne af bl.a. havgræsenge, makroalgeskove og skaldyrsbanker. Der skal foretages en opgørelse af indsatserne for marine naturtyper og levesteder for havpattedyr. Miljøstyrelsen vil præsentere, hvorledes styrelsen tilgår dette planlægningsarbejde.

Baggrund: EU Kommissionens naturgenopretningsforordning (1) trådte i kraft den 18. august 2024. Forordningen udstikker en ramme, inden for hvilken medlemsstaterne skal indføre effektive og områdebaserede genopretningsforanstaltninger for en række økosystemer og levesteder for arter på tværs af EU's land- og havområder. Medlemsstaten skal senest i 2030 gennemføre genopretningsforanstaltning, som dækker mindst 30 % af bestemte grupper af marine naturtyper i ikke-god tilstand, og der er skærpede mål i hhv. 2040 og 2050 for alle grupper af økosystemer, der er omfattet af denne forordnings anvendelsesområde. Medlemsstaten skal senest den 1. september 2026 sende et udkast til genopretningsplan til EU Kommissionen. Det er Styrelsen for Grøn Arealomlægning og Vandmiljø, som er hovedansvarlig for genopretningsplanen.

Danish

Havnaturfondens erfaringer med genopretning af stenrev

Habary, Stine

Havnaturfonden har genoprettet Taarbæk Rev i Øresund med ca. 40.000 tons sten, og er i fuld gang med et af danmarkshistoriens største stenrevsprojekter i Lillebælt, hvor der i løbet af 2026 bliver genoprettet tre stenrev ved Helnæs og Lyø. Vi vil fortælle om de principper, der har været styrende for de to genopretningsprojekter, om vores overvejelser om effektovervågning, og om sigtelinjerne for Havnaturfondens kommende genopretningsprojekter.

Baggrund: I juni 2024 blev der indgået en politisk aftale om etablering af Havnaturfonden, der bl.a. skal bidrage til genopretning af naturen og biodiversiteten under havoverfladen. Med aftalen blev der afsat yderligere midler til genopretningen af Taarbæk Rev i Øresund, samt genopretning af tre stenrev ved Helnæs og Lyø i Lillebælt. Med aftalen er der samlet set afsat 500 mio. kr. til Havnaturfonden.

Danish

Passive Nature Restoration of Marine Habitats (PReMaH) - baseline, development and collaboration

Christensen, Helle Torp[1]; Banta, Gary[2]; Bekkevold, Dorte[1]; Christensen, Asbjørn[1]; Eigaard, Ole[1]; Ernstsen, Verner Brandbyge[3]; Kindt-Larsen, Lotte[1]; Termansen, Mette[4]; van Denderen, Daniël[1]; Wahlberg, Magnus[2]; Worsaae, Katrine[2]; Dinesen, Grete Elisabeth[1]

[1]Danish Technical University, National Institute of Aquatic Resources (DTU Aqua), [2]University of Southern Denmark, Department of Biology (SDU-BIO), [3]Geological Survey of Denmark and Greenland (GEUS), [4]University of Copenhagen, Department of Food and Resource Economics (KU-IFRO)

At the 2023 environmental assessment under the Marine Strategy Framework Directive, multiple Danish seabed habitats did not meet the criteria for a Good Environmental Status (GES). In the ecoregion, Greater North Sea, subtidal mud and gravel habitats are considered adversely affected by bottom trawling, whereas in the Baltic Sea, more than half of the seabed habitats are adversely affected by hypoxia. In the Kattegat, several habitats are adversely affected both by bottom trawling and hypoxia. Thus, to protect and improve the environmental status of our marine waters and to recover and maintain habitats and healthy populations of both sensitive and exploited species, bottom trawling is now banned from Marine Protected Areas (MPAs). The ban is covering approximately 19% of the Danish seabed habitats.

With PReMaH we will over a period of 11 years investigate how the ban of bottom trawling in MPAs, will affect seabed habitat- and ecosystem recovery with respect to climate, environmental and nature effects. It is of particular importance to understand how passive restoration based on recovery by natural processes will lead to improved environmental status ("miljøtilstand") of the MPAs and adjacent areas and how ecosystem structures, functioning and services and the value of these may change.

More specifically the study will assess MPA ecosystem recovery after ban of trawling by focusing on four core elements:

1) Documentation of physical seabed habitats, environmental status, biogeochemical functioning and climate impacts.
2) Quantification of benthic fauna and fish biodiversity, plus, source-sink functions.
3) Effects on food web interactions between benthic fauna, fish and marine mammals.
4) Description and valuation of ecosystem functioning and services.

This is an interdisciplinary and cross institutional project and stakeholder engagement is fundamental. Due to its long duration (11 years) and holistic and ecosystem-based management approach, the project has a large potential to generate further collaboration.
The project results will contribute to implementation of policy goals for a green transition of the fishery while restoring healthy ecosystems and meeting the environmental targets in the Marine Strategy Framework Directive and the Nature Restoration Regulation.

Danish

Assessing food web dynamics and pressure impacts for restoration planning and recovery

Hemraj, Ashley Deevesh;[1]

[1]Aarhus University

Coastal restoration is booming now that the EU and local laws are being enforced. The surge in restoration is very positive, but the various setbacks in long-term ecological recovery suggest that current practices need improvements for rebuilding self-sustaining ecosystems. Among the various routes for improvement, addressing the ongoing cumulative pressures that degrade ecosystems in the first place remains a necessity, but is too often overlooked. Unless strict legal protection is enforced now, more ecosystems will likely be lost than rehabilitation can revitalize. Nonetherless, active rehabilitation of ecosystems remains the one of the major help for ecosystems to recover. The key qestion remains how can we balance protection and active rehabilitation to the benefits of the ecosystem, especially now that seascape restoration (the "coastal mosaic") is resurging as the new breakout trend, making the need for addressing cumulative pressures even more important. Here, we will present models that assess

cumulative impact of pressures on the ecosystem and how we can use them to balance pressure reduction and active rehabilitation. We will focus on a food web network pressure propagation model that can help with identifying the direct and indirect pressures influencing an ecosystem and the main organisms in the food web that are most susceptible. The aim of such a model is to help with marine spatial planning, protection, and rehabilitation prioritization for enhancing the long-term outcomes of restoration efforts.

English

Scientific aims and setup in the Healthy Vejle Fjord project

Flindt, Mogens R.; L. Banke, Timi; E. Balleby, Klaus; F. Christensen, Mads; Dalby, Brit; Nielsen, Benjamin; Gommesen, Mia; H. Hansen, Frederik; K. Lees, Mikkel; Canal-Vergés, Paula; H. Steinfurth, Rune C.

The Healthy Vejle Fjord Project has from 2020-2024 focused on nutrient loading, modelling reduction scenarios, and multiple stressors along the strong eutrophication gradient with the aim of optimizing site selection for the marine restoration activities. The studied stressors along the eutrophication gradient included: bed conditions, nutrient availability (N & P concentrations), benthic light intensity, oxygen conditions (frequency of anoxia), epiphyte coverage and dynamics, opportunistic macroalgae and lugworm densities. It has provided options for creating the largest Danish marine habitat restoration, where we have managed to restore 64 ha mussel banks, 6 ha eelgrass meadows and 8 ha stone reefs buffered by 100 ha of conservation zones. Parts of the restoration include mosaic/seascape nature, where we, in the coming years, continue the quantification of the developing ecosystem services and functions.

Danish

Offshore wind decommissioning as a catalyst for reef restoration in Denmark?

Povidis Delefosse, Matthieu[1]; Wilms, Tim

[1]Vattenfall

Denmark currently hosts over 650 turbines across 17 operating offshore wind farms. As the first projects reach the end of their operational life, decommissioning decisions coincide with a pressing need to restore marine habitats. Among these, stone reefs — once widespread in Danish waters but severely depleted by historic extraction — are a key priority under both national and EU restoration ambitions.

Offshore wind farms already contain structures with reef-like potential. Scour protection consists of quarried rocks deposited around turbine foundations to stabilise the seabed, typically 1,200 tonnes covering 800 m² per turbine. At the scale of a wind farm such as Horns Rev 3, this amounts to 4.5 hectares — similar in size to Denmark's largest marine reef restoration project, the Blue Reef at Læsø. Monitoring demonstrates that scour protection can develop into reef-like habitats, supporting diverse assemblages of invertebrates, crustaceans, and fish with features characteristic of natural stone reefs. This creates a gap between the ecological value of scour protection and the regulatory framework governing wind farm decommissioning.

With no Danish precedent or national guidelines on scour protection management in decommissioning, decisions are expected to follow international practice under OSPAR Decision 98/3, which requires full removal. Yet scientific evidence and international dialogues increasingly question whether this approach always delivers the best ecological and socieoutcomes. Retaining selected scour protection in situ could accelerate biodiversity recovery, safeguard ecosystem functions, and reduce the societal costs of stone reef restoration.

Realising the restoration potential of scour protection requires a national framework linking decommissioning decisions with restoration goals: identifying sites of greatest ecological value, establishing long-term monitoring, and engaging transparently with stakeholders. This approach must also address risks explicitly — including invasive species and pollution — if scour protection retention is to be seen as a credible restoration measure rather than an industry cost-saving exercise. Aligning such measures with restoration ambitions would secure both credibility and impact.

By reframing scour protection as a ready-made reef resource, offshore wind decommissioning can shift from a narrow removal obligation into a catalyst for restoration. Can Denmark afford to dismantle reef-like habitats that restoration projects are striving to rebuild?

English

Marine restoration in a Danish context II (10:50)

Challenges for carbon crediting in Zostera marina (eelgrass) meadows

Dorte Krause-Jensen[1], Carmen Leiva-Duenas[1], Catherine E. Lovelock[2] & Hilary Kennedy[3]

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The protection and restoration of seagrass meadows are recognised contributions to address the combined biodiversity-climate crises because the meadows are hotspots of biodiversity, soil organic carbon (OC) stocks and accumulation rate (CAR) and have experienced major global declines in response to pressures. However, OC storage varies among seagrass species. Based on recent findings of limited OC stocks and CAR for meadows of eelgrass (Zostera marina) in Denmark, we aimed to explore the general potential for carbon crediting in meadows of eelgrass, the globally most widely distributed seagrass species, across its distribution range. Our review targets soil OC stocks and CAR, as well as sources and stability (mineral associated organic matter - MAOM) of the organic matter. We compare our findings for eelgrass, which is a fast-growing colonizing-opportunistic seagrass species, with those for Posidonia oceanica, typifying slow-growing, persistent seagrass species. Eelgrass soil OC stocks and CAR display median stocks 40% and 50% lower, respectively, than those of P. oceanica and median eelgrass CAR is only 28% of the Tier 1 emission factor for seagrass used in the IPCC guidelines. The OC stocks in vegetated areas were generally not significantly different from stocks of nearby unvegetated soils and only 25% of the eelgrass soil samples in this compilation would return positive OC values after subtracting the MAOM fraction, a requirement of some carbon market methodologies. These features may partly be due to the strong spatial heterogeneity and temporal dynamics of eelgrass meadows, general eelgrass traits as well as export of eelgrass carbon beyond the meadows. We discuss implications for carbon crediting of eelgrass restoration projects and conclude that the scope is limited, that restoration of eelgrass meadows makes modest contribution to climate change mitigation, but that the recovery of eelgrass meadows through sustainable management supports multiple additional benefits.

Danish

Low climate benefit of Nordic coastal marshes: a trade-off between carbon storage and stability

Leiva Dueñas, Carmen

Coastal marshes, recognized as effective organic carbon (OC) sinks, have gained attention for their potential contribution to climate mitigation through protection and restoration. However, the climate mitigation potential of Nordic coastal marshes remains understudied, likely due to their heterogeneous and often non-tidal nature. To fill this gap, we examined soil OC storage and accumulation rates, methane emissions, and the effects of grazing, a common management practice, across eight Nordic coastal marsh areas spanning broad climate and environmental gradients. Nordic marshes store a median of 7 kg OC m^{-2} (interquartile range, IQR: 6–8) in the top 15-35 cm of soil and accumulate 41 g OC m^{-2} yr^{-1} (IQR: 32–47). Considering only the additional OC, attributed to the presence of the marsh habitat itself, these values drop to 4 kg OC m^{-2}. (IQR: 2–6) and 21 g OC m^{-2} yr^{-1}. (IQR: 11–33). Globally, both rates are comparatively low. OC stocks and accumulation rates increased with marsh age, root:shoot ratio (stress adaptation), and $\delta^{15}N$ (fast N cycling), but declined with soil $\delta^{13}C$ (faster decomposition under warmer conditions). Denmark's warm, nutrient-rich soils foster plant growth and microbial decay, resulting in high yet vulnerable OC stocks with faster turnover and labile compounds. Conversely, colder Nordic sites have lower but more stable stocks, with slower turnover, more refractory compounds and higher clay content. Soil methane emissions reduced the climate benefit of OC accumulation by 0.15–7.3% in Danish marshes, which remained strong CO_2eq sinks, but by 4–35% in Finnish marshes, low salinity environments, leaving them weaker sinks. Grazing weakly stimulated additional soil OC stocks and had no clear effect on OC accumulation rates or methane fluxes. Estimated greenhouse gas emissions from on-site cattle, even at low grazing intensity, largely outweighed climate benefits of the coastal marshes. A comprehensive Nordic marsh management strategy is needed, extending beyond the focus on their limited, yet relevant, role in climate mitigation, and considering biodiversity, coastal protection and nutrient retention. In a Danish context, protection and restoration should focus on reducing nutrients and favoring finer soils to develop stable, resilient marshes that accumulate stable OC, even if stocks are lower.

English

Biodiversiteten i naturgenoprettede ålegræsenge i Danmark

Husted Steinfurth, Rune Christian; Løvholt Banke, Timi; Nielsen, Benjamin; Flindt, Mogens R.

Ålegræsenge (*Zostera marina*) fungerer som økosystem ingeniører og spiller en central rolle for kystnær biodiversitet, men yder også mange andre vigtige økosystemfunktioner. I Danmark har ålegræsset gennemgået markante tilbagegange, først pga. en svampesygdom i 1930'erne og siden pga. eutrofiering og reduceret sigtdybde. Trods politiske tiltag og reduktion af næringsstofbelastning har naturlig reetablering af ålegræs været begrænset, hvilket kan tilskrives vedvarende stressfaktorer som sediment resuspension, reduceret forankringskapacitet i sedimentet og fysisk påvirkning fra drivende makroalger og bioturbation. Disse mekanismer fastholder økosystemet i en alternativ stabil tilstand uden vegetation.
I lyset af dette fremstår aktiv restaurering som en nødvendig strategi for at genskabe ålegræsengene og genvinde de essentielle økosystemtjenester som de yder. I Horsens Fjord, to steder i Vejle Fjord og i Lunkebugten er det lykkedes at udføre succesfuld genetablering af ålegræs i stor skala. Det er sket på baggrund af et grundigt forarbejde med at finde egnede områder og ved at benytte restaureringsmetoder der kan sikre ålegræsskuddene mod nogle af de ovennævnte stressfaktorer. Som en del af effektundersøgelserne i de genetablerede ålegræsenge er biodiversitetsudviklingen blevet undersøgt. Bedene varierer i alder fra 2 måneder til 5 år, næringsstofbelastning og eksponering for bølgepåvirkning. Dette studie belyser successionen i biodiversitet og hvorledes de lokale forskelle i miljøtilstand kan forme samfundsudviklingen i restaurerede ålegræsbede.

Danish

How to identify suitable sites for restoration of boulder reefs

Stæhr, Peter[1]

[1]Aarhus University

Over the last century, more than 55 km^2 of boulder reefs have been estimated removed by stone fishermen in Danish seas. These temperate reefs provide essential habitats for a range of marine organisms, and large-scale restoration efforts are therefore being planned. Here we present a spatial decision support tool (Stæhr et al. 2025) which is being applied to assess the suitability of areas for restoration of boulder reefs in Danish waters. The tool involves screening of suitable sites in relation to several physical, environmental and historical conditions as well as information on marine area management. The tool is a first important step in the successful selection of areas and later assessment of the ecosystem services gained from planned restoration activities.

English

The effect of timing: settling and growth of Danish Fucus serratus & Fucus vesiculosus

Graudal Levinsen, Jørgen Ulrik[1]; Bruhn, Annette[1]; Boderskov, Teis[1]

[1]Aarhus University

In recent years marine nature restoration is gaining increased attention in Denmark. One form of marine nature restoration is the establishment of boulder reefs, with the aim of providing suitable substrate for growth of macroalgae communities, and increased biodiversity.
The brown algae, Fucus serratus & Fucus vesiculosus are both keystone species and act as ecosystem engineers providing several important ecosystem services, including provisioning of habitat for marine fauna. They are perennial (2-5y) species with an upright, branching, apical growth. They both tolerate the entire salinity range found in Danish coastal waters and can be found from the North Sea to Bornholm at varying abundancies, sometimes forming dense beds. In Denmark, the growth of both species is primarily regulated by presence of suitable substrate and light.
Boulder reef projects are costly, and guidelines exist to help ensure their success. Previous projects have shown that it takes up the several years from reef establishment to the occurence of desired communities, including macroalgae, on the reef.
In present study we placed 50x15x15 concrete h-blocs (artificial reef substrates) monthly from March 2023 – July 2024 in a fucus bed with presence of both F. serratus and F. vesiculosus, in Begtrup Vig, Aarhus Bay. We monitored the settling and growth of both fucoids from April 2023 – September 2025. We found that the timing of substrate placement had significant, species-specific effects on the settling and growth throughout the monitoring period.

F. vesiculosus established itself on all substrates placed during the study, with higher settling and growth on substrates placed between March and June in both 2023 and 2024. F. serratus had a slower and less pronounced establishment than F. vesiculosus. It settled in low densities, interspersed within more abundant F. vesiculosus, on substrates placed between May 2023 and March 2024 except early November and late December 2023. The substrates placed between July and February had lower settling and growth of fucoids, with less fucoid biomass consisting of smaller individuals.
These findings suggest how timing the placement of reef structures may facilitate accelerated establishment of desired reef communities.

Danish

Do blue mussels facilitate recovery of eelgrass beds? Evidence from field observations and ecosystem models

Andersen, Tobias Kuhlmann[1]; Bohr, Emil Hoffmann[1]; Thomasberger, Aris[1]; Taylor, Daniel[1]; Brooks, Mollie[1]; Hermannsen, Line[1]; Timmermann, Karen[1]

[1]National Institute of Aquatic Resources (DTU Aqua), Technical University of Denmark

Eelgrass (*Zostera marina*) and blue mussels (*Mytilus edulis*) are keystone species in Danish coastal ecosystems, providing critical habitat, improving biodiversity, and supporting ecosystem functioning. However, eelgrass meadows have declined to a third of the 1900s reference conditions, with insufficient light availability identified as a primary constraint on recovery. Emerging evidence suggests that blue mussel beds may facilitate eelgrass growth by reducing hydrodynamic stress, and, importantly, improving water clarity through filtration of suspended particulate matter. In this presentation, we evaluate the influence of blue mussel beds on underwater light conditions in adjacent eelgrass habitats. Field measurements were conducted from May to September 2023 at two sites in Lovns Broad, Limfjorden, characterized by contrasting mussel–eelgrass configurations. We continuously monitored currents, water quality, and light availability, and complemented these observations with simulations from a high-resolution, coupled hydrodynamic–biogeochemical MIKE model by DHI tailored to the local study area. Our results show that water clarity was consistently higher above mussel beds compared to eelgrass beds and mixed habitats. Moreover, eelgrass beds located downstream of mussel beds exhibited improved light conditions, suggesting a positive facilitative effect linked to mussel filtration. Model simulations reproduced these patterns and confirmed that grazing by blue mussels can substantially reduce suspended particulate concentrations, thereby enhancing light penetration in the water column. These findings demonstrate that blue mussels can play a significant role in improving the environmental conditions necessary for eelgrass recovery. We predict the facilitative role of blue mussels on eelgrass growth and discuss the potential for a mussel-eelgrass co-restoration tool and its relevance for coastal waterbody management in a restoration perspective.

English

Marine restoration in a Danish context III (13:30)

Five years of blue mussel bed restoration – lessons learned and future perspectives

Løvholt Banke, Timi[1]; Christian Husted Steinfurth, Rune[1]; Nielsen, Benjamin[1]; Ambus Kjær, Rasmus[1]; Høker Petersen, Anders[1]; Hoffmann Hansen, Frederik[1]; Canal-Vergés, Paula[1]; Flindt, Mogens[1]

[1]Department of Biology, University of Southern Denmark (SDU)

Blue mussel beds are vital coastal habitats that support various key ecosystem functions, including increasing habitat complexity and biodiversity, serving as nurseries, and enhancing water clarity. However, in recent decades, a significant decline in blue mussel populations has been observed throughout Scandinavia (Baden et al. 2021; Banke et al. 2024), prompting a need for restoration efforts. In the project "Sund Vejle Fjord," active restoration of blue mussel beds has been carried out for five consecutive years, resulting in 2,000 tons of relayed mussels covering 53 hectares. This effort represents the largest active bivalve restoration project in Europe, providing valuable insights for future initiatives. Blue mussels are cultivated on a local suspended mussel farm, harvested, and relayed once they reach a sufficient size. During the project, mussels have been exposed to various environmental gradients, which have helped identify possible bottlenecks and conditions suitable for restoration. Additionally, different relay densities have been tested in conjunction with population monitoring to determine the most effective restoration approach. Restored beds have been found to thrive across a broad spectrum of

environmental parameters, with the oldest beds still present 5 years after their establishment. Consequently, blue mussel restoration is potentially viable in large coastal areas. A relay density of 4 kg/m² has been found to support the most robust bed structures, allowing mussels to self-organize in complex patterns while limiting internal competition for space. However, unpredictable starfish predation can limit bed longevity. Furthermore, limited recruitment has been observed, with potential implications for the long-term success of restoration. Ecosystem functions of the beds develop rapidly following relay with distinct increases in both species richness and abundance. Nonetheless, while many lessons have been learned, restoration of blue mussels remains in its infancy, with many knowledge gaps regarding long-term bed stability, overflow effects, and associated ecosystem functions and services.

English

Behov for naturgenopretning af blåmuslingebanker?

Nielsen, Pernille[1]; Witte, Sterre[1]; Flensborg, Louise C.[1]; Petersen, Jens Kjerulf[1]

[1]DTU Aqua

Marin naturgenopretning i Danmark er stadig relativt nyt og vigtige erfaringer og viden er opnået i de sidste 15-20 år, hvor der har været gennemført forskellige marine naturgenopretningsprojekter i danske farvande. Projekterne har i høj grad fokuseret på etablering af stenrev og ålegræsbede, mens genopretning af skaldyrsbanker først rigtig er begyndt i de senere år.
Langs de lavvandede danske kyster består de nuværende skaldyrsbanker hovedsageligt af blåmuslingebanker, mens hestemuslinger og europæisk flad østers ofte findes i begrænsede forekomster, hvis overhovedet. Hvorfor så overhovedet igangsætte naturgenopretning af blåmuslingebanker? Dette får du svaret på i denne præsentation, hvor blåmuslingernes historiske udbredelse og vigtige funktion langs de danske farvande gennemgås, en statusopdatering på den nuværende udvikling i internationale og nationale blåmuslingepopulationer, som viser, at den naturlige oprettelse af stabile blåmuslingebanker er udfordret.

Danish

Standardized monitoring of blue mussel reef restoration: A semi-automated workflow for side-scan sonar and video imagery

Steinmann, Anna[1]; Freitas, Pedro; Thomasberger, Aris; Kjerulf Petersen, Jens[1]

[1]DTU Aqua Dansih Shellfish Centre

Blue mussel (*Mytilus edulis*) restoration actions are increasing in Dan[1]ish fjords to enhance habitat value, ecosystem functions and services. Assessing restoration success requires a monitoring program that has clear objectives, is consistent and spatially detailed, capturing changes in mussel bed extent and complexity. However, most restoration monitoring still relies on subjective interpretation, sparse data and a lack of clearly defined metrics, making systematic monitoring and evaluation of restoration success a major bottleneck.

We developed a semi-automated workflow that integrates supervised classification of high-resolution side-scan sonar (SSS) imagery with underwater orthomosaics from drop-video transects to quantitatively map mussel bed structure and dynamics. The approach was tested on two 20x50 m relay plots in Løgstør Bredning, Limfjorden, stocked with a total of 17 t of *M. edulis* at different densities (high: 5.5 kg m²; medium: 3.6 kg m²). We conducted monthly SSS surveys combined with environmental monitoring, and a final video survey on the project footprint (fixed to the restored area) and the area footprint (flexible, includes surrounding affected area).

Over the six month course of this study, both beds persisted but the area footprints shifted about 20 m northeast, likely driven by wind and currents. Structural reorganization occurred rapidly, with increased complexity during the first months. Patch dynamics differed with density: patch sizes were larger in the medium-density bed, while the high-density bed contained more patches overall. Nevertheless, final mussel coverage for the project footprint was similar across treatments, as higher relay density was offset by higher loss rates. Correcting SSS with orthomosaics increased the accuracy of mussel coverage calculations. Final mussel seabed coverage of the area footprint was 16.3% in the high- and 10.2% in the medium-density bed, compared to uncorrected values of 24.4% and 14.6%. At relay, uncorrected coverage was 39.1% and 41.9%, respectively. This highlights the methodological importance of correcting SSS-overestimations with orthomosaic transects.

Our results demonstrate the feasibility of a standardized, semi-automated monitoring protocol for blue mussel habitat restoration. Defined metrics ensure consistency across timepoints, enabling a spatial-temporal comparisons of large datasets without reliance on subjective estimates or variable workflows.

English

Large scale biogenic reef restoration in the Limfjorden

Witte, Sterre[1]; Steinmann, Anna; Seabra Freitas, Pedro[1]; Saurel, Camille[1]; Kjerulf Petersen, Jens[1]

[1]DTU Aqua

Many coastal habitats such as eelgrass meadows, natural stone reefs, salt marshes and shellfish reefs have declined dramatically over the past century. This change in coastal landscapes resulted in a loss of vital ecosystem functions and services provided by these habitats. The EU Nature Restoration Law requires member states to restore 30% of degraded coastal ecosystems to good condition by 2030. Both scientific knowledge and practical experience in coastal restoration are essential to achieve this goal.

The COASTalLIFE project addresses this challenge in Danish coastal zones by restoring multiple habitats while simultaneously addressing key questions in restoration ecology. In this context we restored biogenic reefs, formed by blue mussels (*Mytilus edulis*) and flat oysters (*Ostrea edulis*), on a large scale in the Limfjorden. Mussels were relayed on different seafloor types: a sparse mussel reef, shell material, and bare sand. The impacts of forcing events such as storms on these newly restored beds were then assessed, focusing on differences in survival, biodiversity and pattern formation. Additionally, initial trials using different relay strategies of flat oysters on two seafloor types (bare and with shell material) provide insights in their restoration potential.

We monitor restoration success combining established methods such as benthic sampling and diver transects with emerging technology such as remotely operated vehicles (ROV), high-resolution sidescan sonar, and artificial intelligence (AI)-based image analyses. Abiotic conditions were tracked using CTD and ADCP measurements. This integrated method allows to test how monitoring efficiency, scalability and accessibility can be improved for coastal restoration projects.
Initial results will provide valuable insights into the resilience of restored biogenic reefs to environmental forcing and the effect of seafloor type. This work can inform future restoration approaches and the potential of novel monitoring tools, laying the foundation for long-term evaluation of restoration success. Therefore, the COASTalLIFE project not only rebuilds valuable coastal habitats but also generates actionable knowledge on coastal restoration that advance future restoration projects in Denmark and beyond.

English

From Broodstock to Biogenic Reefs: Hatchery-Based Production of Modiolus modiolus for Biogenic Reef Restoration in Denmark

Kristiansen, Morten[1]; Nielsen, Pernille; Saurel, Camille; Nielsen, Grete

[1]The Technical University of Denmark, DTU AQUA

In Denmark, biogenic reef restoration with bivalves is currently relying on relaying of the abundant, short-lived blue mussel (*Mytilus edulis*) from spat collectors, or the endangered, disease-vulnerable European flat oyster (*Ostrea edulis*) supplied through hatchery production. New efforts aim to add the long-lived horse mussel, *Modiolus modiolus* (Linnaeus, 1758), to the suite of native Danish species available for biogenic reef restoration. Like other bivalves, *M. modiolus* is an ecosystem engineer, with living mussels and old shells aggregating to create biogenic reefs that can be linked to healthy ecosystem functioning and high biodiversity. However, the spatial extent of *M. modiolus* beds in Danish waters has diminished since the early 20th century due to demersal fishing, with environmental changes contributing to further losses, leaving *M. modiolus* reefs endangered. To reverse the trend, biogenic reef restoration efforts aim to enhance recruitment through the relaying of hatchery-grown *M. modiolus* spat. However, no established hatchery protocols currently exist for *M. modiolus* production and past attempts described in the literature achieved only limited success. Low settlement success and survival of spat highlight gaps in our understanding of the species' biology and underscore the need for further study to realise restoration with *M. modiolus.*

M. modiolus broodstock were collected from Limfjorden and studied under controlled hatchery conditions to examine feeding ecology, stressor-induced spawning methods, and early embryo development, with the aim of producing viable spat for restoration. Initial results indicate that a slow thermal-cycling method

consistently induces spawning, providing opportunities to test protocols and setups related to early embryo development and larval rearing in the hatchery, which represent the first steps in producing viable *M. modiolus* spat for restoration purposes.

This research is part of the BioReef project, which supports the restoration of *M. modiolus* populations in the Danish North Sea region to improve biodiversity and ecosystem functioning. BioReef partners: Ørsted, WWF and DTU Aqua.

English

Status, progress and ambitions for restoring native flat oysters in Danish waters

Nielsen, Pernille[1]; Sganga, Daniela[1]; Freitas, Pedro[1]; Steinmann, Anna[1]; Witte, Sterre[1]; Petersen, Jens Kjerulf[1]; Saurel, Camille[1]

[1]DTU Aqua

On a global scale, marine restoration has gained importance as a vital activity to regenerate ecosystems, protect biodiversity, and support ocean sustainability. For more than a decade, the native flat oyster (*Ostrea edulis*) has been central to various marine restoration efforts throughout Europe due to its historical formation of extensive biogenic reefs, although currently, the native oyster reef ecosystem type has collapsed (zu Ermgassen et al. 2024). In 2022, the first Danish flat oyster restoration projects were launched: BioReef (WWF-Ørsted) and Coastal Life (LIFE-EU project), which aim at both recreating flat oyster reefs in Danish waters and establishing scalable hatchery production protocols of oyster seed for restoration purposes. Lessons learned and status updates will be detailed concerning historical distribution, criteria for site selection, baseline monitoring, choice of settling material, and strategies for deploying hatchery produced oyster seed.

Danish

Jorn

Greenland's coastal ecosystems in a changing climate (9:20)

Meltwater from the Greenland ice sheet and its water isotope distribution in Dickson Fjord, East Greenland

Rooijakkers, Fleur

Glacier retreat and mass loss in East Greenland have profound implications for global sea-level rise, making it crucial to understand the complex dynamics of glacier-ocean interactions. Currently, our knowledge of East Greenland glacial fjords is limited, and the processes occurring directly in front of these glaciers, particularly the fate of subglacial meltwater, remain poorly understood. In this study, conducted in Dickson Fjord, East Greenland in August 2022, hydrographic and stable water isotope measurements at various depths and fjord locations were carried out, starting from the terminus of the marine-terminating glacier. Employing a drone-deployed ocean profiler, we obtained salinity and temperature profiles as close as 20 m from the glacier terminus. We found that the terminus is primarily in contact with a cold Polar Water layer, with temperatures ranging between -0.8 and -1.7°C. Within this layer, we observed an increase in temperature close to the glacier terminus. In the Surface Water layer, we identified two distinct depleted water isotope signals originating from the glacier: one located at the surface and the other near the freshwater freezing line, separated by non-depleted water. Based on our findings, we hypothesize that subglacial meltwater undergoes freezing upon encountering the cold Polar Water at the terminus. The buoyant ice crystals (frazil) formed during this refreezing process would then ascend to the surface, where they encounter positive ocean temperatures and melt. This frazil ice crystal formation process would explain the temperature increase in the Polar Water layer (due to latent heat released during freezing) and the depleted water isotope signal around the freshwater freezing line.

English

Drivers of seasonal hydrography in Disko Bay (Qeqertarsuup Tunua), Greenland

Latuta, Linda[1]; Smedsrud, Lars H.[1]; Darelius, Elin[1]; Hansen, Per Juel[2]; Willis, Josh K.[3]

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This study investigates the seasonal dynamics of Disko Bay (Qeqertarsuup Tunua) in West Greenland, a region shaped by ice-ocean interactions, exchange with Ilulissat Icefjord (Kangiata Sullua) in the east, and connectivity with Baffin Bay in the west. Since the mid-1990s, the region has experienced ocean warming, sea-ice decline, and the retreat of Greenland's fastest-flowing marine-terminating glacier. West Greenland Irminger Water (WGIW) is a major heat source behind these changes, yet the timing and pathways of its entry into Disko Bay remain poorly understood. Long-term observations exist but are biased toward April–September, leaving key processes such as the seasonality of WGIW renewal largely unresolved.

We present a two-year (2022–2024) record of Disko Bay hydrography, based on observations from a monitoring station, two profiling floats, and synoptic surveys, providing new insight into the seasonal evolution and spatial structure of Polar Water (PW) and WGIW. Each spring, dense WGIW crosses the topographic barrier between Baffin Bay and Disko Bay, filling the basin and producing the highest observed temperature and density at depth. The PW–WGIW boundary shoals to depths shallow enough to renew Ilulissat Icefjord. In autumn/winter 2022, an additional episodic renewal coincided with strong upwelling-favourable winds along the West Greenland shelf.

While WGIW renewal dominates winter and spring seasonality (a period also marked by sea-ice presence), summer and autumn hydrography are shaped by PW. With the onset of melt season, a fresh stratified layer develops in the upper 50 m, continuing to freshen, deepen, and cool through autumn. Beneath this layer, denser PW warms steadily along isopycnals, with spatial analyses indicating an advective pathway transporting this warming signal along the bay's periphery.

Overall, Disko Bay hydrography reflects the interplay of WGIW seasonality, PW variability, heterogeneous freshwater inputs, air-ice-ocean interactions, and exchanges across the West Greenland shelf. Our findings improve the characterisation of seasonal and spatial dynamics in the bay, providing a baseline for interpreting variability relevant to ice-ocean coupling and ecosystem processes within Disko Bay.

English

Modeling Shrimp Larval Drift in Disko Bay: Linking Ocean Dynamics and Recruitment in a Changing Arctic

Schourup-Kristensen, Vibe; Larsen, Janus; Ishimwe, Ange; Maar, Marie

Fishing remains a cornerstone of Greenlandic society both culturally and economically, with the fishing industry contributing around 25% to the national GDP. As Arctic waters warm, understanding the dispersal and recruitment of key species like northern shrimp (*Pandalus borealis*) becomes increasingly important for sustainable fisheries management.
In this study, we present a new larval drift model for Disko Bay, West Greenland, which integrates high-resolution outputs from the FlexSem hydrodynamic model with biological parameters to simulate shrimp larval trajectories. The model accounts for temperature-dependent hatching, as well as the influence of coastal currents and mesoscale eddies, providing a detailed picture of larval transport dynamics.
Our results highlight how interannual variability in oceanographic conditions affects temperature, stratification, and current patterns. These changes, in turn, influence larval retention, connectivity, and recruitment success. We find that both large-scale circulation and local topographic features shape larval dispersal, with implications for population dynamics.
This work contributes to a more mechanistic understanding of shrimp recruitment variability and offers a first step towards improved understanding of the impact of climate change on Arctic coastal systems.

English

Glacial meltwater increases Arctic coastal carbonate system sensitivity

Henson, Henry

Rapid melt from the Greenland Ice Sheet delivers large volumes of freshwater to Arctic coastal waters, diluting total alkalinity (TA) and weakening the carbonate buffer system. Although biological processes such as photosynthesis, respiration, and sediment-water interactions strongly shape coastal carbon dynamics, their influence under low-alkalinity conditions remains poorly quantified.

Using 19 years of observations from Young Sound, Northeast Greenland, together with controlled mixing experiments and endmember modeling, we show that meltwater dilution enhances the sensitivity of surface pCO_2 to small changes in dissolved inorganic carbon (DIC) or TA. In these low-alkalinity waters, modest biological or sedimentary fluxes drive disproportionately large shifts in pCO_2 and pH compared with well-buffered marine environments. This heightened responsiveness indicates that future increases in freshwater input will magnify the impact of ecosystem metabolism and acidification on air-sea CO_2 exchange.

Long-term ecosystem monitoring by the Greenland Ecosystem Monitoring (GEM) program provides nearly two decades of high-resolution biogeochemical data that help quantify changing fjord carbon dynamics. Preliminary inspection of the time series suggests evolving interannual patterns that may reflect shifts in freshwater export, biological activity, or broader climatic drivers.

These findings underscore that projections of Arctic coastal CO_2 fluxes require not only knowledge of freshwater chemistry but also sustained observations to capture how carbonate system sensitivity changes over time.

English

Mesozooplankton diversity and role in carbon export and food-web efficiency in East Greenland fjords

Koski, Marja

Knowing the functional diversity of mesozooplankton is important to determine their role in ecosystem functions such as biological carbon pump and trophic transfer efficiency. Particularly, the proportion of large calanoid species that exhibit daily vertical migration and produce fast sinking fecal pellets vs. the small non-calanoids that are known to feed on sinking particles is important in determining the export flux and its attenuation. Similarly, a high secondary production of large calanoids tends to promote high food web efficiency. To investigate the zooplankton community composition and its potential effect on vertical flux and secondary production in the Arctic, we measured the vertical distribution and biomass of zooplankton species and life-stages in July-August 2022, at 12 stations located in fjords and coastal areas of East Greenland, between 70 and 76 °N. In addition, ship-board incubation experiments were conducted to estimate the fecal pellet production and aggregate feeding of dominant calanoid and poecilostomatoid copepods, respectively. At most stations, zooplankton biomass was relatively low (5-12 mg C m^{-3}) and dominated by different life-stages of *Calanus* spp., producing 10-20 pellets $ind.^{-1}$ d^{-1}. An exception to this was Dove Bay, where the biomass was >20 mg C m^{-3}, dominated by *Pseudocalanus* sp. and *Triconia borealis*, with high fecal pellet production and aggregate feeding rates. In addition, the concentration of calanoid eggs in Dove Bay exceeded that at the other stations by > 10-fold indicating high reproduction. Dove Bay thus stood out as a productive station where zooplankton biomass and activity were more similar to the productive coastal areas in West Greenland than to the other stations in East Greenland. Our results shed light on the factors controlling the functional diversity of zooplankton in fjords and coastal waters of East Greenland and on the effect that species shifts can have for the ecosystem functions such as secondary production, trophic transfer efficiency and biological carbon pump.

English

Cod in a changing environment - Spatial variation in field metabolic rate of Atlantic cod from Greenland to Denmark

Christensen, Jonathan[1]; Grønkjær, Peter

[1]Aarhus University

Ocean temperatures are projected to rise rapidly, with consequences for species and ecosystems. For many animals, cold and warm distribution limits are well defined, yet the physiological and ecological constraints remain poorly understood. In fish, elevated temperature can increase metabolic rates, which is thought to be beneficial at cold ranges, where the aerobic capacity increases, while disadvantageous at warm ranges, where maintenance costs rise without corresponding gains in aerobic capacity. We conducted novel time-integrated field metabolic rate (FMR) analysis on Atlantic cod (*Gadus morhua*) along one of their offshore cold (west Greenland; 59–72°N) distribution limits and compared these to environmental conditions. Cod were sampled via bottom-trawl surveys in late spring/early summer. FMR integrated over ~2-3 months prior to capture and was estimated based on $\delta^{13}C$ values of otolith

aragonite obtained from surface drilling. For the Greenlandic cod, temperature and population had only minor effects; however, the Greenlandic and Icelandic offshore populations showed higher FMR, indicating a higher energy budget compared to the Greenlandic inshore population. Temperature did not constrain the northern distributional margin, as metabolic rates never approached maximum metabolic rate (MMR), even at the lowest temperatures. Instead, spatial variability in FMR corresponded with food availability and quality, suggesting these as primary drivers of distribution. The findings demonstrate that temperature effects are not necessarily a good predictor for cod physiology, distribution and fitness, with other drivers like food intake playing a key role. This challenges assumptions of many bioenergetic growth models, which assume fixed temperature effects on metabolism, which could lead to false growth projections. The temperature sensitivity and spatial variability will shortly be compared to similar studies on other cod populations from the North Sea and Barents Sea.

English

The North Atlantic: Impacts on Climate and Ecosystems (10:50)

Hindcasting and Decoding the North Atlantic Subpolar Gyre Index: Past Variability and Future Climate Implications

Chauhan, Anshul; MacKenzie, Brian[1]; Hátún, Hjálmar[2]

[1]DTU Aqua, Technical University of Denmark, [2]Havstovan - Faroe Marine Research Institute

The North Atlantic Subpolar Gyre (NASPG) is a key driver of ocean circulation and nutrient redistribution, with major implications for marine productivity and ecosystem functioning. By regulating silicate transport, the gyre supports diatom growth, which underpins the structure of the food web and carbon sequestration. Variations in gyre strength and extent cascade through the ecosystem, from plankton to fish, ultimately shaping productivity and fisheries yields. Capturing these dynamics requires reliable indices of gyre variability. However, existing indices are relatively short, beginning only in the satellite era, and thus limit our ability to assess long-term links between gyre dynamics and ecological responses.

This project addresses that gap by hindcasting a multi-decadal SPG index extending back to before the 1990s, when consistent satellite observations first became available. The index reconstruction combines statistical and deep learning approaches. As a baseline, Empirical Orthogonal Function (EOF) analysis coupled with regression is used to extract dominant spatial patterns from recent decades and apply them to historical model data, producing a simple and interpretable reconstruction. To capture non-linear relationships and provide uncertainty estimates, we also implement Quantile Convolutional Neural Networks (QCNNs). These models integrate multiple gridded oceanographic variables, including sea surface height, temperature, salinity, wind stress, and mixed layer depth, while quantile outputs generate confidence intervals for hindcast predictions.

The extended index is then used to investigate long-term variability in the SPG since the 1950s, focusing on key features such as long-term trends, shifts in periodicity, and evidence of regime changes. Finally, we assess how the gyre might respond under future climate scenarios, providing a broader perspective on circulation variability and its ecological consequences. By combining statistical and machine learning methods with extended temporal analyses, this project establishes a robust foundation for understanding the past and future variability of the NASPG.

English

Two-way nesting around the Faroe Islands improves simulated water mass transports over the Iceland-Scotland Ridge

Gierisch, Andrea M. U.[1]; Hansen, Bogi[2]; Larsen, Karin M. H.[2]; Olsen, Steffen M.[1]

[1]Danish Meteorological Institute, [2]Faroe Marine Research Institute

In the region between Iceland and Scotland, the warm water currents towards North and the cold water currents towards South are crossing a submarine ridge. Due to this complex bathymetry it is challenging for large scale ocean models to simulate the water flow realistically. High-resolution models perform better but are computationally more expensive. In this study, we investigate whether refining the model grid locally between Iceland and Scotland can improve the simulation of both the warm Atlantic Water (AW) inflow and the cold deep overflow. The model grid is refined from 10 km to 3 km by using a two-way nest in a regional setup of the NEMO-TOP ocean model. A dye passive tracer is used to clarify the course of cold overflow water masses. Comparing the simulated water transports with in-situ observations

around the Faroe Islands illustrates the benefit of the nest: 1) With the nest, more AW flows over the Iceland-Faroe Ridge and less through the Faroe-Shetland Channel, hence correcting the under-/overestimation seen in the coarse resolution model. 2) Overflow of deep water in the Faroe-Bank-Channel is increased by the nest, such that the bias is reduced to less than 0.1 Sv. Additionally, the dye passive tracer simulation reveals that the nest enables the overflow water masses to sink slightly deeper. These results indicate that the use of a local grid refinement by a two-way nest in a confined region is a promising but cost-efficient approach for improving the simulation of large scale water transports in the Atlantic.

English

A low-salinity top layer in the southern Nordic Seas

Hátún, Hjálmar

Seasonal melting in the Arctic creates a near-surface layer of low-salinity water, each summer and fall. While this freshwater restratification has been thoroughly studied in the Labrador Sea, it has received less attention in the Nordic Seas. This study presents the first assessment of the eastward propagation of this fresh layer, from the Iceland Sea and the Icelandic shelf into the southern Norwegian Sea. High-resolution hydrographic sections provide a detailed vertical and lateral characterization of this layer, and document its seasonal and inter-annual variability. Connectivity between these sections is demonstrated using surface drifters, Lagrangian particle tracking experiments based on a realistic ocean reanalysis product (GLORYS12, 1/12°), and satellite sea-surface salinity data. We quantify volume transport and the fate of this freshwater mass, as well as assess its ecological significance and potential climate implications.

The East Greenland Polar Front as a mediator of climate-ocean-ecosystem variability along Southeast Greenland

Gjelstrup, Caroline; Boye, Jesper[1]; MacKenzie, Brian[1]; Post, Søren[2]; Werner, Karl-Michael[3]; Visser, André[1]; Stedmon, Colin[1]

[1]Technical University of Denmark, National Institute of Aquatic Resources (DTU Aqua), [2]Grønlands Naturinstitut, [3]Thünen Institute of Sea Fisheries

The southeast Greenland region features a confluence of Arctic- and Atlantic origin waters along the continental shelf-break, forming the East Greenland Polar Front (EGPF). Here we examine the role of the EGPF in mediating climate-ocean-ecosystem variability. We observe systematic temporal variability in frontal intensity related to regional Subpolar Gyre dynamics via gyre spin-up. By combining sea surface temperature derived frontal metrics with sea surface height, sea-ice concentration, surface chlorophyll-a concentration, and fisheries survey data, we demonstrate how gyre-induced oceanic variability is reflected in the shelf ecosystem. Elevated chlorophyll-a concentrations along the continental slope correspond to periods when the Subpolar gyre is in a negative phase, the Irminger Gyre is spun-up and the EGPF is strong. In addition to the temporal variability, the EGPF exhibits spatial variability on seasonal and interannual timescales across the wide Ammassalik shelf. As such, the EGPF has migrated 90 km shoreward in tandem with sea-ice retreat since the early 2010's. This migration led to increased chlorophyll-a concentrations over shallow banks and decreased chlorophyll-a concentrations over the outer shelf and slope areas. Our findings underscore the critical role of the EGPF in mediating interactions between the physical and biological components of the southeast Greenland ecosystem.

English

Will ICES Fishery Advice Be Blowing in the Wind? - A Northeast Atlantic Case Study

Cappelli, Costanza[1]; Hátún, Hjálmar; Jacobsen, Jan Arge; Visser, Andre W.; Nielsen, Anders; Berg, Casper W.; A. Ferreira, A. Sofia; MacKenzie, Brian R.

[1]DTU Aqua

Recruitment variability in fish populations poses challenges to the sustainable management of fisheries. Impacts of climatic and ocean processes and humans, including fishing, are complex, often interactive and difficult to quantify. Here we show how a recently detected relationship between climate-ocean variability and recruitment in a large northeast Atlantic fish stock (blue whiting, *Micromesistius poutassou*) could potentially be used to improve short-term forecasts of recruitment. The link involves the effect of wind stress curl on ocean conditions near the main spawning and larval nursery areas and is currently the

only variable identified to have a significant impact on blue whiting recruitment during the 43 years of the ICES assessment. We show using retrospective out-of-sample skill assessment that forecasts using this relationship are more reliable than current ICES working group procedure. We then illustrate for exploratory purposes how inclusion of this link could impact real-world fishery advice, as exemplified by applying it inside the forecasting framework commonly used by ICES fish stock assessment working groups. Identifying such relationships and demonstrating their potential impacts on assessment and forecast products can contribute to improved understanding of stock and fishery dynamics and to the implementation of ecosystem-based, including climate-sensitive, approaches to management.

English

Transport of blue whiting eggs and larvae: Insights from an Agent-Based Model (ABM)

Cappelli, Costanza[1]; Hátún, Hjálmar[2]; Jacobsen, Jan Arge; Visser, Andre; Hansen, Flemming T.; Mortensen, Jonas B.; Rodrigues, Maria Francisca; MacKenzie, Brian[3]

[1]DTU Aqua, Danmarks Tekniske Universitet, [2]Faroe Marine Research Institute (Havstovan), [3]DTU Aqua

Recruitment variability in marine fish populations is strongly influenced by climate-driven oceanographic processes, with important implications for ecosystem productivity and fisheries management. Blue whiting (*Micromesistius poutassou*) is one of the largest commercial fish stocks in the North Atlantic, yet the mechanisms linking climate variability to recruitment remain poorly understood. Previous studies have identified associations between blue whiting recruitment and large-scale atmospheric forcing, particularly wind stress curl (WSC), but the mechanisms behind this correlation remain unclear.
Here, we use an agent-based model (ABM) forced with GLORYS12V1 flow fields to simulate the drift of blue whiting eggs and larvae during the peak spring spawning period. We run simulations for 12 years representing extremes in recruitment (six highest, six lowest), releasing particles from four main spawning areas west of the British Isles that encompass blue whiting major spawning grounds.
Our results show that transport conditions differ markedly among spawning areas and between high and low recruitment years. In particular, we identify two regions where physical transport processes are strongly linked to recruitment success: (1) Porcupine Bank, where larval retention enhances recruitment, and (2) the area west of the Hebrides, where northward dispersal favors successful recruitment. By contrast, other spawning areas show weaker or more variable links between transport patterns and recruitment.
These findings provide mechanistic insight into how regional circulation and climate-driven variability shape recruitment dynamics of blue whiting. They also highlight the importance of considering both retention and dispersal processes in assessing the dynamics of North Atlantic fish stocks under changing climate conditions. More broadly, this study demonstrates how process-based models can be used to bridge physical-biological linkages, contributing to improved understanding of climate-ecosystem interactions and supporting sustainable management of key fisheries in the North Atlantic.

English

Hav og Klima (13:30)

ROPEWALK (Rescuing Old data with People's Efforts: Weather and climate Archives from LogbooK records) – a digitization project for three centuries of weather observations on board of Danish ships

Stendel, Martin[1]; Kronegh, Adam Jon[2]; Haubro Skov, Esben[2]

[1]Danish Meteorological Institute, [2]Rigsarkivet (National Archive of Denmark)

ROPEWALK, funded by the AP Møller Mærsk Fund, is a joint initiative of the Danish National Archive and the Danish Meteorological Institute, which aims at digitizing and transcribing all weather observations in Danish ship journals and logbooks stored in the Danish National Archive, consisting of more than 750 shelf metres beginning as early as the 1680s. With the exception of the Napoleonic wars and subsequent Danish state bankruptcy in 1814, the data is complete.

Ship journals over large parts of the Northern Hemisphere are kept in the archive, with two regions of particular interest, Greenland and the Øresund.

The Greenlandic Trade Company had a monopoly for commerce with the colony of Greenland for nearly 200 years, and foreign ships would not be allowed to call a port. The company conducted these

"Greenland Voyages" to western Greenland several times per year, starting as early as 1721 and through the 1930s. Weather observations from these voyages often include detailed sea ice observations.

Every ship passing the sound or belts in Denmark had to pay for passage between 1426 and 1857. To ensure payment, Danish war ships were placed at strategic locations near Copenhagen, Helsingør and Nyborg. Weather observations on board of these ships go back to the end of the Little Ice Age. In several cases, observations were conducted every time the ship bell was struck, resulting in as many as 48 observations in the course of a single day.

The scanning of the original logbooks and ship journals by the National Archive in highest possible resolution took 13 person-years, resulting in 2.1 million images covering more than 2.5 TB of data. Up to roughly 1750, the data consists of diary-like daily notes in free text. Starting in the 1710s, observations are recorded as numbers in preprinted tables. We have transcribed this latter dataset, constructed a data model, trained a machine learning algorithm and conducted quality control. Free text data will be considered later.

First results will be presented. All transcribed data will be made publicly available and can be used for future research or as input for reanalysis projects.

English

Holstebro og Storåen: 150 års gentagne oversvømmelser og glemsel

Poulsen, Bo[1]; Isager, Lotte

[1]Aalborg University

Selv om Holstebro ligger 30 km fra Vesterhavet og blev grundlagt på sikker afstand af Storåen, har byen oplevet mindst 64 oversvømmelser siden 1870'erne – langt flere end de 10-15 hændelser, der normalt huskes og nævnes i den lokale offentlighed. Denne case illustrerer, hvordan vandløbs- og oversvømmelsesrisiko ofte undervurderes, når hændelser hurtigt forsvinder ud af både den politiske og kollektive hukommelse.
Med afsæt i kommunale arkiver, lokalaviser, tekniske rapporter og fotografier har vi udviklet et severity-index (1–5), som kategoriserer hændelserne fra mindre mark- og kælderoversvømmelser til fuldskala evakuering og store materielle skader, som under katastrofen i 1970.
Med den usædvanligt lange tidsserie kan vi se de gentagne oversvømmelser både som enkeltstående begivenheder og som en længere historisk rytme, hvor mange små hændelser forekommer regelmæssigt.
Som en lang serie af sammenlignelige hændelser, peger vores resultater på to centrale dynamikker:

Maladaptation: Gentagne tekniske løsninger – fra landindvinding og kanalregulering til opførelse af vandkraftværk og ny byudvikling på åncære arealer – har skabt utilsigtede effekter, der forøger fremtidige oversvømmelsesrisici.

Glemsel: Fraværet af vedblivende kollektiv erindringspraksis, hvor oversvømmelser sjældent er blevet brugt som afsæt for læring og varig tilpasning.

Holstebro-casen viser dermed, at sårbarhed ikke alene er et natur- eller klimafænomen, men også et produkt af governance, af politisk kultur og forholdet mellem samfund og vandløb. For nutidens klimatilpasning indebærer dette, at risikohåndtering må forstås i en historisk og social kontekst, hvor både naturens dynamik og den menneskelige hukommelse spiller afgørende roller.

Danish

Sea Level Budgets using over 20 years of GRACE and 30 years of Altimetry data

Ludwigsen, Carsten[1]; Andersen, Ole

[1]DTU Space

Closing the sea level budget requires reconciling GRACE, GRACE-FO, altimetry, and terrestrial/ice mass contributions. Despite progress, inconsistencies

remain (Wang et al., 2022; Barnoud et al., 2022), highlighting uncertainties in Earth's mass dynamics. Building on Ludwigsen et al. (2024), which validated two decades

of GRACE with independent land surface mass estimates, we extend the analysis to the 30-year altimetry record to examine transient and long-term drivers of sea level

change. Our results confirm strong agreement between GRACE and ocean mass reconstructions until 2020. Afterward, reconstructions show larger ocean mass

increases, mainly due to underestimated precipitation over West Africa in ERA5, a bias confirmed by GRACE land mass data. Correcting for this improves model-

observation consistency. Comparative analysis further indicates that discrepancies with steric-corrected altimetry stem largely from ARGO salinity drift and Jason-3

radiometer wet path delay, with smaller contributions from GIA and other biases.

Danish

Marine hedebølger i Danmark - Forekomst og konsekvenser for livet i havet

Andersen, Flora Marence Brix; Mandøe Andreasen, Ditte; Husen, Magnus; Schou Jacobsen, Pernille; R. Payne, Mark; Margrethe Ringgaard, Ida; W. Behrens, Jane

Marine hedebølger, defineret som perioder med usædvanligt høje havtemperaturer, er et stigende globalt fænomen. Dette virksomhedsprojekt, udført med DTU Aqua og i samarbejde med Tænketanken Hav, har til formål at analysere marine hedebølger i Danmark.
Projektet kombinerer forskellige typer af datasæt (fx. data fra målestationer og satellitdata). På baggrund af disse data identificeres marine hedebølger i danske kystnære områder, med fokus på deres hyppighed, varighed og intensitet. Derudover belyses de drivkræfter, der ligger til grund for udviklingen af marine hedebølger i vores farvande.
Et yderligere centralt element i projektet er at undersøge konsekvenserne for marint liv og økosystemer. Fokus er særligt på ålegræs, men også på potentielle effekter for andre habitater og arter, bl.a. forekomsten af invasive arter.
Projektet vil således give et indblik i både de klimatiske drivkræfter bag marine hedebølger og deres betydning for livet i danske farvande – samt hvordan forskningsbaseret viden kan bruges aktivt i forvaltning og kommunikation til offentligheden.

Danish

Klimaforandringers kobling til iltsvind i danske farvande

Kristensen, Erik; Kristensen, Erik

Klimaforandringerne giver et varmere hav i danske farvande. Faktisk er den årlige gennemsnitstemperatur i danske havområder steget med 2°C siden 1980. I samme periode er vi blevet ramt af flere og større iltsvind i de samme havområder trods store reduktioner i kvælstofudledningen. Det er paradoksalt, at arealet med iltsvind har været i stød stigende siden år 2000 på trods af, at kvælstoftilførslen til havområderne siden da har været konstante. Faktisk er der en signifikant korrelation mellem havets bundtemperatur og omfanget af iltsvind. Årsagen er at den højere temperatur giver tidligere og større vækst af alger om foråret og hurtigere iltkrævende bakteriel nedbrydning ved bunden. Desuden vil tilgængeligt kvælstof genbruges flere gange om året nu end tidligere. Dette kan kun afhjælpes ved endnu større reduktion af kvælstofudledningen fra land end den målsætning der i 2024 blev vedtaget for den Grønne Trepart.

Danish

Klimaatlas dykker ned under havoverfladen

Ringgaard, Ida Margrethe[1]; Payne, Mark[1]; Su, Jian[1]

[1]Danmarks Meteorologiske Institut

Dyk ned under havoverfladen og svøm ind i fremtiden med DMI's nye marine udvidelse af Klimaatlas. DMI's Klimaatlas er en autoritativ og ensartet kilde til viden om hvordan klimaforandringerne vil ramme Danmark, og er derved et vigtigt redskab til klimatilpasning. Som en del af DMI's bidrag til UN Ocean Decade suppleres de eksisterende vandstandsrelaterede indikatorer med nye om havmiljøet. I den første udvidelse tager vi temperaturen på fremtidens klima i de danske farvande med bl.a. indikatorer på marine hedebølger. Ud fra højopløste satellitmålinger af havtemperaturen omkring Danmark, kan vi allerede nu se en signifikant stigning i hyppigheden af marine hedebølger. Vores klimafremskrivninger for havet viser, at denne tendens kun vil forstærkes i fremtiden, hvilket kan få store konsekvenser for livet i havet.

Så kom med os under overfladen og udforsk fremtiden med os.

Danish

Øresundssalen

Marin Biodiversitet (9:20)

Marine and Coastal Nature-based Solutions in Europe: Diversity, Gaps, and the Need for Consensus

Flensborg, Louise

Marine and coastal ecosystems are increasingly recognized as priority areas for implementing Nature-based Solutions (NbS) to address biodiversity loss, climate change, and human pressures. However, despite growing policy and management interest in Europe, the concept of NbS in marine environments suffers from fragmented implementation. This systematic review of 113 peer-reviewed articles synthesizes how marine and coastal NbS are applied across Europe, revealing wide variation in definitions, objectives, and monitoring approaches. Such diversity and the lack of standardized assessment frameworks dilute the conceptual strength of NbS, making it difficult to compare outcomes, evaluate effectiveness, and integrate NbS into evidence-based biodiversity management. By mapping current practices and identifying these gaps, the review highlights the urgent need for common standards and science-based guidance. Establishing shared frameworks will help ensure NbS can reliably support biodiversity conservation, ecosystem recovery, and informed decision-making and management interventions.

English

Marine Geodiversity Cinderella

Ernstsen, Verner Brandbyge[1]; Blok, Carlette Neline[1]; Larsen, Isak Ring[1]; Hansen, Lars Øbro[1]; Andersen, Mikkel Skovgaard[1]; Nielsen, Nina Lei Juul[1]; Al-Hamdani, Zyad[1]

[1]GEUS

Nature is composed of both living (biotic) and non-living (abiotic) components, and the diversity of nature (i.e. biodiversity and geodiversity) is essential for the sustainability of society. Schrodt et al. (2019) advocate a holistic approach that recognises the biotic and abiotic components of ecosystems and geosystems as the most effective means to address global environmental challenges. They propose the development and integration of Essential Geodiversity Variables (EGVs) in line with the existing Essential Variables (EVs) on climate, oceans, biodiversity and sustainable development goals.
Geodiversity is "the natural range of geological, geomorphological, soil and hydrological features; and it includes their assemblages, structures, systems and contributions to landscapes". The concept was introduced in the 1990s, and it has evolved and developed on land. However, Kaskela et al. (2017) performed a basin-wide analysis of the Baltic Sea to assess geodiversity measures and patterns based on parameters like richness, patchiness and a geodiversity index, thereby introducing the application of the geodiversity concept in the marine realm.
The geodiversity concept is relevant in relation to e.g. the EU Marine Strategy Framework Directive (MSFD) and the EU Nature Restoration Law (NRL). As examples, seafloor integrity includes both geo- and biodiversity elements, but there is no agreed upon standard on integrated assessments. In nature restoration projects, abiotic features constituting geodiversity (e.g. stone reefs) are constructed in order to increase biodiversity and restore ecosystem functions and services.
We present examples of the application of the geodiversity concept in mapping, classifying and analysing abiotic seabed structures and functions. Our rationale is that comprehensive, accessible and operational data, information and knowledge about seabed geosystem structures, functions and services are a prerequisite for sustainable seabed planning and management.

Danish

Modern methods for assessing marine biodiversity through multi-species foraging patterns

Broadus, Lindsey[1]

[1]Aarhus University

Understanding spatial patterns of marine biodiversity is important for effective conservation and management (Sequeira et al., 2025). We present an innovative methodological framework that leverages GPS tracking data from multiple marine species to infer biodiversity patterns through systematic

analysis of foraging behavior. Our approach combines three key components: (1) GPS telemetry data collection from multiple marine predator species, (2) Hidden Markov Models (HMMs) to identify behavioral states, particularly foraging events, and (3) an interactive R Shiny application for large-scale data visualization and analysis. The HMM framework processes movement trajectories to distinguish between behavioral states (transiting or foraging) based on step lengths and turning angles (demonstrated in Neves et al., 2023). By identifying foraging locations across multiple species, we create spatially explicit maps of foraging intensity that serve as proxies for prey availability and ecosystem productivity. The underlying idea behind this approach is that areas with high multi-species foraging activity indicate higher biodiversity and resource availability. These foraging points can then be used with predictive statistical models to identify detailed environmental influences that make an area attractive in order to pinpoint drivers of biodiversity. Our R Shiny application enables researchers to visualize and analyze these complex, multi-dimensional datasets interactively. Users can filter by species, time periods, and behavioral states, overlay environmental variables, and generate biodiversity hotspot maps. The application handles datasets with millions of GPS locations from dozens of individuals across multiple species, providing real-time visualization and analysis capabilities. This methodology has been successfully applied to assess biodiversity patterns in the Cabo Verde and Azores archipelagos. The method is particularly valuable for identifying temporal changes in biodiversity distribution and discovering previously unknown areas of ecological importance. Our framework offers several advantages: non-invasive biodiversity monitoring, continuous temporal coverage, identification of fine-scale habitat use patterns, and cost-effectiveness for large marine areas. This methodology can support marine spatial planning, conservation area designation, and ecosystem-based management decisions. The open-source tools and reproducible workflow ensure accessibility for researchers and managers working with limited resources.

English

Oceanographic Drivers of Biodiversity in the North Sea–Skagerrak–Kattegat: Cross-Border Management Insights from the Biodiversa+ 'Climate Invasive' Project

Prins, Erik[1]; Kallstrom, Bjorn[2]; Granhag, Lena[3]; Arneborg, Lars[4]; Carlstedt, Linn[4]; Fredriksson, Sam[4]; Brunnabend, Sandra-Esther[4]; Dahlgren, Thomas Gunnar[5]; Glenner, Henrik[6]

[1]Prins Engineering, [2]Göteborgs Marinbiologiska Laboratorium,, [3]Chalmers, [4]SMHI, [5]NORCE, [6]University of Bergen

The Skagerrak region is among the most productive coastal marine areas in Europe, receiving strong nutrient inflows from the Atlantic, the Baltic, and recurrent upwelling. Together with the North Sea and Kattegat, it forms an internationally recognised biological hotspot, notable for its high productivity, biodiversity, and economic importance to fisheries. Yet the ecosystem's functioning is increasingly threatened by fragmented management, climate change and weak protection of marine protected areas (MPAs). A critical knowledge gap remains regarding which physical variables drive species distribution and richness—information essential for effective cross-border management and climate-change preparedness.

Within the Biodiversa+ project *Climate Invasive*, we assessed vertebrate biodiversity in relation to oceanographic variables using comprehensive species records from open European databases. Oceanographic and species data spanning 1983 to the present were combined to develop robust prediction models for 11 seabird species, 28 fish species, and five marine mammal species, as well as scenarios of overall richness and functional groups. Fronts and currents emerged as key drivers shaping richness patterns. Clustering of oceanographic variables with single-species predictions revealed distinct species groups sharing similar traits. For example, salinity thresholds and frontal metrics identified by neural networks enhanced machine-learning predictions of species presence and richness.

Our results demonstrate that the current design and management of MPAs in this region rest on a weak empirical foundation and call for stronger cross-border coordination. We also observed a contraction of species richness in the Kattegat, suggesting that the methods and models presented here can serve as a basis for long-term biodiversity monitoring. Extending this approach to include primary producers and chemical indicators could further deepen understanding of ecosystem processes and improve foresight on climate-change impacts.

English

Understanding past biodiversity using ancient environmental DNA

Holman, Luke Earl[1]; Zampirolo, Giulia[2]; Gopalakrishnan, Shyam[2]; Pedersen, Mikkel Winther; Bohmann, Kristine[2]

[1]University of Copenhagen, [2]Globe Institute, University of Copenhagen

Against the backdrop of the escalating climate and biodiversity crises there is a pressing need to better understand marine ecosystems and the crucial ecosystem services they provide. However, most monitoring programs span only decades, while global human impacts on marine ecosystems have been occurring for centuries or even millennia. Thus, we have limited knowledge of the pre-impacted state of most ecosystems, and most biodiversity baseline data likely represents a snapshot of an already degraded ecosystem. Here we present SeaChange, an ongoing interdisciplinary project that explores the impact of human cultural shifts on biodiversity across thousands of years. Across case studies from the North Sea, North Atlantic and Antarctica the project combines data on human impacts, climatic changes and biodiversity shifts from marine sediments, bones and shells. Here, we present our analyses of biodiversity change across marine sediment records collected from shelf seas across the different case studies. In each example, age-depth models for each core were generated using C14 or Pb210 dating and metabarcoding of environmental DNA extracted from sediments were used to generate temporally constrained biodiversity data. We find that some periods, such as the founding of Iceland, appear to have had limited impacts on marine biodiversity. While others, for example climate change in Antarctica, are already leaving a strong signal of biodiversity change. We discuss what measures of biodiversity can (and cannot) be generated from ancient marine sediments, how our results are important for contextualising modern monitoring or ecosystem restoration programs, and propose that a full understanding of modern biodiversity requires us to look far back into the oceans of the past.

English

WinDNA - eDNA based monitoring of biodiversity at offshore wind farms:

Degn, Karoline; Jacobsen, Lars Magnus Wulff; Nielsen, Einar Eg; Maginni, Sara; Dischereit, Annkathrin

The transition to sustainable energy is central to global efforts to combat climate change, with offshore windfarms expanding rapidly. In the North Sea, political ambitions outlined in the Esbjerg Declaration aim to increase wind power production tenfold by 2050 (WindEurope, 2023). This large-scale expansion raises concerns about biodiversity impacts. Political goals have therefore shifted from “No Net Loss” to “Marine Net Gain”, requiring wind farms to support rather than harm marine ecosystems.

This study, part of the WINDNA project, applies environmental DNA (eDNA) metabarcoding to monitor marine biodiversity around offshore wind farms. The study uses the Horns Rev II wind park located in the North Sea ~30 km off the coast of Jutland as a unique model system. Seawater samples have been collected in 2023 and 2024 along crosscutting transects covering inside and outside the park, across seasons, and during a 48-hour intensive sampling campaign. This design provides high spatial and temporal resolution of marine biodiversity patterns.

The project aims to test three hypotheses: 1) spatial variation in biodiversity around wind-parks is directly determined by environmental features such as sea currents, depth, and scour protection; 2) temporal variation is shaped by seasonal, daily, and diurnal patterns; and 3) the natural reef effect from man-made structures drive successional changes in biodiversity.
The overarching goal is to develop a robust, cost-efficient eDNA-based tool for marine environmental impact assessment. This will help ensure that future wind farms support the transition to sustainable energy while also promoting nature-based solutions and contributing positively to marine biodiversity.

English

Green solutions or green washing – science industrial cooperation in solving future challenges (10:50)

Fra påvirkning til ansvar: Hvordan forskning og erhverv kan samarbejde om at håndtere miljøpåvirkninger i havet

Westergaard, Lene[1]; Agersnap, Sune[1]

[1]Tænketanken Hav

Havet er under massivt pres fra erhvervsaktiviteter som fiskeri, shipping, råstofindvinding, landbrug, akvakultur og offshoreanlæg. Disse aktiviteter bidrager til fysiske forstyrrelser af havbunden, udledning af næringsstoffer og kemikalier, undervandsstøj samt tab af biodiversitet. Samtidig øges presset yderligere af klimaændringer, hvilket svækker havets økosystemers modstandskraft.
På baggrund af Tænketanken Havs analyser præsenteres en ramme for vurdering af havrelaterede risici, som giver virksomheder mulighed for systematisk at identificere deres aftryk på havmiljøet og omsætte viden til handling. Rammen kobler erhvervsaktiviteter med typiske miljøpåvirkninger, sårbare økosystemer og relevante datakilder og kan dermed fungere som et fælles sprog mellem forskning, erhverv og finanssektor.
Præsentationen diskuterer, hvordan forskning kan understøtte virksomheder i at navigere mellem regulatoriske krav (CSRD, CSDDD, ecodesign, Green Claims) og behovet for solid miljødokumentation, uden at armslængdeprincippet kompromitteres. Særligt fremhæves gråzoner, hvor manglende data risikerer at blive brugt til at udskyde handling, samt hvordan forskningsbaseret viden kan anvendes til at sætte reduktionsmål, selv når baseline-data er ufuldstændige (Jouffray et al., 2025).
Pointen er, at miljøpåvirkninger ikke kun er en risiko, men også en driver for innovation. Når virksomheder forstår og reducerer deres aftryk, åbner det muligheder for konkurrencemæssige fordele, adgang til grøn kapital og styrket legitimitet. Samarbejdet mellem forskning og erhverv er derfor afgørende, ikke alene for at mindske pres på havmiljøet, men også for at udvikle fremtidens grønne løsninger på et solidt vidensgrundlag.

Danish

15 års samarbejde mellem forskning og erhverv: Erfaringer fra det pelagiske fiskeri

Sparrevohn, Claus Reedtz, Lise Laustens og Esben Sverdrup [1]

[1]Danmarks Pelagiske Producentorganisation

Traditionelt har fiskerierhvervet haft et ry for at være i opposition til den videnskabelige fiskerirådgivning og forvaltning. For at ændre dette og styrke samspillet mellem fiskeri og forskning, startede Danmarks Pelagiske Producentorganisation (DPPO) for 15 år siden arbejdet med at involvere sig mere i dataindsamling, fiskerirådgivning, uddannelse og videnskabelige projekter. I dette foredrag fortæller DPPO om processen med at involvere os i EU-projekter, have PhD studerende, deltage i ICES arbejde og udvikle forvaltningsplaner. En proces som i 2024 endte ud med, at alle DPPO's fartøjer i Danmark frivilligt installerede CCTV-kameraer ombord. Udover eksempler på, hvordan data og information har bidraget til fiskeriforskningen, vil vi i dette foredrag også beskrive, hvilket tiltag vi har taget for at sikre høj integritet og høj faglighed i slutprodukterne.

Danish

To Be or Not to Be – Clarifying Marine and Coastal Nature-Based Solutions (NbS)

David Lusseau, Christian Riisager-Simonsen, Jens Kjerulf Petersen, Louise Catharina Flensborg

DTU Aqua

Nature-based Solutions (NbS have gained prominence in EU policy frameworks over the past decade. Yet, conceptual ambiguity—particularly in marine and coastal contexts—poses risks of greenwashing and undermines effective implementation. These environments are characterized by dynamic ecosystems and complex governance structures, making it challenging to define, evaluate, and operationalize NbS. To address this, the Horizon Europe project TRANSEATION explored the potential for developing intuitive criteria to distinguish NbS from related concepts. Through a multi-method approach—including stakeholder dialogues, policy mapping, scientific literature review, industry standard analysis, and open online consultations—the project identified key gaps and opportunities for conceptual alignment.
This presentation shares the project's core findings and proposes a set of criteria aimed at enhancing clarity, fostering stakeholder consensus, and supporting robust integration of NbS into EU marine and coastal policy landscapes.

Nyt om forskningsprogrammer, -finansiering og -infrastruktur (13:30)

Options for funding through the Danish Center for Marine Research

Christian Riisager-Simonsen, Colin Stedmon

The Danish Centre for Marine Research (DCH) aims to strengthen and stimulate Danish marine research across all marine research institutions in Denmark. This is done by being a formal focal point for Danish marine research in formal matters, and primarily by administering funds for chartering research vessels. In this presentation, the DCH secretariat will present opportunities for financing, borrowing equipment and more.

News from the funding landscape

Christian Riisager-Simonsen, H. Cecilie Petersen

The funding landscape which the DK marine research community depends on evolves. In this presentation we will try to outline present opportunities and outline key trends in the coming years, with particular focus on the EU landscape. Where possible guests will be invited to share detailed insights into the programmes they follow to raise the collective Danish awareness of the opportunities, and options for synergies.

Advancement of marine research infrastructure in Denmark, Greenland and the Faroe Islands

Friedrich Wilhelm Koester[1], Helle Siegstad[2] & Leon Smith[3]

[1]DTU Aqua

[2]Greenland Institute of Natural Resources

[3]Faroe Marine Research Institute

The Kingdom of Denmark has made substantial steps to renew its ocean and arctic going research fleet, consisting of Jakup Sverri a 54m vessel build in 2020, Tarajoq a 61m vessel build in 2021, Dana V a 70m vessel replacing Dana IV in 2027.
Jákup Sverri and Tarajoq are the largest and Dana V one of the largest investments in research to date by the Government of the Faroe Islands, the Government of Greenland and the Government of Denmark, respectively. The aim in all cases is to increase the overall understanding of how life in the sea and the marine and climatic environment interact and how marine resources can be protected and managed sustainably.
The talk will describe the capabilities and operations of these vessels, e.g. their operational areas, scientific tasks and their research equipment, deployment of independent observation systems such as surface and subsurface drones, buoys and anchored systems and how they complement each other.
There are periods, when the research vessels are not in operation and increased cooperation across the research community of all parts of the Kingdom of Denmark would intensify their use for the benefit of science, innovation, education and marine/maritime services.
It is hoped that the overview on the research vessel capabilities in combination with upcoming research opportunities presented in the session and the conference can intensify utilization and scientific output of conducted research level based activities on national and international level. This would help make their operations financially more effective but also enable intensifying inter- and multidisciplinary research in various marine and maritime fields for which these vessels are designed.
Apart from overviews given by the respective responsible institutions, possibilities for Q&A and raising suggestions for project establishment benefitting from the availability of this state-of-the-art infrastructures, upcoming new research programs and their funding as well as other complementing research infrastructure will hopefully be generated, also in follow-up of the conference.

English

BlueActionBANOS: Community-Led Actions and Transition Agendas for Mission Ocean & Waters

Petersen, Cecilie[1]

[1]University of Southern Denmark, SDU

BlueActionBANOS project supports the implementation of the EU Mission “Restore our Ocean and Waters” by supporting and mobilising communities across the Baltic and North Sea (BANOS) region. The project supports Mission Ocean & Waters objectives to protect and restore ecosystems, eliminate pollution, and enable a sustainable blue economy through regionally tailored, participatory approaches. The project

aim is to fund and support this through community-led actions and development of transition agendas. The project will fund and guide 20 transition agendas: strategic roadmaps that bring together innovation, management, and practice to identify pathways for addressing local challenges and ambitions within the objectives. These co-created stretegies provide actionable directions, ensuring that the Mission's objectives are translated into local and regionally relevant solutions and measurable impacts.
In addition funding and launch of several community-led actions will act as the driver of local transformation and implementation. Through implementation of innovative and sustainable solutions and building of communities of practice and engaging stakeholders at all levels, the goal is to create inclusive spaces for dialogue, co-design, and experimentation. These processes ensure that solutions are not only evidence-based but also socially legitimate and anchored in local and regional realities.
By strengthening collaboration across stakeholders, BlueActionBANOS demonstrates how Mission Ocean & Waters can act as a catalyst for systemic change. The project showcases the added value of aligning national, regional, and EU-level efforts, while empowering local actors to shape and own the transition.

English

The Danish Mission Ocean Hub: Connecting Stakeholders and Driving Synergies for Mission Ocean & Waters

Petersen, Cecilie[1]

[1]University of Southern Denmark, SDU

The Danish Mission Ocean Hub is a national initiative designed to strengthen Denmark's contribution to the EU Mission "Restore our Ocean and Waters". Hosted by the Danish Ministry of Higher Education and Science and facilitated by SDU, DTU Aqua, and the Southern Denmark EU Office, the Hub serves as a cross-sectoral platform for mobilising Danish stakeholders and aligning efforts with the Mission's objectives.
The Hub's structure is built around regular webinars and newsletters, which provide inspiration, share knowledge from national and international conferences, highlight funding opportunities, and showcase examples of good practice. By systematically communicating updates, success stories, and calls for collaboration, the Hub fosters synergies across sectors, enabling Danish actors to connect, learn, and co-develop solutions.
Participation in the Hub is deliberately broad and inclusive. It brings together research and innovation institutions, ministries, agencies, municipalities, SMEs, industry, and civil society communities, ensuring that Mission activities are grounded in diverse perspectives and practical needs. In doing so, the Hub strengthens Denmark's role as both a contributor to and beneficiary of Europe's mission-driven approach to restoring ocean and water health.
A key milestone for the Hub was the Conference on Mission Ocean & Waters during the Danish Presidency of the Council of the EU. The conference provided a unique platform for national and European actors to exchange knowledge, showcase achievements, and shape collective priorities for the implementation of the Misson Ocean & Waters. The Hub builds on this momentum, aim to reinforce Denmark's leadership in connecting stakeholders, driving innovation, and embedding mission-oriented approaches into national and regional strategies.

English

C13

Benthic fauna communities (10:50)

Four decades of macrozoobenthos trends in the Danish Wadden Sea

Greve, Annika[1]

[1]Aarhus University, Dept. of Ecoscience –

Tidal flats provide important ecosystem services and support high benthic biodiversity. The Wadden Sea, a UNESCO World Heritage site and one of the world's largest tidal flat ecosystems, is worming twice as fast as the global average (Buschbaum et al., 2024). Yet, the impacts of worming on benthic biodiversity and community structure remain largely unknown.

In the Danish part of the Wadden Sea, benthic fauna has been monitored since 1980, but the long-term data have never been analysed in detail. In this study, we used 44 years of the NOVANA monitoring data to identify long-term trends and evaluates whether community-wide shifts in the benthic fauna are linked

to environmental change. Using 6 sites, quantified changes in benthic biomass, density, species richness, and community composition across the Danish Wadden Sea. We related the related the findings from the Dutch Wadden Sea, where long-term monitoring effects have shown changes in species richness and biomass associated with climate warming, eutrophication dynamics, and predator-prey interactions (Beukema & Dekker, 2020).

Our data provides the first comprehensive analysis of long-term trends in Danish macrozoobenthos. The results will help to clarify how climate change and sea level rise is driving benthic community changes, and the associated consequences for ecosystem functioning and the food-web dynamics.

Danish

Spatial and Temporal Patterns of Benthic Infauna Development in the Restored Gyldensteen Coastal Lagoon

Ahlmann, Katrine[1]; Kiilerich, Karoline; Quintana, Cintia; Kristensen, Erik; Flindt, Mogens

[1]Syddansk Universitet

Benthic invertebrate communities in Danish coastal waters are vital for ecosystem functioning, serving as a food source for fish and birds, and supporting biogeochemical cycling. Managed realignment (MR) is increasingly applied to restore coastal ecosystems, yet the long-term development of benthic communities in former agricultural land within lagoonal settings remains poorly understood. In 2014, sea dikes were breached at Gyldensteen Coastal Lagoon, offering a rare opportunity to investigate the spatial and temporal dynamics of infaunal communities following restoration.

This study combines 10 years of monitoring with high-resolution temporal and spatial surveys. Sediment grab samples were collected annually from 6-30 stations between 2014 and 2023. Species richness, diversity, and community composition were analyzed in relation to sediment conditions and water exchange.

Results reveal substantial interannual fluctuations in species diversity, with early colonization dominated by opportunistic species such as *Hediste diversicolor* and *Capitella* sp. Species richness and Shannon-Wiener indices fluctuated without a consistent long-term trend. Abundances of key taxa varied spatially, and species interactions shaped the community structure. NMDS analyses indicate a clear east-west differentiation, followed by convergence of community composition by 2023. Sediment conditions and water exchange frequency influenced local patterns of diversity.

These findings highlight the role of environmental heterogeneity and stress in shaping the successional trajectories of benthic infauna and the persistence of pioneer species. Long-term monitoring proved essential for capturing temporal and spatial dynamics in community composition. By relating patterns of species dominance and diversity to sediment conditions and water exchange, the study provides insights into the processes driving benthic succession and ecosystem functioning in MR locations, offering valuable guidance for adaptive management of restored coastal habitats.

English

What are we restoring to? A past and present perspective on seabed health

Lauridsen, Bodil Wesenberg

The sedimentary seabed holds crucial information for understanding the state of our ocean environment. Our study builds on the essential premise that marine restoration requires a baseline for evaluating seabed health. To constrain the environmental impact caused by human activities we apply multiple parameters measured through marine sediment cores, providing us with a past to present timeline perspective (e.g. last 10.000 years). By combining biological, geological, geochemical and geophysical data we can establish seabed conditions prior to human activities such as trawl fishing, hydrocarbon production, mineral extraction and major offshore constructions.
Implicit in developing an anthropogenic baseline is the need for investigating natural factors that can influence the environment. A specific quest linked with platform abandonment has been to identify passageways of recent and historic methane gas leakage and distinguishing between natural and production-related gas release (Lauridsen et al. submitted).
Characterization of shell-forming benthic organisms; foraminifera and bivalves, combined with organic and inorganic geochemistry and microbial DNA signatures provide the key markers by which we compare past-to-present seabed environments. For generating a time-line chronology we C^{14} dating

techniques. Based on this multidisciplinary toolbox we can provide a holistic context for understanding anthropogenic seabed impacts, for example related to physical disturbances (e.g. trawling, infrastructure), pollutant fluxes (e.g. nutrient, metals) and preservation of organic matter (*Blue Carbon)* that implicates the national CO_2 budget. Our anthropogenic baseline approach and tools for defining seabed health may be applied regionally or for local areas, depending on data availability and the needs required by industry, agencies and policymakers.

English

Commercial eDNA analysis enables opportunities for applied benthic community monitoring

Brodnicke, Ole; Szekely, Dora[1]; Mortensen, Lars[1]; Dannisoee, Jesper[1]; Povidisa-Delefosse, Katrina[2]

Benthic invertebrate communities are central to marine ecosystem functioning, providing food for higher trophic levels and driving sedimentary biogeochemical processes. Monitoring their biodiversity is therefore crucial, but traditional sampling methods are spatially restricted and resource intensive. In recent years, environmental DNA (eDNA) has become increasingly commercially available as a monitoring tool, offering rapid, cost-effective, and non-invasive biodiversity assessments. This study evaluates the performance of eDNA compared to conventional morphological methods for benthic community monitoring around the Dan F platform in the North Sea.

Across seven stations, a total of 203 taxa were detected by combining sediment eDNA, bulk eDNA, and bulk morphological identification. Sediment eDNA revealed the highest richness, detecting 113 taxa, including 56 unique to this method. Bulk eDNA identified the least (87), while bulk morphological detected 103 taxa. Polychaetes dominated across methods, followed by molluscs and arthropods. The platform reference stations yielded the highest species counts. At all but one station, sediment eDNA outperformed the other methods in terms of richness.

Despite overall high detection rates, overlap among methods was low: only 5.4% of taxa were consistently observed across all three. Sediment eDNA was particularly effective in capturing widespread taxa, with 41 species recorded at three or more stations compared to 27 using morphology. The eDNA methods are evaluated to be more cost effective than morphological methods in commercial context. Finally, the methods are contrasted using the newly developed Biodiversity State Indicator. A small number of taxa detected via eDNA were unlikely residents of the North Sea, underlining the need for cautious interpretation.

Community composition analyses indicated that sediment eDNA and morphology produced relatively consistent assemblages, whereas bulk eDNA exhibited high inter-method variation. Importantly, each method revealed distinct species subsets, demonstrating their complementarity.
Overall, sediment eDNA provided the highest species richness and best efficiency in terms of taxa detected per sampling effort. Our findings demonstrate the strong potential of eDNA—now increasingly available to practitioners—as a powerful tool in routine benthic monitoring. Combining eDNA with traditional morphology offers the most comprehensive biodiversity assessment, strengthening ecosystem evaluations in Danish marine waters.

English

Toxic Metal Enrichment in Sediments and Benthic Flatfish Around Offshore Oil Installations

Bonciani, Neri[1]; Lauridsen, Bodil[2]; Jakobsen, Rasmus[2]; Sloth, Jens[3]; Feilberg, Karen[1]

[1]DTU Offshore, [2]GEUS, [3]DTU Food

Offshore oilfields in the North Sea remain significant energy assets, but the large discharges of produced water (PW) and drilling mud/cuttings continue to pose environmental concerns. These effluents, often saline and enriched with production chemicals, vary widely in their content of metals and particulates. Due to their density and release depth, PW plumes are generally expected to sink towards the seafloor, where they can alter the geochemical composition of surrounding sediments.
Offshore discharges contain both dissolved and suspended metal(loid)s, making benthic organisms particularly relevant bioindicators for assessing ecological impacts near offshore platforms. Flatfish, such as L. limanda, are of particular interest because they are demersal species living close to the seabed, occur frequently around installations, and represent a common food source in Denmark.
During a fish survey in July 2023, initially planned for cod tagging and distribution studies, dab samples collected near one Danish platform provided an opportunity to evaluate metal exposure. Muscle tissue

from fish caught within 50 m of the installation was analyzed for a range of toxic elements, including B, Ni, Cu, Zn, As, Cd, Sn, Sb, Ba, Hg, and Tl. Complementary superficial sediment studies were conducted around two platforms and at control sites using sediment cores. ICP-MS and a sequential extraction enabled the analysis of 24 elements and their mobility.
Results indicated hyperpigmentation of many fish individuals and arsenic contamination in 92% of muscle tissues (> 5 mg/kg). Clear geochemical differences were found between sediments near platforms and those from distant or stratigraphically older deposits. Notably, close to platform As could be released at up to 1.6 µg/m2 of sediment, and it correlated with P and Cu in the sulfides/organic matter sediment fraction. Anomalies of Br, Ba, Ni, and Zn were also observed in platform-proximal sediments. Sediment quality indices confirmed considerable enrichment and geo-accumulation of toxic metals, particularly at one site with continuous PW discharge, underscoring localized impacts of offshore petroleum activity.

English

The pelagic ecosystem: Environmental drivers and structuring processes shaping spatial and temporal dynamics across scales (13:30)

Ciliatplanktonets termodynamik - betydning af ernæringsform og artsrigdom

HansenJørgen L.S.

Aarhus Universitet, Ecoscience,

Sammensætningen af planktonsamfund anvendes som indikator for vandmiljøets tilstand. Det encellede plankton har korte generationstider og skulle derfor hurtigt kunne tilpasse sig det omgivende miljø. Men hvor hurtigt ændrer artssammensætningen sig og hvad styrer denne ændring? og er et encellet planktonsamfund i ligevægt med det omgivende miljø. Disse spørgsmål blev undersøgt i et sæsonstudie af artsturnover i ciliatplanktonet i Roskilde Fjord. Prøverne blev indsamlet dagligt/hver anden dag i løbet af en periode på 15 måneder og artssammensætningen blev bestemt vha. automatiserede FlowCam analyser med efterfølgende krydsvalidering mod 18S rDNA-sekvenser og taxonomisk litteratur. Vi identificerede 27 fænotyper og 8 genotyper af mixo- og heterotrofe ciliater som viste meget tydelige sæsonvariationer i tæthed, biomasse, diversitet og artsturnover afhængigt af ciliaternes ernæringsform. De mixotrofe ciliater øgedes 30 gange fra vinter til sommer mens de heterotofe ciliater kun øgedes 5 gange. For diversiteten i var det omvendt: Her steg antallet af heterotrofe ciliater fra 5 arter i en 10 ml prøve vinteren til 10.5 om sommeren mens de mixotrofe ciliaters artsrigdom var konstant hen over året på ca. 3 arter pr 10 ml. prøve. Vi anvendte "decay of similarity" som proxy for den momentane artsturnover og fandt at similariteten i sammensætningen af heterotrofe ciliater ændrede sig med en rate hhv. 3.1, 15.8 and 30.6 % pr. dag om vinteren, foråret og summer. Disse rater var signifikant relateret til gennemsnitlige vandtemperaturer på 4.8, 8.4 and 16 °C i de tre sæsoner. De mixotrofe ciliaters artsturnover var også temperaturafhængig men var ca. den halve af raten for de heterotrofe ciliater. Det kan forklares med at oscillerende rovdyr-byttedyr interaktioner spiller en større rolle for de obligat heterotrofe ciliater. Temperaturafhængigheden af artsturnoveren i ciliatplanktonet kan ses som en analogi til "Q10" der beskriver den eksponentielle rate forøgelse af biologiske og biokemiske processer ved en temperaturændring på 10 grader.

Danish

Determining the influence of marine heatwaves on phytoplankton productivity in Danish coastal waters

Hemraj, Ashley Deevesh; Jacobsen, Hans[1]

[1]Aarhus University

Marine heatwaves (MHW) are increasing in frequency and intensity globally. Their impact on ecosystems is driven by the thermal anomalies that exert a pressure on ecosystem processes and organismal physiology. Interestingly, little is know on the impact of MHWs on biogeochemical interactions driving primary productivity in the water column. While is it know that MHWs can shift phytoplankton biomass and community dynamics, such shifts are generally primarily driven by the biochemistry within the water column, such as nutrient availability. This is especially important in Denmark where nutrient load in coastal waters are excessive. Here, we modelled the MHW parameters around Denmark over the last 30 years. We then look into how thermal anomalies force confounding interactions between other environmental parameters, driving phytolankton community shifts and anomalies in phytoplakton biomass. Therefore, we shed some light on the impacts of MHWs on primary productivity in coastal waters in Denmark.

English

Development in the Danish NOVANA phytoplankton

Jakobsen, Hans

Since 2022, AU has been working on revising and consolidating NOVANA plankton data. I will present parts of the analyses of the phytoplankton and its implications, including the temporal development in both time and space, as well as selected examples from specific stations.
In 2024, we observed patterns in the phytoplankton dynamics that deviated from our previous understanding of pelagic dynamics in fjords and coastal areas. There are increasing chlorophyll levels, lower primary production (PP) than usual, and no clear spring bloom in the phytoplankton carbon biomass. At the same time, we saw an increase in light attenuation (Kd).
One possible interpretation is that PP does not reach its maximum potential because the increased light attenuation limits growth. Temperatures are rising as expected, which increases grazing pressure—primarily from ciliates, which isnot linked to light but follow temperature. The biomass of ciliates appears to be close to normal in 2024.
This could mean that the food for meroplankton (mussel larvae, etc.) is insufficient to support their biomass development. Copepods have their optimal egg production during the spring bloom—provided there is enough food available. If phytoplankton is absent in the spring months, it may prevent zooplankton from developing properly and result in the summer biomass of copepods not being built up. As a result, phytoplankton escapes grazing control and can produce unusually large biomass in June

English

Spatiotemporal and environmental impacts on the winter distribution of key native and invasive gelatinous zooplankton species in the North Sea

Gibbs-Brown, Troy

Projected increase of North Sea surface temperatures is expected to alter the spatial and temporal distribution of gelatinous zooplankton, which predate on fish larvae and mesozooplankton. The North Sea is an economically important fishing ground, and expanded jellyfish ranges pose a threat to commercially relevant fish populations and overall ecosystem functioning. The native *Cyanea capillata* and *C. lamarckii* (presented here as *Cyanea spp.)* and invasive *Mnemiopsis leidyi* occur frequently in coastal North Sea waters. However, it remains unknown how their populations respond to current and future warming during winter months. Here, we use recent bottom trawl survey data from the Danish IBTS from 2020-2025 to investigate the distribution of the two species in response to the spatiotemporal structure and environmental conditions. Three SDMs were constructed to predict species-specific probability of presence in response to the spatial and temporal structures (Model 1), environmental conditions (temperature, salinity, and oxygen) (Model 2), and the shared variation between the two separate models (Model 3). Model 1 attributed 85.1% of the variability to spatiotemporal effects, identifying the highest probability of presence for both species along the Danish west coast. The probability of *Cyanea spp.* presence decreased across the study period while that of *M. leidyi* increased. Probabilities for both species began to increase earlier into the year over time. Model 2 attributed 39.2% of the variability to environmental variables, indicating positive relationships with bottom oxygen and negative relationships with surface salinity for both species. Surface temperature influenced the species' relationships with salinity and oxygen, as warmer temperatures were associated with higher probabilities of presence. General analysis of Model 3 revealed that *Cyanea spp.* variability was more accurately captured by the spatiotemporal patterns in Model 1, while that of *M. leidyi* was better represented by the environmental interactions in Model 2. Model 1 accurately predicted 97.2% of the observations across both species, compared to Model 2 at 85.6%. These predictive models can serve as templates for understanding how *Cyanea spp.* and *M. leidyi* distributions may change under different climatic conditions, useful for the management of fisheries and the identification of areas suitable for bloom events.

English

Tobislarver i Nordsøen: artsfordeling, udbredelse og størrelse

Hindholm, Margit[1]

[1]Danmarks Pelagiske Producent Organisation

Tobislarver i Nordsøen: artsfordeling, udbredelse og størrelse.
(Margit Ravn Hindholm, Claus Reedtz Sparrevohn, Ole Henriksen, Dorte Bekkevold) (DTU Aqua)
(Danmarks Pelagiske Producent Organisation)
Tobis (Ammodytidae) er en vigtig fisk i Nordsøens økosystem, som føde for både fisk, fugle og

havpattedyr og en vigtig kommerciel art i det pelagiske fiskeri. Der findes flere arter af tobis i Nordsøen - blandt andet havtobis (A. marinus), der gyder om vinteren, samt kysttobis (A. tobianus), der gyder om foråret. En bedre forståelse af forekomsten og artsfordelingen af tobislarver i Nordsøen kan bidrage til mere præcise bestandsvurderinger og bæredygtig forvaltning af de voksne bestande, da larverne kan give information om rekrutteringsmønstre og betydningen af de voksne fisks gydetidspunkt og -områder. I dette studie undersøges tobislarver indsamlet i Nordsøen fra et område, hvor der normalt ikke er set store koncentrationer af larver. Dette dataset giver et spændende grundlag for at undersøge, hvilke arter larverne tilhører, deres udbredelse og størrelsesfordeling i området. Artsbestemmelse af tobis larver kan være visuelt udfordrende, da de tidlige udviklingsstadier ligner hinanden meget morfologisk. For sikker artsbestemmelse af larverne anvendes derfor DNA-baseret identifikation. Kombineret med længdemålinger, rumlig fordeling og sammenligning med historiske data kan dette give et bedre indblik i larvernes sammensætning og dynamik i Nordsøen.

Danish

Explaining variability in veined squid (Loligo forbesii) distribution at the Faroe Islands

Bach, Nathalie Rosenberg[1]; Homrum, Eydna Í.[2]; Gaard, Eilif[2]; Neuheimer, Anna[1]

[1]Aarhus University, [2]Havstovan - Faroe Marine Research Institute

Squids are fundamental ecological players in many pelagic ecosystems, playing roles as predators and prey, and, increasingly, as the target species of fisheries. Squid distribution will vary in time, the result of biological factors interacting with the environment. Distribution changes of squid will impact both trophic interactions and fisheries management. In this study, we develop a species distribution model to explain variability in distribution for the veined squid (*Loligo forbesii*) around the Faroe Islands. The study uses data from bottom trawl surveys from 1994 to 2023 to develop the first temporal and spatial distribution model for this species at its northernmost range. The model is used to explain distribution over space and time, and link probability of presence to the environment and squid's life cycle. The results indicate a hotspot in probability of squid presence at the Faroe Bank, followed by the Faroe Plateau, along with a peak in probability of presence in 2013 in all areas. We link model patterns to temperature, depth and day of year: predicted presence increases with temperature, decreases with bottom depth and follows seasonal patterns consistent with our current understanding of *L. forbesii* spawning period. We discuss our results with respect to squid ecology, the hydrography of the area as well as prediction of future presence and possible range shifts.

English

Postere

Tirsdag d. 20-1 Postersession I

C13 – Poster I: 1-30

Marine birds in Danish waters

P1: 1 Long-term Great Cormorant (Phalacrocorax carbo) diet data as a tool for understanding fish–bird interactions in Danish coastal ecosystems (1980–2024)

Fleet, Frederick

Many marine and coastal species of birds depend on fish and information on their diet may be used to understand the state of local ecosystems. At Aarhus University we have compiled a unique dataset covering 1980–2024, documenting the diet of Great Cormorants (*Phalacrocorax carbo*). The data are based on regurgitated pellets collected at colonies across Denmark, mainly during the breeding season (April–June). This long-term dataset makes it possible to study predator–prey relationships in coastal

waters.
Case studies from the colonies at Vorsø in Horsens Fjord and Melsig in Limfjorden illustrate: (i) temporal change in diet composition over four decades; (ii) spatial contrasts between North Sea and Kattegat/Baltic coastal habitats; and (iii) derivation of prey size and biomass from bony remains (otoliths and skeletal elements) using species-specific regressions.
Methodological limitations were determined from the ongoing work. Digestive erosion affects which fish remains are recovered, resulting in conservative (minimum) estimates of prey size and mass and under-representation of small or fragile taxa. Consequently, biomass reconstructions can be skewed by the overabundance of durable remains.
Even with these limitations, pellet-based diet studies are highly valuable. They can: (a) serve as indicators of local coastal fish status in the vicinity of breeding colonies; (b) refine estimates of avian predation pressure; (c) reveal potential patterns of regional prey depletion; (d) infer prey preferences conditioned by accessibility; and (e) when combined with colony counts and chick survival, provide an integrated view of how local cormorants and fish populations are performing.
By connecting seabird diet with fish community data over more than 40 years, this study demonstrates how long-term monitoring can inform our understanding of marine biodiversity and food-web dynamics.

P1: 2 The importance of ping-rate in estimation of the gillnet fisheries? What are the technical requirements and why is it so important to get them right.

Stounberg, Jonathan[1]

[1]DTU-Aqua

Knowing where a fishery is taking place and being able to quantify the effort of the fishery is key in estimating bycatch of protected species. However, getting this information is no easy task. Currently DTU-Aqua is co-developing a new approach to detect fishing operations and the effort by using highly spatially resolved positions, that promises greater understanding of the fishery. However, to achieve this an improvement of the spatial data coverage of the Danish small-scale fleet is needed. A new EU implementation [1] is stating that all vessels should have collection of positions data, with a ping rate of at least 30 minutes, however this resolution is far from sufficient.
A method, using machine learning modeling to detect where hauling is taking place, and geo-computation to determine when the net was set, shows promise to increase the accuracy of the special distribution, of the fishery, from roughly 62 to 93 percent. Along with this much higher precision on where they fish, comes a better chance to determine how long the individual nets are and how long they have been fishing. This method is, however, verry reliant on the resolution of the spatial data, one setting event can be as short as 5 minutes, which is impossible to detect with a ping rate every 30 minutes. Figure 1 shows how decreasing the ping rate dramatically decreases the accuracy of fishing detection. Now that all boats likely will be equipped with tracking systems, this underlines the importance of seizing the opportunity to get the data in a sufficient resolution to make these estimates properly. Not for control purposes, but just for having the most basic understanding of the fishery.

Sensing the Sea – Advancing Marine Monitoring

P1: 3 A Novel Photosynthesis Index for Enhanced Monitoring of Marine Ecosystems

Prins, Erik

[1]Prins Engineering

Marine biodiversity, particularly submerged aquatic vegetation (SAV) such as seagrass, has become a priority on the international biodiversity agenda and is now recognized as an Essential Biodiversity Variable (EBV). Satellite Remote Sensing (SRS) provides powerful tools for assessing SAV; however, phytoplankton communities, dissolved and suspended matter, and water-column effects continue to complicate marine remote sensing. At present, no mid-resolution multispectral index reliably isolates photosynthetic components in the marine environment—especially in inshore waters.

We present a novel Marine Photosynthesis Index (MPI), specifically designed to penetrate deep into the water column while capturing high variability in photosynthetic activity. MPI leverages visible-spectrum bands (450–620 nm) optimized for macrophyte mapping and demonstrates strong sensitivity to photosynthetic activity across a range of marine organisms—including prokaryotes at the base of the marine food web. Tested under estuarine and offshore conditions in Denmark and Sweden using radiometrically, sun-glint, and atmospherically corrected mid-resolution SRS data, MPI significantly outperforms traditional indices for SAV mapping.

In addition, MPI differentiates photosynthetic activity between algal and plant SAV and responds strongly to substrate variation on both soft and hard bottoms. It also detects early stages of photosynthetic activity, including downwelling and upwelling events observed in the Skagerrak and the Red Sea. MPI's robust performance—deep-water penetration, sensitivity to diverse photosynthetic organisms, and resistance to noise, phenology, and seasonal variability—is further enhanced by multitemporal analysis. For example, high MPI responses in spring were linked to areas that later experienced eutrophication and oxygen depletion.

Developed within the EU Biodiversa+ *Climate Invasive* project, MPI has already been used to produce a habitat map of Limfjorden identifying areas at risk of alien species invasion. First presented at the European Space Agency's BioSpace25 conference and highlighted in the EU mid-term evaluation, MPI demonstrated ~85% agreement with Danish NOVANA eelgrass data for the entire Limfjorden. These capabilities make MPI a promising SRS index for continuous monitoring and habitat mapping in coastal marine ecosystems, filling a critical gap in effective ecosystem assessment.

P1: 4 Autonom iltsvindsovervågning syd for Lillebælt

Toftegård, Bodil[1]; Stedmon, Colin[1]

[1]DTU Aqua

I samarbejde med Styrelsen for Grøn Areal Omlægning og Havmiljø har DTU Aqua testet muligheden for at anvende en ARGO-bøje som forankret målestation. ARGO-bøjer er normalt fritflydende og profilerer vandsøjlen ned til 2000 m ca. hver tiende dag, hvorefter data sendes til de internationale ARGO-datacentre. Fordelen ved at bruge en sådan bøje frem for traditionelle forankrede sensorer er, at den leverer målinger gennem hele vandsøjlen og sender data i realtid – særligt værdifuldt i lagdelte farvande som de danske.

I april 2025 blev en bøje forankret syd for Lillebælt med det dobbelte formål at teste forankringskonceptet og overvåge hele iltsvindssæsonen. Testen viste, at forankringen fungerede efter hensigten uden at påvirke bøjen negativt. Ved udsættelsen, blev der fortaget en skibs-CTD profil, til at validere bøjens sensorer. Desuden er det en stor fordel at ilt sensoren på bøjen ofte kan lave målinger i luften, da der derved at korrigeres for off-set og drift i sensoren over tid. De indsamlede data giver en bedre indsigt i et dynamisk bundmiljø gennem iltsvindssæsonen, hvor saltindhold, temperatur og ilt kan variere markant over få timer og dage.

P1_ 6 Advancing Benthic Biodiversity Assessments with Multi-Camera 3D Underwater Reconstructions

Alonso Fernández, Javier; Francis Thompson, Fletcher

This project presents an advanced workflow for the ecological analysis of shallow-water benthic environments using high-resolution three-dimensional (3D) reconstructions. An optimized four-camera configuration [1], combined with Ultra-Short Baseline (USBL) positioning and depth sensors mounted on a Remotely Operated Vehicle (ROV) (Figure 1a), enables efficient data acquisition [1]. After dedicated preprocessing, including filter applications, keyframe selection and extraction; and enhanced postprocessing steps such as orientation refinement, the data were used to generate georeferenced 3D models (Figure 1b) with sub-millimeter precision and scale (Figure 2a showing a validation example: measurement of a beer bottle on the seafloor (real length 23 cm); and 2b with a sea anemone vertical profile with sub-milimeter precision).

Standard outputs such as 3D tiles, orthophotos, and Digital Elevation Models (DEMs) (Figure 3a) were analyzed in visualization platforms to extract Essential Biodiversity Variables (EBVs). The results highlight the advantages of 3D over traditional 2D mapping, as 3D models provide richer spatial information and multiple perspectives (Figure 2b). When coupled with Machine Learning techniques, this additional dimensionality enables improved detection of benthic features and reduces misclassification errors, while also supporting automated habitat classification and biodiversity assessment (Figure 3b). Together, these advances will allow for scalable and repeatable monitoring strategies in benthic ecosystems [2].

Marine Biogeochemistry

P1: 7 Drivers and patterns of sediment organic carbon in European regional seas

Lønborg, Christian; Løvgren Graversen, Anna Elizabeth[1]; Maria Addamo, Anna[2]; Assis, Jorge[3]; Timothy Burrows, Michael[4]; Stewart, Eleanor[5]; Lillis, Helen; John Costello, Mark[2]; Krause-Jensen, Dorte[1]

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Sediment organic carbon (OC) content shows high regional variability, shaped by a complex interplay of physical, chemical, biological and anthropogenic factors. In this presentation, we present an assessment of drivers and patterns of sediment OC across European regional seas, with a particular focus on the role of large-scale habitat types, substrate characteristics, and environmental conditions. To investigate these relationships, we integrated datasets encompassing benthic habitats, sediment substrates and a range of environmental variables. Applying machine learning techniques, we identified the most influential predictors of sediment OC content across European regional seas. Our findings offer new insights into controls of sediment OC levels over large scales, highlighting the importance of factors such as wave exposure, light attenuation, seafloor morphology, and temperature. This data-driven approach provides a robust foundation for identifying OC-rich sediments, which are critical for conservation planning and assessing anthropogenic impacts on OC storage.

P1: 8 Four Fjords, Three Decades, One Coastline: Lessons from Danish Waters

Lønborg, Christian; Thorez, Gaëlle; Fuentes Santos, Isabel; Carreira, Catia

Danish fjords are typically shallow, nutrients-rich ecosystems, that are vulnerable to eutrophication and associated ecological disturbances. In this study, we investigated four fjords (Horsens, Vejle, Aabenraa, and Flensborg fjord) along the eastern coast of Jutland, selected for their comparable salinity regimes but differing local environmental settings. Using nearly 35 years of data from the Danish national marine monitoring program (NOVANA), we analysed seasonal dynamics and long-term trends in key biogeochemical parameters. Our analysis reveals both shared temporal patterns across the fjords, as well as site-specific differences driven by local factors such as nutrient loading and land use. This long-term perspective provides valuable insights into the interplay between regional pressures and local conditions in shaping these Danish fjords.

P1: 9 Pressure-induced leakage of dissolved organic matter from sinking diatom aggregates fuels pelagic microbial communities

Stief, Peter[1]; Niggemann, Jutta; Bligh, Margot; Buck-Wiese, Hagen; Wünsch, Urban; Steinke, Michael; Glud, Ronnie

[1]Syddansk Universitet

Marine snow particles form at the ocean surface, sink to depth, and ultimately enable carbon sequestration in the seabed. Fast-sinking particles, such as diatom aggregates, encounter a rapid increase in hydrostatic pressure during their descent. Here, we report that diatom aggregates incubated in rotating pressure tanks leaked up to ~50% of their initial carbon contents as dissolved organic matter (DOM) into the seawater at pressures corresponding to 2-6 km water depth. DOM leakage occurred during pressurization rather than depressurization of the incubation tanks and was thus not a sample recovery artefact. DOM leakage was diatom-derived and led to increased levels of dissolved organic carbon, total dissolved nitrogen, protein-like and humic-like DOM fluorescence, total proteins and carbohydrates, the storage polysaccharide laminarin, and the osmolyte dimethylsulfoniopropionate in the seawater. Ultrahigh-resolution mass spectrometry classified the diatom-derived DOM as recently bio-produced, and thus presumably labile. This was corroborated by rapid, yet incomplete, utilization of diatom-derived DOM by a pelagic microbial community. Pressure-induced DOM leakage represents a hitherto overlooked pathway of carbon supply to the deep ocean that may fuel the microbial loop and the persistent pelagic DOM pool. Given the depth range at which DOM leakage occurs, this pathway locks away carbon in the deep ocean on centennial to millenial timescales.

P1: 10 Sulfate reduction in hadal sediments: A case study from the Atacama Trench

Chen, Yen-Ting[1]; Schauberger, Clemens[2]; Trouche, Blandine[2]; Zabel, Matthias[3]; Berg, Peter[4]; Wenzhöfer, Frank[2,5,6]; Kjeldsen, Kasper U.[7]; Thamdrup, Bo[2]; Glud, Ronnie N.[2,8,9]

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Sulfate reduction dominates organic carbon mineralization in coastal sediments, yet its contribution decreases with increasing water depth due to lower organic matter availability, resulting in a negligible contribution to organic carbon mineralization in the vast abyssal plains of the ocean. However, recent studies have repeatedly observed high organic matter turnover resulting in shallow oxygen penetration in hadal trench sediments, hinting to an increased importance of anaerobic processes, potentially including sulfate reduction. In this study, we report on sulfate reduction rates in the Atacama Trench and explore the abundance, taxonomic identity, and community assemblage of the putative microbes that drive this process. Using ^{35}S radioactive tracer techniques, we revealed that sulfate reduction contributed 19-49% of the anaerobic organic matter degradation in the Atacama Trench. Accumulation of reduced inorganic sulfur, a distinct indicator of cumulative sulfate reduction over time, further confirmed active sulfate reduction in surface sediments at these extreme depths. Utilizing metagenomic sequences, we found a diverse set of sulfate-reducing microbes in the sulfate-reducing sediment layers, spanning across 19 known phyla. The relative abundance and composition of the microbial assemblages further correlated with the sulfate reduction rates. Our findings suggest that sulfate reduction, which has hitherto been largely neglected in the deep sea, reappears as a key carbon cycling pathway in the deepest parts of the global ocean. The presence and apparent activity of highly diverse sulfate-reducing lineages suggest that microbial adaptation to hadal depths is feasible across different branches of the microbial Tree of Life. However, this raises some fundamental questions regarding the potentials and processes of microbial adaptation to extreme conditions.

P1: 11 The genomic landscape of deepsea microbes

Chen, Yen-Ting[1]; Trouche, Blandine[1]; Schauberger, Clemens[1]; Kwan, Yick Hang[1]; Jensen, Thomas B. N.[2]; Dall, Sebastian M.[2]; Albertsen, Mads[2]; Glud, Ronnie N.[3,4,1]

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Hadal trenches, 6 – 11 km below sea level, act as depocenters of focused and event-driven depositions of organic matter, sustaining microbial communities along the trench axis. Studies have shown that these microbial assemblages are not only significantly different from the adjacent deepsea environments but also form distinct groups in each respective trench. While the assemblages differ, members of the microbial communities are, however, shared between trench systems. The trench microbes are considerably diverse and spread over known branches of the microbial Tree of Life. These observations indicate that the trench microbes originated in shallower waters and then efficiently adapt to the extreme conditions of deeper waters, yet the drivers and processes that affects the restructuring of microbial assembly across bathymetric depths is unclear. In this study, we gathered genomic evidence at a community scale utilizing metagenomes collected across the surface sediments from the Atacama, Kermadec, Aleutian, and South Sandwich Trenches along with the neighboring abyssal and bathyal seafloors to investigate bathymetric restructuring of microbes. While roughly half of the metagenome-assembled genomes were only reconstructed once throughout the analysis, a portion of the genomes was repeatedly reconstructed across different trench systems and water depths, suggesting some connectivity of the benthic microbial populations across the global bathymetric landscape. Preliminary analyses on genomic single nucleotide polymorphism revealed a decreasing intraspecific diversity downward into the trench axes by each trench system. In addition, bathymetric decrease in metagenomic diversity (N_d) was present among trench systems. These observations indicate the

presence of a global deep-sea microbial seed bank, with an intensifying intraspecific homogenizing force with increasing water depth.

P1: 12 Stirred Sediments, Shifting Microbes

Carreira, Catia; Chen, Qi; Zheng, Qiang; G. Morán, Xelu Anxelu; Gonzalez, Daniel; Herzog, Simon David; Markager, Stiig; Høgslund, Signe; Lønborg, Christian

Bottom trawling stirs up coastal sediments, releasing a mix of organic and inorganic matter into the overlaying water column. These pulses of material can fuel microbial communities, shift their composition, and change local biogeochemical cycles. In a series of sediment resuspension experiments, we found clear boosts in microbial abundance, biomass, and productivity, alongside marked changes in community structure. Microbial groups linked to sulfur cycling increased, while others more adapted to nutrient-poor waters declined. Overall, the microbial diversity also increased, reflecting an influx of sediment-associated microbes into the water column. Together, these findings show that disturbing the sediment fuels microbial activity and reshapes communities, with potential consequences for coastal carbon and nutrient cycling.

P1: 13 Phosphorous dynamics in shallow (< 30 m water depth) coastal waters of the German Baltic Sea under transient hypoxia

Henkel, Jan[1]; Ahmerkamp, Soeren[1]; Holtermann, Peter[1]

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Phosphorus (P) is a primary driver of Baltic Sea eutrophication. Despite external load reductions in the last decades, concentrations remain high due to persistent internal P-pools in marine sediments. These pools are redox-sensitive, meaning that presence and absence of oxygen affects retention or liberation of phosphate from sediments and are predicted to worsen in future climate scenarios. Beyond inorganic P-pools, a potentially large – but poorly constrained – microbial polyphosphate (polyP) reservoir may as well sequester or release phosphate under oscillating redox conditions.
In a very recent research cruise (EMB373) with the German vessel Elisabeth Mann Borgese, we studied a depth transect in the German Lübeck Bight from nearshore (~3–4 m) to the deeper basin (25 m), spanning sandy to muddy substrates and oxic to anoxic bottom waters. For the present study we quantify the pool size of total P, dissolved inorganic P and polyP and study P uptake–release kinetics during controlled laboratory incubations of intact surface sediment cores under changing redox conditions. In parallel, we characterize surface-sediment microbial communities to link observed results to abundance and community composition.
Sample analyses and data evaluation are in progress, but preliminary results show strong differences in uptake and release kinetics under varying redox conditions across sampled sediment types. These observations aim to provide a mechanistic understanding of coastal sediments acting as P-sinks or sources under fluctuating redox conditions that may mitigate or enhance P-loads to central parts of the Baltic Sea in future climate scenarios.

P1: 14 At the sediment–water boundary: Benthic microalgae control of nutrient dynamics in Danish estuaries

Høgslund, Signe[1], Henrik Fossing and Jacob Carstensen

[1]Aarhus University

Microphytobenthos (MPB) – the microscopic algae growing at the sediment surface – act as a light-sensitive “nutrient filter” between seabed and bottom water in shallow coastal systems. Their ecological role is well recognized, but their quantitative effect has been difficult to document.
We analyzed more than 3,000 benthic flux measurements from sediment cores collected in five Danish estuaries to assess how MPB regulate nutrient exchange across the sediment–water interface. MPB substantially intercepted fluxes of ammonium (NH_4^+), nitrate (NO_3^-), and dissolved silica (DSi) under both light and dark conditions, while phosphate (PO_4^{3-}) was only significantly reduced in light.
The strength of the MPB filter varied seasonally, with the largest relative impact in spring and a weaker effect in autumn, despite continued photosynthetic activity. The proportion of the annual sediment–water flux influenced by MPB reached up to 65% for NH_4^+, 73% for NO_3^-, 89% for PO_4^{3-}, and 96% for DSi.
Importantly, MPB influence depended strongly on light availability: above a threshold of 5% irradiance at the seafloor, interception increased sharply, demonstrating that changes in water clarity directly affect nutrient dynamics.
Our findings demonstrate that MPB are central to nutrient regulation in Danish estuaries and shallow

coastal waters. For management, this means that light climate—shaped by eutrophication, climate change, and physical disturbance—can critically alter the nutrient balance between sediments and water via benthic primary producers.

P1: 15 Conductive mineral particles as a niche for electroactive microbial communities in marine subsurface sediments

Kjeldsen, Kasper Urup

Marine sediments are rich in electrically conductive mineral particles, which may provide niches for electroactive microbial communities. We developed a method to extract electrically conductive ferromagnetic mineral particles from sediment samples. Using this approach, we characterized the identity and abundance of these particles, as well as their associated microbial communities, in Baltic Sea sediments.
Ferromagnetic particles were consistently found at all sediment depths and across geochemical zones and primarily consisted of the electrically conductive minerals magnetite and pyrite-greigite. The microbial communities associated with ferromagnetic particles were dominated by members of the bacterial genus *Desulfatiglans*. While known members of this genus grow by dissimilatory sulfate reduction, genome-resolved metagenomics revealed that the *Desulfatiglans*populations associated with ferromagnetic particles lack the genetic potential for this anaerobic respiration pathway. Instead, they may grow by acetate oxidation coupled with extracellular electron transfer, consistent with a conductive-mineral-associated lifestyle. Interestingly, the *Desulfatiglans* populations peaked in abundance within the methanic zone of the sediments. Radiotracer experiments demonstrated that methanogenesis in this zone is fueled by reducing equivalents from acetate oxidation to CO_2. We hypothesize that *Desulfatiglans* serves as the acetate-oxidizing partner in this syntrophic process, and that it is facilitated by conductive particle-mediated interspecies electron transfer.

P1: 16 A method to map cable bacteria activity in sediment by applied electric inhibition

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Microbial respiration accounts for the majority of oxygen consumption in marine and freshwater sediments, shaping redox gradients and driving biogeochemical cycles. Cable bacteria can account for up to 90% of total sediment oxygen consumption, making them dominant regulators of benthic oxygen budgets. These filamentous *Desulfobulbaceae* bacteria couple sulphide oxidation in anoxic layers to oxygen reduction at the sediment surface via long-distance electron transport (LDET). This activity can have a profound impact on sediment biogeochemistry, producing characteristic oxygen, pH, sulfide, and electric potential (EP) gradients, while also protecting benthic fauna and flora from sulfide toxicity during oxygen depletion. Despite their importance, the spatial and temporal variation in cable bacteria respiration remains unresolved. In this study, we developed a non-destructive method to measure cable bacteria respiration in sediment at µm and seconds resolution, inspired by the light–dark shift technique of Revsbech and Jorgensen (1983) for measuring rates of photosynthesis. Just as light–dark shifts remove photosynthetic oxygen production to isolate consumption, OCEM applies external potential differences to selectively block LDET and separate cable bacteria respiration from other oxygen consumption processes. By combining this perturbation with oxygen microsensor measurements, OCEM enables investigation of vertical, horizontal, and temporal variation in cable bacteria oxygen consumption. This approach can be used to refine our understanding of how cable bacteria respiration shapes benthic oxygen dynamics, providing a bridge between microscale activity and ecosystem-level impact..

Marine Mammals in a Changing Seascape

P1: 17 Are porpoises sexist? Effects of dolphin sex on porpoise avoidance behavior

Filatova, Olga[1]; Fedutin, Ivan[2]; Kindt-Larsen, Lotte[3]; Wahlberg, Magnus[1]

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Top predators affect ecosystems by controlling prey populations both directly through consumption and indirectly through fear. The threat of predation affects the spatial behaviour of prey species and can even drive emigration from areas with higher predation risk.
The most common cetacean species in the Danish waters is the harbour porpoise. A few years ago,

several bottlenose dolphins arrived from Scotland and settled in different areas around Denmark. Bottlenose dolphins are known to harass and kill harbour porpoises. This behaviour is usually observed in males during breeding season and can be a form of aggressive play in frustrated males with high testosterone levels and limited access to receptive females. Indeed, among five Danish dolphins observed in 2022-2025, two males were reported to kill porpoises, while there were no reliable observations of the three female dolphins performing this behaviour. It is however unknown whether porpoises are aware of the lower risk coming from female dolphins compared to males, and whether this affects their avoidance behavior. Here we report the results of passive acoustic monitoring of the dolphin and porpoise presence in areas where the dolphins occurred: Svendborg, Thyborøn and Lillebælt. We used underwater dataloggers (F-PODs) to detect click trains of porpoises and the dolphins. We calculated the detection-positive minutes (DPMs) of porpoise clicks during three periods: half an hour before the appearance of dolphin clicks, throughout the period of dolphin acoustic presence, and half an hour after. In our presentation we will compare the differences in porpoise avoidance behavior in response to the presence of male and female bottlenose dolphins and discuss the implications for porpoise habitat exclusion in case if more dolphins colonize Danish waters.
This study was supported by Aage V. Jensen Naturfond.

P1: 18 Seals at the net: Assessing depredation in Danish gillnet fisheries

Warrer, Cornelia Hindhede[1]; Glemarec, Gildas[1]; Kroner, Anne-Mette[1]; Kindt-Larsen, Lotte[1]

[1]DTU Aqua

Since the protection of seals in the 1970s, populations of grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) have increased substantially in Danish waters. While this recovery represents a conservation success, it has also led to growing conflicts with coastal fisheries. Gillnet fishers frequently report considerable economic losses from seal depredation. These losses include both visible catch losses, through damaged or partially consumed fish, hidden losses, where fish are removed entirely from the nets without leaving any visible fish remains, as well as damages to the fishing gears that need to be fixed or replaced. While the impacts of seal depredation are well documented in neighbouring Baltic Sea countries, the scale and distribution of seal-related damage in Danish gillnet fisheries remains unevaluated. In this study, we assess seal interactions with Danish gillnet fisheries using three complementary approaches: 1) a nationwide survey among gillnet fishers to provide insight into the spatial and temporal patterns of seal-related damages across regions, seasons, and fisheries target species; 2) a statistical analysis of electronic monitoring data from commercial fishers to identify the predictors of seal-damaged catches, including gear characteristics and fishing practices; and 3) field experiments to quantify the extent of hidden losses in a commercial gillnet fishery operating off the Danish west coast by estimating daily rates of injured and stolen fish. By combining fisher knowledge, monitoring data, and field experiments, this study provides an updated assessment of the extent of seal interactions with Danish gillnet fisheries. Our results offer a crucial insight for the development of management strategies that support both seal conservation and sustainable coastal fisheries.

P1: 19 Offshore wind decommissioning—what could it sound like? First field data

Povidis Delefosse, matthieu[1]; Pace, Federica; Laier Dybdal, Svenning; Schenone, Camillo; Nunes, Nuno; Sarnocińska-Kot, Joanna

[1]Vattenfall

Most research and mitigation on offshore wind noise has focused on installation (e.g., monopile impact piling). In Denmark and across Europe, the first large-scale decommissioning projects are expected within the next few years, making it timely and relevant to ask whether noise from wind-farm removal operations may pose risks to marine life, particularly marine mammals. Several technical solutions for monopile removal are under development, but few have been tested at sea; among current options, abrasive cutting appears the most technically viable offshore.

Between 19 November and 1 December 2024, we measured underwater sound during the removal of a steel monopile structurally similar to typical offshore wind turbine foundations at Store Middelgrund (Denmark). Two acoustic recorders, each with dual hydrophones, were deployed at 250 m and 750 m, recording continuously (10 Hz–256 kHz) to capture ambient conditions and the full operational sequence: dredging (2–3 days), jacking, and abrasive cutting (<1 day).

The loudest operation was dredging (177 dB re 1 $\mu Pa^2 \cdot m^2$ @1 m), followed by jacking (175 dB) and cutting (164 dB). The behavioural threshold of Lp,125ms = 103 dB, re 1μPa^2 was exceeded for 49% of the time during dredging, 99% during jacking, and <1% during cutting, and was also crossed during periods

when operations were halted due to weather limits. None of the operations triggered permanent threshold shift (PTS) at 750 m, and modelling indicated that PTS could occur within tens of metres from the source.

Importantly, the acoustic footprint of the surrounding operation—notably dredging and jacking—often equalled or exceeded that of the cutting tool itself. This highlights that monitoring the entire operation may be as important for underwater-noise risk assessment and management as characterising the cutting activity alone. Taken together, these measurements provide the first empirical reference for offshore-wind-relevant decommissioning noise and demonstrate how integrated acoustic monitoring across the operational footprint can guide impact assessment proportionate mitigation in future offshore wind decommissioning.

P1: 20 Sea-ice habitat associations of the declining endemic Kangia ringed seal population

Rikke Guldborg Hansen

Although the ringed seal (*Pusa hispida*) is one of the most widespread Arctic marine mammals, occurring throughout the circumpolar region, major knowledge gaps remain regarding its abundance, population connectivity, and genetic structure. Despite its pan-Arctic distribution, only a few systematic assessments have been conducted, the last one more than 20 years ago. In Greenland, a few local aerial surveys were undertaken in the late 1970s and early 1980s, leaving large uncertainties about population trends. Here, we present aerial survey data from 2018 and 2025 for the genetically distinct Kangia ringed seal, a genetically ecotype, uniquely adapted to the environment found in the UNESCO-listed Ilulissat Icefjord. Aerial surveys conducted in 2025 revealed a decline in observed abundance relative to 2018, raising concern for the status of the population. To understand how environmental factors influence seal density and distribution, we modelled survey data in relation to satellite-derived sea-ice concentration and proximity to glacier fronts. This habitat-based approach identified key areas of seasonal importance and a strong association between seals hauling out and areas of sea ice cover >90%, highlighting their preference for dense ice conditions during the moulting period. While ringed seals are generally wide-ranging, telemetry from confined glacial fjord systems demonstrates strong site fidelity and restricted local movements, thus underscoring the vulnerability of localized ecotypes to regional environmental change. This study provides a trend in abundance of this population and demonstrates the value of combining monitoring time series with spatial habitat modelling in marine mammal conservation.

Coastal Fish and their Habitats in Denmark

P1: 21 Bacteriophages for disease control in aquaculture: How do we get there?

Landor, Lotta[1]; Ruffo, Valeria[1]; Middelboe, Mathias[1]; Traving, Sachia[1,2]

[1]University of Copenhagen, [2]University of Southern Denmark

The spread of antimicrobial resistance poses a challenge to the sustainability of the aquaculture industry. The use of bacteria-infecting viruses, bacteriophages (phages), is considered a promising alternative to antibiotics to treat aquaculture-associated diseases. Despite promising experimental outcomes, phage-based treatment options are not widely available. Here, we present solutions to overcome challenges in using phages as disease-control, as well as suggestions for the next steps towards commercial viability. We propose that phage therapy in aquaculture should focus on outbreak contingency through disease prevention, thereby reducing the need for antimicrobials. Additionally, suitable phage-delivery strategies should be developed to target differences in pathogen distribution at different stages of the production chain. Finally, we provide some thoughts on the regulatory challenges surrounding the use of phages in the European Union.

P1: 22 Beneath the Surface: How Temperature Shapes Cod Growth from the Inside Out

Palasai, Amphornphan[1]; Gronkjær, Peter[1]; Sparrevohn, Alexander[1]

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Temperature may impact fish growth and physiology, with elevated thermal conditions often acting as stressors that disrupt normal growth patterns. In Atlantic cod (*Gadus morhua*), understanding how growth responds to temperature variability is essential for anticipating ecological responses to climate change. This study uses otolith microstructure analysis to evaluate daily growth rates under different thermal environments. Otoliths act as biological chronologies, preserving detailed records of growth that related with environmental exposures throughout the fish's life. A total of 61 juvenile cod were collected from the Western Baltic Sea in 2023, 63 juvenile cod Hou, Denmark in 2023 and 30 juvenile cod from Hou,

Denmark in 2024. We compared growth between individuals exposed to different thermal conditions, particularly between shallow (surface) and bottom habitats, using concurrent oceanographic temperature data. The sagittal otoliths were measured for increment widths and utilised to model growth in relation to temperature. The results suggest that juvenile cod experience thermal stress in the Western Baltic and Kattegat. The findings also highlight how small-scale differences in the environment can influence early growth and give insights into how cod respond to heat and adapt to changing conditions. Overall, the research contributes to an improved understanding of how ongoing ocean warming affect cod productivity and supports the need for climate-aware fisheries management in the future.

Keywords: Atlantic cod, Otolith microstructure, Thermal stress, Thermal optimum, Growth rate, Baltic Sea

P1: 23 Can stock assessments inform us about the ecological situation in our waters?

van Deurs, Mikael Seehusen Kruchov; Henriksen, Ole

For decades, the condition of fish populations in Danish waters, from fjords to the open sea, has been the subject of intense debate. Yet surprisingly little robust data exists to support these discussions. The International Council for the Exploration of the Sea (ICES) provides annual stock assessments and catch advice for fish and shellfish stocks across the North Atlantic, forming the backbone of sustainable fisheries management and environmental policy, including MSFD Descriptor 3. In this presentation, we focus on fish stocks with substantial geographic overlap with Danish waters. Drawing on ICES advice, we analyze current trends in stock size. We also evaluate the status of these stocks by comparing average biomass and fishing pressure against established reference points, where available. These reference points represent the minimum biomass threshold required to ensure sustainable stock productivity. Two-thirds of the stocks show declining biomass, and nearly all exhibit decreasing catches. However, about half remain above the critical lower biomass threshold. Stocks such as cod and herring are in particularly poor condition, whereas some plaice and a whiting stock seem to be doing good. We ask: What lies beneath the surface of the numbers? Do these assessments truly reflect the environmental status of Danish seas? What insights do they offer, and what important limitations must be acknowledged?

P1: 24 Nøglefiskerprojektet Citizen science projekt med 20 års jubilæum monitering af danske kystnære fiskeforekomster

Pedersen, Eva Maria Fenger[1] Mette K. Schiønning, Elliot J. Brown, Josianne G. Støttrup & Mikael van Deurs

[1]DTU Aqua

Nøglefiskerprojektet kunne i 2024 fejre 20 års jubilæum i sin nuværende form. Projektet er et vellykket eksempel på, hvordan et langsigtet Citizen science program kan bidrage til dokumentation af kystnære fiskebestande på en omkostningseffektiv måde og levere vigtige tidsserier om kystnære fiskebestande.

Præsentationen sigter på en overordnet beskrivelse af projektet, herunder baggrunden for projektets opståen, metoden og dets bidrag til bl.a. national rådgivning, Fiskeatlas og HELCOM i form af skrubbe og ålekvabbe forekomster som miljøindikator.

Nøglefiskerprojektet opstod på baggrund af fiskernes insisteren i 90'erne på, at fiskene var ved at forsvinde fra kysterne. Fiskeforekomster moniteres primært med større skibe, på vanddybder over 10m, hvorved de kystnære områder og fjorde ikke moniteres. Der var ikke udsigt til ressourcer til en kystnær monitering og derfor blev samarbejdet mellem fritidsfiskere og biologer skabt, da fangstregistrering baseret på frivillig arbejdskraft kan holde udgifterne på et minimum samtidigt med at alle kystområder moniteres og over flere sæsoner/måneder.

Projektet har op til 100 frivillige fritidsfiskere som deltagere og disse søges fordelt så godt som muligt ud på alle danske kystnære områder. For at gøre resultaterne så sammenlignelige som muligt mellem område og år fisker "Nøglefiskerne" på faste positioner med standardiserede redskaber (tre garn og/eller tre ruser) der stilles til rådighed af projektet. Positionerne vælges af fiskerne selv, koordineres af DTU Aqua og rapporteres til Fiskerikontrollen. Resultaterne fra nøglefiskerprojektet udmøntes hvert 3. år i en rapport der beskriver fangsterne i 21 kystnære områder. Seneste rapport om projektet er DTU Aqua-rapport nr. 428-2023

Projektet er finansieret af Fiskeplejen hvis midler genereres gennem salg af fisketegn til lyst- og fritidsfiskere.

P1: 25 Fiskens fortid som fremtidens fundament

Thomassen, Jasmin Ann-Christine[1]; Henriksen, Ole[1]; Eigaard, Ole R.[1]; MacKenzie, Brian R.[1]; Hunt, Georgina L.[2]; van Deurs, Mikael[1]; Poulsen, Bo[3] Voss, Jon[4]

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Hvordan undersøger man udviklingen af fiskebestande fra en tid hvor fiskeriet og videnskabelige undersøgelser havde en helt anden karakter? Og kan det overhovedet sammenstilles med de data vi har i dag? Selvom systematisk indsamlet landingsdata rækker mere end 100 år tilbage, kan disse ikke stå alene, hvis vi vil forstå hvordan bestandene har udviklet sig. Dette skyldes at landingsdata i høj grad er påvirket af hvordan fiskeriet blev praktiseret og reguleret på det givne tidspunkt. Gennem det sidste århundrede er der sket en markant teknologisk udvikling, hvilket løbende har medført ændringer i de praktiserede fiskerier. For at tage højde for disse ændringer, må der indsamles historisk statistisk data for fiskerindsatsen, sideløbende med tekniske specifikationer for fiskeredskaber og fiskefartøjer, for ikke at forglemme information om lovgivning og forvaltning. I de indledende undersøgelser, vi vil præsentere, har vi digitaliseret historiske danske fiskeri data fra perioden 1888 til 1911. Formålet er at opnå en bedre forståelse af fiskebestandenes "naturlige" udvikling i danske fjorde før den omfattende industrialisering af fiskeriet, som tog fart fra midten af det 20. århundrede og frem til begyndelsen af det 21. århundrede. På sigt håber vi at kunne beskrive bestandsændringer og muliggøre etableringen af en historisk baseline, som kan anvendes i arbejdet med genopretning af habitater og fiskebestande.

P1: 26 A guide to sharks and skates in Danish and adjacent water waters

Kroner, Anne-Mette[1]; Schiønning, Mette[1]; Werner Thomsen, Jan[1]; Mildenberger, Tobias[1]; Rask Møller, Peter[2]; Carl, Henrik[2]

[1]DTU Aqua, [2]KU

Sharks, skates and rays (elasmobranchs) are long-lived fishes characterised by late maturation and low fecundity. These life-history traits make them particularly susceptible to fishing pressure and other anthropogenic impacts. Accurate monitoring of elasmobranch fisheries has been challenged by the difficulty in distinguishing between species, leading to considerable uncertainty in catch data. To ensure sustainable exploitation, it is essential to monitor elasmobranch stocks and report landings at the species level. To support improved species identification in the field, a guide to sharks and skates in Danish and adjacent waters has been developed. The guide is intended for use by DTU Aqua staff, fishers, and other stakeholders. It covers 14 species of sharks and 16 species of skates found in the region, highlighting both common and less frequently encountered species. Each species comprises biological descriptions and a distribution map based on data from scientific bottom trawl surveys conducted by research vessels from Northern Europe.

P1: 27 Seasonal changes in epifaunal community structure in transplanted eelgrass in Vejle Fjord

Ötvös, Lilla Ágnes[1]; Nielsen, Benjamin[1]; Husted Steinfurth, Rune Christian[1]; Flindt, Mogens[1]

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Eutrophication and alteration of coastal habitats had led to the deterioration of coastal ecosystems, which included the severe decline of seagrass meadows. These habitats are biodiversity hotspots and are key areas in the lifecycles of several fish and crustacean species. With the decline of these ecosystems, coastal areas have become less productive, and the loss of diversity made them more susceptible to disturbances. Furthermore, following the reduction of nutrient discharge in Danish waters, the expected recovery of eelgrass meadows did not take place. Therefore, large-scale transplantations of eelgrass have been carried out in Vejle Fjord (VF) as an active restoration project by the marine group of SDU every year since 2019. The aim of this study was to survey the successional state of these transplanted eelgrass meadows in VF, through spatio-temporal dynamics of epifauna communities.
Accordingly, samplings were carried out with a beach seine net on seven occasions during daytime from October 2023 till April 2025 and on two different dates during nighttime in September and October 2024. The sampling sites were at 4 different eelgrass transplantation sites with varying ages (transplanted in 2019, 2020, 2021 and 2022), and at two control sites including bare bottom and a natural eelgrass meadow. Specimens in the samples were identified to species level and body length measurements were taken in order to calculate basic fauna metrics and assess ecosystem functionality.
The results showed that the oldest and most developed transplantations (T19, T20) had similar fauna

metrics and seasonal variability to the natural bed, indicating that these transplanted areas reached a successional state where they provide ecosystem functions comparable to the natural meadow. However, the younger and less vegetated transplantations (T21, T22) represented a transitional state between the bare bottom and the natural bed.

P1: 28 Shore crab (Carcinus maenas) in inner Danish waters: A case study in the Lillebælt fishery

Freitas, Pedro

The European shore crab *Carcinus maenas* is native to northeast Atlantic, but a significant invasive species elsewhere, inhabiting a wide range of habitats in coastal waters due to its extraordinary phenotypic plasticity, environmental tolerance and omnivorous diet.

Qualitative data on shore crab populations is very limited or non-existent, but it is generally accepted that populations in inland and coastal Danish waters are very large and/or increasing. Shore crab fishing in Denmark thus has the potential to expand and become a viable and sustainable exploited resource. In this study, the shore crab pot fishery in the Lillebælt was monitored monthly to bimonthly between May 2023 to September 2024 to assess seasonal variation in catches and its composition, and fish bycatch. In addition, the short-term fishing impact on a local shore crab population (ca. 0.14 km2) was evaluated from two 2-week intense fishing trials in early July and September 2024.

Shore crab catch rates were highest in late spring and summer (> 100 crabs/pot/day) and lowest in winter (< 10 crabs/pot/day), and spatially variable between sites. Catch rates increased weakly with water temperature but were unaffected by water depth or the nearby presence of eelgrass. Male crabs dominated catches and the predominance of the red and green colour morphotypes varied with season and sex. Fish bycatch varied seasonally, being mainly wrasses (62%), gobies (19%) and juvenile cod (10%).

Impact from intensive fishing was limited to shallow locations where the coastline imposed a boundary limiting migration of crabs, while in deeper further offshore locations catch rates were unchanged. Lower catch rates in the second trial followed the seasonal decrease in catches. Catches were male dominated, but spatially variable with female abundance increasing in shallow locations. No decreasing trend in crab size was observed during the trials, with migration explaining larger females and smaller males observed in the second trial. Even though 7,800 and 4,840 kg and ca. 250,000 and 170,000 shore crabs were caught from a small area in the two week trials, the local shore crab population showed significant resilience and recovery ability to short term impacts from intensive fishing.

P1: 29 Testing a mass marking technique using alizarin complexone on reared European flounders (Platichthys flesus) to quantify restocking efficacy

Schiønning, Mette Kjellerup[1]; Davies, Julie Coad[1]; Deurs, Mikael van[1]; Krüger-Johnsen, Maria[1]; Støttrup, Josianne Gatt[1]; Brown, Elliot John[1]; Hüssy, Karin[1]

[1]DTU Aqua

Since 1993, more than 1.6 million reared European flounders (*Platichthys flesus*) have been released in the Limfjorden to support stock enhancement. Despite this effort, little is known about their survival, growth and contribution to the local and regional fishery. Tagging hatchery-reared fishes prior to release enables differentiation from wild stocks and assessment of restocking success. Alizarin complexone (ALC) is a fluorescent dye and a well-known mass-marking technique that leaves a lasting mark in otoliths without harming the fish when applied with an appropriate dose. However, the optimal dose varies by species and life stage. While ALC tagging has been used in related species such as Japanese flounder (*Paralichthys olivaceus*) and turbot (*Scophthalmus maximus*), no established protocol exists for European flounder. We tested a range of ALC concentrations (0–100 mg/L) on reared age-0 European flounder (n = 136; T_L: 31–110 mm) via 24-hour immersion in ALC solutions to identify the most optimal, non-lethal dose. In addition, a subsample (n = 15; T_L: 79–103 mm) was double-tagged with ALC, 21 days apart, to evaluate the potential of separating close cohorts and tracking growth. Preliminary results indicate that concentrations of 50 mg/L or higher produce clear, detectable marks under fluorescence microscopy, and that double tagging can be used to separate close cohorts. To our knowledge, this is the first study to apply ALC immersion tagging to European flounder, offering a promising and practical tool for long-term monitoring of restocking efforts.

P1: 30 Where does the Western Baltic cod (Gadus morhua) spawn: Insights from local fishers and habitat modelling

Bering, Line; Funk, Steffen; Mittermayer-Schmittmann, Felix; B. Neuheimer, Anna

The Western Baltic Sea is one of the most researched marine areas in the world. Still, one of the ecosystems' key species, the Atlantic Cod (*Gadus Morhua*), has experienced dramatic declines in recent decades (ICES, 2025; Möllmann et al., 2021), raising questions about the condition and protection of its spawning habitats and the time of spawning. While most research point to overfishing and environmental change as key drivers (Birgersson et al., 2022), less attention has been paid to the spatial characteristics of spawning grounds and how they shape recruitment success. Understanding the role of spawning habitats in these declines is essential for developing effective management and conservation measures.

In this study, we combine fishers' ecological knowledge (FEK) with open-source geospatial data to characterize cod spawning habitats in the Western Baltic. Semi-structured interviews with local fishers were conducted to identify historically and presently important spawning areas of cod in the area. Participants drew spawning grounds on maps and described their characteristics, including depth, bottom structure, relief, and seasonal patterns of cod occurrence both present and historic. Simply put: When and where do the fishers catch the large, spawning adults? To test the hypothesis that fisher-identified spawning areas are different from the rest of the Western Baltic, we applied Generalized Additive Models (GAMs), integrating open-source geospatial data on bathymetry, slope, and sediment type.

Preliminary results show that the areas identified by fishers differ significantly from the broader Western Baltic in terms of sediment type and depth. Moreover, fishers consistently reported declines in both the abundance and size of spawning cod, alongside observed changes in spawning seasonality. By integrating local knowledge with open-source geospatial data and statistical modelling, this study provides a foundation for identifying and protecting essential spawning habitats of cod in the Western Baltic. Ultimately, this knowledge can support spatial management initiatives, including the designation of marine protected areas and targeted fishing closures, thereby strengthening the foundation for sustainable fisheries in the Western Baltic Sea.

Scherfig – Poster I: 31-48

Development of Digital Twin of Ocean (DTO)

P1: 31 Building an on-demand hydrodynamic coastal model for North Sea – Baltic Sea

Frisfelds, Vilnis; She, Jun[1]; Murawski, Jens[2]

[1]Danmarks Meteologiske Institut, [2]Danmarks Meteorogiske Institut

Building a high resolution coastal hydrodynamics model can take several months to create and tune the setup until it meets the desired expectations. With the Edito Digital Twin Ocean we propose to use an on-demand tool for hydrodynamic ocean circulation model, where user attaches a desired extent of coastal system to already tuned North Sea – Baltic Sea model setup and runs the whole setup in a single configuration using two-way nesting. HBM oceanographic model is used for that enables handle multiple two-way nests efficiently. The horizontal resolution of coastal model can reach up to 2 arc seconds. As basis bathymetry the combination of EmodNET 2020 bathymetry and Danish digital bathymetry model of 2024 is used over North Sea – Baltic Sea area. DMI Harmonie is used as weather forcing. Several examples have been examined which uses high resolution 50m hydrodynamics with the on-demand tool including Copenhagen area, Randers fjord, South Fyn archipelago sea, Anholt, Kriegers flak, proving stability over storm events. The high resolution areas have to nest to intermediate resolution areas in order to have seamless transition from coastal areas to the open seas. The user does not need to care about boundary conditions, initial conditions, met-forcing, river inflow as they are considered already in the basis setup of North Sea – Baltic Sea. The user have just to select the domain boundaries, select the parent domain, select desired time period, and possibly add linear obstacles, narrow water ways and change the bottom friction within the selected domain. Afterwards, the whole setup can be executed on a HPC computing facility using both OpenMP and MPI parallelization, enabling fast processing time. Thus, the on-demand tool can be effectively used for coastal planing, where the first hydrodynamics analysis is possible even after a few hours, depending on the complexity of the setup.

P1: 32 The role of marine robotics in DTO: applications in near real-time mapping above and below the surface

Thompson, Fletcher; Mariani, Patrizio

Marine robotics have the potential to be a vital resource towards the realization of a complete Digital Twin of the Ocean (DTO), where there is a need for multi-source, high-resolution data to be continuously integrated into dynamic models of marine and coastal environments. In this work, we demonstrate the application of an autonomous surface vehicle (Otter Pro Mk3, Maritime Robotics) equipped with a state-of-the-art shallow-water multibeam echosounder and a high-resolution LiDAR scanner. Together, these complementary sensing modalities provide seamless three-dimensional point cloud data of both the underwater and terrestrial domains, captured with centimeter-level accuracy through RTK positioning (5 cm horizontal and vertical certainty). This dual-domain mapping capability enables continuous monitoring of transitional zones at the land–sea interface, a critical area for understanding ecosystem processes and human impacts.

The integration of near real-time point cloud data streams supports diverse applications central to the DTO vision. In coastal development, repeated surveys allow for the quantification of morphological change, sediment transport, and shoreline dynamics resulting from construction and dredging activities. Above the waterline, LiDAR observations facilitate monitoring of relevant maritime infrastructure, compensation for loss or impairment of GNSS service, and for monitoring of nearby marine traffic. Below the surface, multibeam data provide robust characterization of seabed morphology and structural health of marine infrastructure, including ports, pipelines, and renewable energy assets. In addition, high frequency multibeam data (200 kHz +) can be used to identify macro-algae and benthos coverage distribution in the benthic zone. Further, the system is equipped with a winch-mounted water profiler which enhancs the collected spatial data with water property profiles. The fusion of these datasets within a near real-time operational framework bridges the current gap between data acquisition and actionable insight during survey operations, enabling decision-makers to track environmental status and predict responses to both natural and anthropogenic drivers.

By embedding robotic survey systems into the DTO framework, we move toward persistent, high-resolution representations of the ocean that underpin sustainable management. The demonstrated capability highlights how autonomous marine platforms and advanced sensing technologies can deliver timely, spatially continuous information, ultimately accelerating progress toward the global objectives of the Digital Twin of the Ocean.

Co-existence at sea – opportunities and challenges

P1: 33 Geological Service for Europe towards decision making modules in the marine and coastal realms

Larsen, Isak Ring[1]; Ernstsen, Verner Brandbyge[1]

[1]GEUS

Ensuring transparent, science-based decision-making is paramount, as challenges of climate change, coastal hazards, and renewable energy expansion continue to evolve. Within the EU project Geological Service for Europe (GSEU, https://www.geologicalservice.eu/), an in-depth inventory of existing Decision Support Systems (DSSs), Decision Support Tools (DSTs), and Decision Support Indices (DSIs) used by Geological Survey Organisations (GSOs) across Europe in relation to coastal vulnerability assessment and offshore windfarm siting was collated (Larsen et al., 2025). The inventory is available on the European Geological Data Infrastructure (EGDI, https://www.europe-geology.eu/). A structured questionnaire was circulated among GSOs to gather insights into their methodologies, tools, and outputs. The findings underscored the critical role of DSSs and DSTs in enabling evidence-based decision-making for both coastal vulnerability and offshore windfarm siting. While significant progress has been made in developing decision-support frameworks, challenges remain in standardising methodologies, integrating advanced technologies, and fostering cross-institutional collaboration.
Moving forward, efforts will focus on developing best-practice decision-support modules that build upon the existing inventory of DSSs. The refinement of standardised geological indices will be essential to improving the comparability and consistency of assessments across different regions. Additionally, the integration of Bayesian Networks, AI-driven modelling, and geospatial visualisation tools will enhance predictive capabilities and allow for more comprehensive risk assessments. Strengthening collaboration between GSOs, policymakers, and industry partners will be key to aligning research efforts with practical applications, ultimately leading to more resilient coastal management and sustainable offshore wind energy development.

P1: 34 Early benthic community dynamics on offshore wind structures: a case study from Kriegers Flak

Andersen, Karolina; Reducha Andersen, Karolina; Leslie Koziol, Adam; Anton Upadhyay Stæhr, Peter; Dahl, Karsten; Buur, Helle; Winding, Anne; Sapkota, Rumakanta; Göke, Cordula

Offshore wind farms (OWFs) are rapidly expanding across northern Europe as a cornerstone of the green transition. Multi-use concepts, such as integrating renewable energy with aquaculture or biodiversity enhancement, are increasingly promoted to alleviate spatial competition at sea. Yet the ecological implications of introducing large anthropogenic structures into marine ecosystems remain poorly understood.
The aim of this study is to document early colonisation patterns and to compare monitoring methods. Using scraping samples, ROV video transects, and environmental DNA (eDNA) metabarcoding, we assessed artificial substrates and nearby natural reefs.
Preliminary results showed rapid colonisation of turbine foundations by dense beds of blue mussels (*Mytilus trossulus*), generating high local biomass and supporting epifaunal assemblages. Community composition, however, differed markedly from natural reefs, with reduced structural heterogeneity and dominance by a few taxa.
The methods comparison highlighted complementary strengths. Scraping yielded detailed taxonomy of sessile species; ROV offered broad spatial coverage but limited resolution; eDNA revealed additional taxa, though with interpretive challenges.
From a multi-use perspective, these findings illustrate both potential and risk. OWFs can host productive communities and offer synergies for co-located aquaculture. At the same time, OWF structures do not replicate the biodiversity or ecological functions of natural systems. Instead, they create novel habitats by converting soft-sediment seafloor into hard substrate. This habitat transformation may conflict with EU conservation targets. Under the Marine Strategy Framework Directive, Member States must safeguard existing seabed types, and irreversible habitat loss is limited to 2% per broad-scale habitat type. This highlights the need for nuanced evaluation, where habitat conversion is not automatically considered a net ecological gain. Robust, multi-method, long-term studies are essential to ensure that multi-use OWFs balance resource production with marine ecosystem protection.

Marine virkemidler som driver for et godt havmiljø

P1: 35 Life Cycle Assessment as a Tool for Improving the Marine Environment in Construction Projects

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The expansion of coastal areas for infrastructure and other human activities places increasing pressure on the ecological condition of the marine environment. The destruction of natural habitats has a documented negative impact on marine ecosystems, and the establishment of hard habitats is therefore essential to mitigate damage and support ecological restoration.
Concrete is a key material in marine construction, but its production and use contribute significantly to environmental impact. At the same time, literature reports a lack of interdisciplinary communication between engineering and biological disciplines, which restricts the development of more sustainable solutions.
Life Cycle Assessment (LCA) is a crucial tool for quantifying and optimizing the environmental impact of marine structures. LCA should not only be used for post-project evaluation but should be integrated early in the design phase to guide material selection and design decisions towards reduced environmental impact. The LCA modeling of the Køge Bay reef structure “Circle Reef” demonstrates how changes in cement type and concrete design can reduce environmental burdens. Furthermore, the analysis highlights the importance of including multiple impact categories, as improvements in one category (e.g., carbon footprint) may lead to trade-offs in another (e.g., marine ecotoxicity).
This emphasizes the need for a holistic approach, where LCA is used as a strategic tool to promote sustainability in marine projects—not merely as documentation, but as an active foundation for decision-making in design and implementation.

P1: 36 Muslingeopdræt som Marint Virkemiddel: Økosystemtjenester og Naturgenopretning

Lyngsgaard, Maren[1]; Kristensen, Louise; Plesner, Lisbeth; Vismann, Bent; Engell-Sørensen, Kirsten; Dolmer, Per

[1]WSP Danmark

Opdræt af muslinger i vandsøjlen kan være et omkostningseffektivt marint virkemiddel, der kan forbedre vandkvaliteten i mange af vores fjorde og kystområder. Muslinger vurderes som det mest effektive virkemiddel sammenlignet med for eksempel tang (Bruhn et al., 2020) til at fjerne næringsstoffer fra fjordene, når muslingerne høstes. Internationale undersøgelser viser, at af det kvælstof og fosfor, som plankton i fjorde og kystvande optager fra vandsøjlen, stammer henholdsvis 15-32 % og 17-100 % fra intern belastning, sedimentets recirkulerede næringsstofpulje (Knudsen-Lerbeck et al., 2017). Det er derfor væsentligt for et sundt havmiljø, at der også arbejdes med reduktion af den interne belastning.
Flere områder i Limfjorden er blevet undersøgt i en række projekter med henblik på at dokumentere positive og negative effekter af muslingeopdræt i vandsøjlen. Undersøgelser af påvirkningen under muslingeanlæg og på referencestationer viser, at der ikke er nogen forringelse af bundfaunasamfundet under muslingeopdræt sammenlignet med referenceområder i Skive Fjord, Venøsund og ved Jegindø. Iltforbruget under muslingeopdræt er signifikant højere under anlæg end på referencestationer, når flere anlæg i samme fjordområde vurderes samlet. Dog er der ingen signifikant forskel på iltforbruget, når anlæggene analyseres enkeltvis.
Muslingeyngel opdrættet i vandsøjlen kan bruges til etablering af biogene rev, hvilket yderligere kan forbedre biodiversiteten og den økologiske status. En case study fra Blå Biomasse viser, at muslingebiomasse dyrket i Venøsund kan fungere som yngel til naturgenopretningsprojekter med etablering af biogene rev. Med EU's naturgenopretningsforordning, der kræver genoprettelse af 20 % af havområderne inden 2030, vil det blive nødvendigt at anvende muslingeyngel opdrættet i vandsøjlen til genopretning af historiske biogene rev.
Disse resultater understøtter, at muslingeopdræt kan være en løsning til at forbedre vandkvaliteten og øge biodiversiteten i danske fjorde og kystområder.

P1: 37 Kunstige rev af støbte havblokke

Kaufmann, Stina[1]; Svendsen, Jon[2]; Kunther, Wolfgang[3]

[1]Dalgas A/S, [2]DTU Aqua, [3]DTU Sustain

Circle Reef-projektet, etableret i april 2025 i Køge Bugt, undersøger i et kontrolleret studie, om betonrev kan bidrage til marin biodiversitet på samme niveau som traditionelle stenrev. Projektet omfatter fire kunstige rev – to af sten og to af beton – med ens dimensioner, og sammenligner deres evne til at tiltrække fisk, tang, ålegræs og bundlevende organismer i forhold til bar sandbund.

Betonrevene evalueres desuden for deres materialeegenskaber og strukturelle design, med henblik på at fremme biologisk kolonisering. Projektet undersøger også CO_2-binding både gennem betonens karbonatisering og via biologisk begroning fra bentiske organismer.

Målet er at vurdere, om beton kan fungere som en lokal, bæredygtig erstatning for importerede sten, og dermed åbne nye muligheder for etablering af marine habitater.

Ocean prediction and coastal modelling

P1: 38 Enhancing Storm Surge Forecasting through Coupled Ocean Circulation and Wave Modeling: A Case Study of Storm Babet Oct 2023

Murawski, Jens

Storms with prevailing easterlies in the southwest Baltic Sea have the potential to generate record high sea levels, strong waves and wave induced coastal erosion due to the relative long fetches. In October 2023, storm Babet hit the coastline of Denmark and Germany, broke dikes, destroyed harbors and generated severe property damage of about a billion euro. The measured significant wave height reached values of up to 6 meters at Kriegers Flak wind farm. The operational storm surge model of the Danish Meteorological Institute (DMI) significantly under-predicted the values of the maximum sea level in regions with high waves in the southwest Baltic Sea. One potential reason can be that the operational ocean model does not resolve sufficiently the impact of the waves on the sea levels. This led to detailed research on coupling processes implemented in the operational ocean circulation DMI-HBM and wave model WAM. The study includes: (1.) the momentum input into the ocean model by implementing wave induced surface force (divergence of the radiation stress), (2.) wave affected atmospheric momentum flux into the ocean and (3.) surface drag parameterizations in the momentum solver and the turbulence model. Our presentation demonstrates positive impacts of the model coupling processes on the forecasting quality of sea level. The coupled model system was used successfully to predict the near-shore ocean dynamics using high-resolution model grids with horizontal resolution of up to 185 meter (0.1 nmi). At this grid resolution, the model is able to represent the complex coastlines in the study area, which

covers the southwest Baltic Sea. The development of the coupled model system has benefitted the assessment of sea level, coastal currents, transport and coastal erosion along the southeastern Danish coast. The presentation summarizes the ongoing development work and ends with a look at future directions and applications.

P1: 39 Geoarchaeology and Offshore Wind: Integrating Submerged Landscape Analysis and Seabed Surveys into Marine Environmental Research

Daniel Peter Dalicsek

COWI

Offshore wind development intersects with submerged prehistoric landscapes, requiring integrated approaches to cultural heritage impact assessments. Geoarchaeology—combining methods from geology and archaeology—provides valuable insights into past sea-level change, sediment dynamics, and human-environment interactions.
This poster/presentation highlights the role of geoarchaeological analyses in offshore wind projects, including:

- Mapping paleolandscapes using seismic and sediment core data
- Identifying potential archaeological sites in submerged contexts
- Supporting environmental impact assessments with long-term perspectives on marine change

Case studies from the North Sea and Kattegat demonstrate how ancient coastal zones, now underwater, can inform both turbine planning and provide valuable information to marine environmental research. Geoarchaeology strengthens the understanding of seabed history while helping protect underwater cultural heritage and creates an opportunity for collaboration with other marine sciences. Furthermore, geoarchaeology provides the basis for extensive fieldwork campaigns, where maritime archaeologists conduct dive surveys. These surveys often collect large quantities of data that could be useful for environmental research.

P1: 40 Contrasting Responses of Stratification and Primary Production to Offshore Wind Farm Development between the North Sea and the Baltic Sea

Marie Maar[1]*, Vibe Schourup-Kristensen[1], Christian Mohn[1], Ange P. Ishimwe[1], Eva Friis Møller[1], Charlotte H. Clubley[1], Andrea Hahmann[2], Marc Imberger[2], and Janus Larsen[1]

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Large-scale offshore wind farm developments are planned for the North Sea and the Baltic Sea becoming Green Power Plants for northern Europe. Offshore wind farms are expected to influence the physical and biogeochemical environment through two mechanisms: decreased wind stress at the sea surface (wake effect) and increased friction (drag effect) around monopiles. We applied 3D numerical models to study impacts of offshore wind farms on stratification and primary production in the North Sea and western Baltic Sea. The future Y2030 scenario, defined by the Danish Energy Agency, projects an increase of 50 GW for onshore wind farms and 158 GW for offshore wind farms. The changes were compared to a reference scenario without any onshore and offshore wind farms.

Our findings revealed contrasting responses between the two seas due to differences in current speeds and levels of stratification. The North Sea showed a complex spatial pattern with both positive and negative changes in stratification and primary production depending on the current speed, stratification, and wind farm capacity. The Baltic Sea showed far-field effect with stronger stratification and lower primary production. Generally, the monopile drag effect dominated over the wind wake effect at current speeds above 0.25 m/s. Hence, offshore wind can affect the marine environment differently depending on the underlying hydrodynamics.

P1: 41 Enhancing Storm Surge Prediction Through Assimilation of Satellite Altimetry and Tide Gauge Observations: a storm Babet case study

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Storm surges represent dangerous elevations in sea level caused by meteorological forces during severe weather events, posing significant threats to coastal communities and infrastructure. Reliable forecasting of these extreme water levels is essential for effective coastal management, evacuation planning, and the operation of protective measures in vulnerable coastal regions.

This study evaluates the impact of sea level data assimilation on improving extreme event prediction with ocean numerical models. Using the PDAF package with the Local Error Subspace Transform Kalman (LESTK) filter, we assimilated 5-Hz satellite altimetry observations from CMEMS Copernicus service and tide gauge data from CMEMS In-Situ product at 3-hourly intervals. The assimilation system employs a semi-climatological ensemble multivariate ensemble anomalies sampled from 10-year hindcast simulation using a sliding time window resulting in fully three-dimensional time varying error covariances.

The evaluation of the scheme during the storm Babet (October 2023) demonstrated significant improvements in storm surge prediction capabilities, with the assimilation greatly reducing peak errors during storm events and consistently improving root-mean-square error (RMSE) across all independent verification stations. This study provides evidence that combining high-frequency satellite altimetry with tide gauge observations through ensemble-based data assimilation can substantially enhance extreme sea level prediction, representing a significant advancement for operational storm surge forecasting systems with important implications for coastal risk management.

Keywords: Data assimilation, storm surge, satellite altimetry, tide gauges, LESTK filter, extreme events

P1: 42 Hydrografiske undersøgelser i forbindelse med Østlig Ringvej Projektet

Christensen, Bo Brahtz; Jakobsen, Flemming

Østlig Ringvej skal forbinde Nordhavn med Kastrup Halvøen, og undervejs føres den igennem Lynetteholm og Prøvestenen. Den består af tre adskilte delstrækninger, som opføres med sænketunnel på åbent vand, mens de resterende strækninger opføres som cut & cover. I forbindelse med MKVen er der gennemført detaljerede hydrografiske analyser. En 3D hydrodynamisk model af Øresund er sat op, hvor resultaterne er sammenholdt med målinger. En kort oversigt af projektet præsenteres, og derefter er fokus på de detaljerede hydrografiske analyser. Sammenligninger af målte og beregnede vandstande, strømme og saltholdigheder vises. Endelig vil der være fokus på overstrømningen af Drogden Tærsklen, den hydrauliske kontrol i H-H snittet, og modstand og ændringen af modstanden i Øresund.

P1: 43 Developing high resolution operational forecasts at wind farms and aquafarms

Frishfelds, Vilnis[1]; Murawski, Jens[1]; She, Jun[1]

[1]Danmarks Meteorologiske Institut

Operation of wind farms and aqua farms require detailed weather forecasts for operations and maintenance. The European research project OLAMUR investigates the potential for sustainable multi-use of marine space by combining offshore wind energy installations with lower trophic layer aqua-farming. Within the project, the Danish Meteorological Institute (DMI) contributes with high-resolution, operational wind, wave and ocean dynamic forecasts for extreme event warning service and operations planning. Together with the offshore wind farm operator Vattenfall, DMI is improving model configurations and consider wake effects created by the turbines. A first version of the wave-ocean circulation modeling system runs operationally at DMI, providing up to 2 ocean wave and 4 ocean circulation forecasts per day with forecast period of more than 60 hours. The high resolution areas (resolution for 185m hydrodynamics, and for 370m waves) at Kriegers flak, Helgoland and Tagalaht are two-way nested in North Sea – Baltic Sea model. As there are multiple Vatenfall wave riders are placed in different locations within the wind farm, it enables to address the impact of the wind farm.

P1: 44 Modeling the Impact of Offshore Wind Farm Drag on Ocean Circulation and Turbulence in the North and Baltic Seas

Mukherjee, Sonaljit

Rapid expansion of offshore wind farms (OWFs) in the North Sea and Baltic Sea has led to new local sources to coastal turbulence through frictional drag imposed by turbine structures. As part of the OLAMUR project, we investigate the regional-scale impacts of OWF aggregations on ocean circulation and turbulence using a modified HBM (Hiromb-Boos Model) with a k–omega vertical mixing scheme. The frictional drag induced by wind turbines is parameterized as a subgrid-scale energy production, which enables the assessment of its effect on the local ocean circulation without resolving individual turbines. We present simulation results with resolutions at 0.1 to 1 nautical mile (nm) across the North Sea, Danish Straits, and the Baltic Sea.

The results indicate enhanced submesoscale turbulence and mixing near wind farms, as evidenced by increased Rossby numbers, potential vorticity anomalies, and vertical velocity variance. The local frictional drag at the turbines also triggered gravity waves, which reflected along the land boundaries and produced sharp local anomalies in the ocean properties. This was mitigated through partial-slip boundary conditions near the land, resulting in improved model stability. These findings demonstrate the importance of incorporating OWF-induced drag in regional ocean models, especially for maritime zones integrating aquaculture and renewable energy.

P1: 45 Enhancing Marine Modelling Accuracy: Recent Developments in the FLEXSEM System

Ishimwe, Ange Pacifique[1]; Larsen, Janus[1]

[1]Aarhus Universitet

The marine dynamic modelling system FlexSem, developed at EcoScience, Aarhus University, has recently undergone a series of numerical upgrades aimed at improving accuracy and stability in realistic marine applications. A key enhancement is the implementation of a higher-order spatial discretization for horizontal tracer advection, which significantly reduces numerical diffusion and improves the resolution of sharp gradients—allowing for more accurate representation of thermocline and pycnocline structures.

In the momentum equations, the surface wind stress parameterization has been revised to incorporate a wind-speed-dependent drag coefficient, establishing a more consistent link between atmospheric forcing and ocean surface response. Additionally, the agent-based model (ABM) module has been extended with a diffusive operator, enabling the simulation of subgrid-scale dispersion in Lagrangian particle tracking.

These improvements have been tested across several recent model setups, demonstrating clear benefits to both hydrodynamic and tracer simulations. The enhanced FlexSem system offers a robust and flexible platform for addressing complex marine processes with greater precision.

P1: 46 Coastal DIAMONDS (Danish IntegrAted Marine ObservatioN & Data System). Integrating real time data to strengthen monitoring capabilities in Danish marine waters.

Wong, Xin Huei; Chr. Erichsen, Anders[1]; Kronborg, Mai-Britt[1]

[1]DHI A/S

Denmark is transitioning toward a more holistic and data-driven approach to marine environmental monitoring. Historically, Denmark relied on ship-based sampling. While thorough, this method limits frequency and spatial coverage and requires considerable resources. Although new technologies, such as Earth Observation (EO), buoy-mounted sensors, and autonomous platforms, are increasingly adopted worldwide, they are not yet systematically integrated into European monitoring programmes cf. Water Framework Directive (WFD).

Coastal DIAMONDS represents a shift toward a more integrated solution in a new operational framework designed to support key European directives. The project assimilates Copernicus Marine Service's real-time datasets, which includes measurements from buoys, bottle sampling, and ferry boxes into regional and then down-scaled national biogeochemical models, complementing national monitoring efforts. Copernicus Marine data is specially featured due to its capabilities of providing open data from all sectors.

This project parallels the "Integrated Marine Monitoring (IMM)" joint initiative between Danish Agency for Green Transition and Aquatic Environment (SGAV) and DHI, with their real time in-situ platform providing model results and sharing monitored data from various sources, complementing the data-sources beyond national data from NOVANA.

At the core of the system is a modelling framework built on the DHI MIKE suite. Advanced data assimilation methods, including Optimal Interpolation and the Ensemble Kalman filter, are applied to calibrate environmental variables against observed data. This enables accurate and timely insights into marine ecosystem dynamics. The model complex constitutes several mechanistic models covering Danish water bodies in the North Sea as well as in the Baltic Sea, then downscaling from North Sea and Baltic Sea scale to costal bays and enclosed estuaries.

A major challenge in assessing ecological health is the reliable tracking of summer chlorophyll-a concentrations and assessment of oxygen depletion events. These form the basis of the two use-cases within Coastal DIAMONDS. Chlorophyll serves as a critical indicator of eutrophication and depletion events impact habitats and ecosystems the most.

Chlorophyll-a and oxygen estimates from the operational models are intended for publication on Denmark's national environmental data portal, ensuring that researchers and citizens can access up-to-date information and follow national efforts toward improved marine ecosystem health.

P1: 47 Monitoring and modelling of ocean currents inside the Anholt Offshore Wind Farm (Kattegat, Denmark)

Mohn, Christian[1]; Maar, Marie[1]; Larsen, Janus[1]

[1]Department of Ecoscience, Aarhus University

This study investigates the complex and still insufficiently understood interactions between ocean currents and offshore wind farms (OWFs), with a focus on local-scale hydrodynamic effects near individual wind turbine foundations. Despite growing interest in the environmental impacts of OWFs, empirical field data on local-scale current dynamics within OWFs remain sparse. We present results from in-situ sampling inside the Anholt OWF conducted over a 9-day period in August 2024. We conducted high-resolution measurements of current velocity, acoustic backscatter, temperature, and salinity using Acoustic Doppler Current Profilers (ADCPs) and CT (Conductivity, Temperature) sensors placed upstream and downstream of an OWF monopile. The study was motivated by the need to calibrate and validate hydrodynamic models that simulate flow dynamics, vertical mixing, and stratification in OWF environments. The measurements showed that wind forcing dominated the observed variations in water mass properties and currents, complicating efforts to isolate turbine-induced effects. However, data collected downstream of the monopile revealed a persistent near-bottom shear layer, alongside enhanced acoustic backscatter suggesting enhanced turbulence or sediment transport. Despite the brief sampling period, the observations captured a broad range of physical processes (e.g., wind and tide driven currents and episodic variations in the temperature and salinity record), demonstrating the potential of such local area data for validating and refining numerical models. From a modelling perspective, results from a hydrodynamic flume model (FlexSem) showed good agreement between simulated and measured flow characteristics, particularly when incorporating monopile drag parameterizations. We conclude that short-term field studies, while informative, are insufficient for capturing the full variability of OWF impacts. Therefore, we recommend longer-term monitoring, the deployment of denser ADCP arrays, and complementary ship-based surveys using vessel mounted (VM) ADCPs and CTD (Conductivity, Temperature, Depth) systems.

Onsdag 21-1 Postersession II

C13 – Poster II: 1-30

Pollution effects, assessment, and monitoring in the context of multiple stressors in the marine environment

P2: 1 Ecotoxicity of synthetic oils used in offshore wind turbines with bacteria, algae and copepods.

Fernandez Gonzalez, Carlota Marola[1]; Baun, Anders[2]; Skjolding, Lars Michael[2]

[1]DTU Sustain, [2]Technical University of Denmark

Offshore wind energy is expanding to support the global green energy transition, yet the environmental risks of associated chemical discharges remain unclear (Hengstmann et al., 2025). Especially, the high-performance synthetic oil present in up to 8,000 L for each offshore wind turbine (OWT).
Thus, the aim of this study is to determine the ecotoxicity of five synthetic oils (gear, lubricant, hydraulic, dielectric, and cooling oils) used in OWTs towards three regulatory-relevant marine species: *Aliivibrio fischeri* (bacteria), *Skeletonema pseudocostatum* (algae), and *Acartia tonsa* (copepod). The water accommodated fraction (WAF) was tested for new and spent oils. Additionally, the total organic carbon

(TOC) of each oil was measured to assess their contribution to the ecotoxicological response.
Growth inhibition of algae (*S. pseudocostatum*) was found to be the most sensitive endpoint among the tested organisms with toxicity (EC_{50}) ranging from highest to lowest: gear oil (0.0017%) > lubricant oil (0.021%) > dielectric oil (0.19%) > hydraulic oil (0.37%) > cooling oil (1.4%). New oils were generally more toxic than their used counterparts. Besides, normalization with TOC did not show linear correlation with the ecotoxicological response of the tested oils.
These findings highlight that oils used in OWTs can pose a risk on marine organisms, with gear and lubricant oils indicating the highest toxicity levels. Further studies to address the persistency and release rate of the synthetic oils are necessary to determine the long-term environmental impact of offshore wind energy, especially given the projected expansion.

P2: 2 Reading lifetime hormone profiles from fish bones

Gauthier, Charlotte[1]; Grønkjær, Peter[1]

[1]Aarhus University, Aquatic Biology

Fish populations undergo rapid environmental change, threatening their long-term sustainability. Warming waters, hypoxia, and contaminants can disrupt growth, reproduction, and survival by triggering physiological responses that reduce individual fitness, i.e., the ability to survive and contribute to the future population with offspring. Since changes in physiology often precede shifts at the population level, they can serve as early and sensitive indicators of environmental disturbance. However, such indicators are rarely used in fisheries management, largely due to methodological challenges — conventional tissues like blood or gonads offer only a short-term snapshot of fish condition. To overcome this, archival tissues such as otoliths and fish bones, which record aspects of a fish's physiological and environmental history throughout its life, offer an innovative solution. While initial work has shown that fish bones can retain hormone signals, their full potential to reveal detailed, long-term physiological profiles remains largely unexplored.
Our project introduces a new method combining lipid extraction with LC-MS/MS hormone quantification to reconstruct lifetime histories of stress and reproduction in individual fish using the steroid hormones trapped in their archival tissues. The objectives are to validate hormonal profiles in fish opercula as indicators of reproductive and stress history and use them to assess the effects of marine heatwaves on juvenile cod. This new method will deepen our understanding of how environmental pressures shape fish fitness and provide novel tools for more responsive, physiology-informed fisheries management. As the analyses are ongoing, this poster will focus on the theoretical basis of the approach and its planned validation steps, rather than on results.

Non-indigenous marine species – dispersal, effects, monitoring and mitigation.

P2: 3 The Limfjord as a Model for Invasive Homesteading and Habitat Transformation

Høeg, Jens T[1,1]; glenner, henrik[2]; Kjerulf Petersen, Jens[3]; Björn Källström, Björn; Granhag, Lena; Dahlgren, Thomas; Prins, Erik; Arnborg, Lars; Fredriksson, Sam; Brunnabend, Sandra-Esther; Carlstedt, Linn[4]; Bollongino, Pauline[2]; Rees, David John

[1]University of Copenhagen, [2]University of Bergen, [3]DTU Aqua, [4]Swedish Meteorological and Hydrological Institute

We propose the concept of *invasive homesteading* to describe how invasive foundation species can restructure habitats in ways that recreate key features of their native ecosystems. By engineering such "familiar" environments, these species open the door for other exotics from the same biogeographic region—often present only in small, scattered populations—to establish, thrive, and outcompete native flora and fauna. In this way, invasives gain an evolutionary advantage not as isolated pioneers, but as ecosystem builders that pave the way for further colonization.
A striking example comes from Limfjorden, where the Pacific oyster (*Magallana gigas*), introduced from Northwest Pacific coastal ecosystems recently has created extensive reef systems on formerly soft sandy bottoms. These oyster reefs act as ecological scaffolds, facilitating the settlement of additional non-native species from the same region and gradually transforming local communities toward an Asian coastal assemblage. Such developments illustrate how invasive homesteading can drive profound and lasting ecosystem change, highlighting that the ecological impact of biological invasions lies not only in single species introductions, but in the synergistic transformation of entire habitats.

P2: 4 Aggression and Competition Between Native and Invasive Shore Crabs in Northern Europe

Værøy, Tor

The Japanese shore crabs *Hemigrapsus takanoi* and *Hemigrapsus sanguineus* are both invasive in intertidal habitats of southern Scandinavia. They have been established for many years in the Wadden Sea (Denmark) and along the Swedish Kattegat coast, and more recently they have also been recorded in southeastern Denmark, the Limfjord, and southeastern Norway.
It has been suggested that their success in northern Europe is linked to a higher level of aggressiveness compared to their only direct native competitor in southern Scandinavia, the shore crab *Carcinus maenas*. In the present study, we report results from inter- and intraspecific behavioral experiments involving the three species. These experiments show that *H. sanguineus* is the most aggressive, followed by *H. takanoi* and *C.maenas*. Furthermore, *C. maenas* were the most active, presenting more opportunity for interaction. Additional territorial experiments were done, where the results suggest that *H. takanoi are* more territorial of shelter, than *C. maenas*.
The behavioral difference may help explain the observed decline of *C. maenas* in high intertidal Atlantic coastal zones of northern Europe and suggests that a similar decline may be expected in Scandinavia.

P2: 5 Comparison of different types of filters for retention of environmental DNA in marine aquarium water

Knudsen, Steen[1]; Møller, Peter[2]; Andersen, Jesper[1]

[1]NIVA Danmark, [2]Natural History Museum Denmark, University of Copenhagen

Monitoring of environmental DNA (eDNA) has over the past seven years been implemented in the Danish monitoring of marine non-indigenous species (Knudsen et al. 2022). The monitoring approach has been based on using enclosed 0.22 um pore size filters (Spens et al., 2017) that often end up being blocked by particles in the water. This might prevent sufficient volumes of water from being filtered and thereby limiting the detection of rare DNA molecules. In the attempt to narrow down if other filters could be used for this task, and if they can retain more of the targeted DNA molecules, we set up a water filtration experiment in the public marine aquarium 'Øresundsakvariet' (Figure 1). We tested 10 different filters in 16 replicates and used 6 species specific assays in a digital droplet PCR setup afterwards, to evaluate the levels of DNA retained from various species. A filter with a pore size of 3.0 um proved to be a thousand times better at retaining eDNA. Unfortunately, this was only evident from one of the six species targeted, and whether more eDNA can be withheld using larger pore size filters for other species is not possible to conclude from our limited study. Filters with a larger pore size can be complicated to handle, and are less easy to work with during fieldwork, compared with smaller pore size filters that are encapsulated in protective plastic cylinders. Our results do suggest that with an expanded study set up differently, there could be potential for increasing the chances of detecting low levels of eDNA with different types of filters.

P2: 6 Invasive and indigenous copepod species found in Danish waters

Engell-Sørensen, Kirsten Engell-Sørensen; Seebach, Poul

Copepods comprise a major part of the marine zooplankton biomass in Danish Waters. The poster will present a map visualizing the most important copepod species found in the Danish Waters during the NOVANA surveillance programme by the Danish Ministry of the Environment. We will present the most abundant, indigenous species, but also invasive copepod species, some that invaded years ago, like *Acartia tonsa* Dana, 1849-1852, and others that invaded recently.

Since 2021 three new copepod species were found in the Danish Waters. The calanoid copepod *Pseudodiaptomus marinus* Sato, 1913, discovered in The Limfjord and in the northern North (M. Utteri et al., 2023). The calanoid copepod *Tortanus (Boreotortanus) discaudatus* Thompson I.C. & Scott A. (In Herdman, Thompson & Scott, 1897), found in The Limfjord, The Sound and Kattegat and a cyclopoid copepod *Oithona* sp., yet to be species determined, well established in *The Sound, but also found in Kattegat, North Sea and Baltic Sea.* The poster will include the 3 invasive copepods and discuss possibilities of pathways of introduction.

P2: 7 NIS settlement in Danish harbors: Importance of environmental conditions and harbor type

Montesanto, Federica[1]; Montesanto, Federica; Koziol, Adam; Buur, Helle; Sapkota, Rumakanta; Winding, Anne; Staehr, Peter

[1]Ecoscience Department, Aarhus University

Coastal zones are biodiversity-rich ecosystems providing key services but are increasingly under pressure from urbanization, maritime traffic, and climate change. Harbors and marinas, concentrate many of these pressures: they provide artificial substrata that foster biofouling communities, yet differ markedly from natural habitats in environmental conditions and species composition (Seebens et al., 2013). A particularity of these artificial environments is their role as hotspots for non-indigenous species (NIS), which may dominate local assemblages and use harbors as stepping-stones for further spread. Strong environmental gradients within harbors, such as temperature, oxygen, salinity, depth, likely shape community composition and may enhance NIS persistence (Jensen et al., 2023).
Building on recent national surveys that identified more than 30 NIS across Danish ports and marinas combining conventional sampling methods with molecular tools such as eDNA, we aim to investigate how such gradients influence NIS distribution and community structure.
This work will provide a case study for understanding the role of artificial coastal infrastructures in shaping invasion dynamics. By integrating marinas and ports into monitoring frameworks and explicitly considering environmental heterogeneity, we seek to develop improved strategies for early detection and management of NIS, contributing to policy objectives under the EU Marine Strategy Framework Directive.

P2: 8 Comparative genomics of genes associated with local adaptation in non-indigenous species

Pujolar, Jose Martin; Jaspers, Cornelia

Centre for Gelatinous Plankton Ecology and Evolution, DTU Aqua - Technical University of Denmark

Non-indigenous species can pose significant ecological threats by outcompeting native species, disrupting local ecosystems and altering food webs. Among these, ctenophores (comb jellies) are known to establish and spread rapidly, often with considerable ecological impacts. Successful invasions often depend on local adaptation to specific environmental conditions such as salinity, light or temperature. Here, we use a comparative genomics approach to analyze the genomes of several ctenophore species, native and invasive to northern Europe. By taking advantage of the recent availability of fully annotated genomes, we interrogate the genomes for the presence/absence and percentage identify of key genes related to potential invasion traits. We identify bioluminescence as important target for successful invasions and discuss the implications in an invasion context.

P2: 9 Monitoring plastics in stomachs of northern fulmars from West and East Greenland

Strand, Jakob[1]

[1]Aarhus Universitet, Ecoscience

The amount and composition of ingested plastic in stomach of the seabird northern fulmar (*Fulmarus glacialis*) from two new sampling campaigns by local hunters in 2020, 2022 and 2024 in West and East Greenland, respectively, have been studied as part of the SUMAG-project with the aim of contributing to the monitoring and assessment of plastic pollution in the Arctic. The highest levels of ingested plastic were found in the birds collected in coastal waters of East Greenland nearby Tasiilaq (65° N latitude) in 2022, where 100% contained at least one piece of plastic and 68% with >0.1 g plastic. The birds contained 64 plastic particles in average, and with a maximum count of 403 particles in one bird.
Among the birds from West Greenland (also 65° N latitude), 93% contained at least one piece of plastic and 23% of the birds with >0.1 g plastic. These birds contained 15 plastic particles, in average and with a maximum of 61 particles. The populations from both sites exceeded thereby the OSPAR EcoQO threshold level defined as maximum 10% of birds must contain >0.1 g plastic. This can indicate less exposed populations.
The composition of ingested plastic was at both sites dominated by hard plastic fragments, but also film, foam, threads and other plastic particles were present. Especially foamed plastic occurred much more in samples from West Greenland with 31% of all particles compared to only 1% in East Greenland. Some more recognizable plastic items like net cuttings, softgun bullets, tag strings for cloths and toy pearls were also observed among the ingested plastic. The plastic particles mainly composed of the low-density polymers polyethylene, polypropylene and polystyrene, although few particles of other polymers were

also observed.
The data set will together with previous generated data from West Greenland from 2000 and 2016 and Northeast Greenland in 2017 contribute to wider assessments of plastic pollution in the Arctic marine environment on this AMAP and OSPAR recommended monitoring indicator.

Miljøfarlige stoffer og Plastik i Havmiljøet

P2: 10 Monitoring shoreline litter in Greenland

Strand, Jakob[1]; Bach, Lis[2]; Juul Pedersen, Thomas[3]

[1]Aarhus Universitet, Ecoscience, [2]Aarhus University, Dept. Ecoscience, [3]Greenland Institute for Natural Resources

Since 2016, the SUMAG project has conducted nearly 140 beach litter monitoring surveys, covering more than 11,000 meters of shoreline. These surveys have been carried out annually at several fixed shoreline locations in West and East Greenland, in collaboration with a dedicated local network of surveyors, including both volunteers and researchers in Greenland. The surveys employed a modified version of the OSPAR CEMP monitoring guideline, incorporating additional categories inspired by EU MSFD monitoring guidance and also adding some other items identified as more relevant for the Arctic.
The results of the surveys showed that plastic litter was more prevalent on the shorelines in West Greenland than in East Greenland. Additionally, compositional analyses revealed that single-use Plastics (SUP) and other land-based plastic items were more common in West Greenland, while fishery-related items were more prevalent in East Greenland. Further analysis suggested that local sources in West Greenland were the primary contributor to marine litter.
However, the study also found encouraging signs of progress. Trend analyses showed a decreasing tendency in litter amounts at the shorelines in some areas of West Greenland, suggesting that local management plans to reduce plastic use and improve waste handling, coupled with increased public awareness, are beginning to have a reduce plastic use and improve waste handling, coupled with increased public awareness, are beginning to have a positive impact on reducing plastic pollution in the sea.

P2: 11 Seabirds Under Pressure (SUPRE): Opstart af undersøgelser på ilanddrevne havfugle i danske farvande

Strand, Jakob[1]; S. Christiansen, Simon; Krag Petersen, Ib[2]; Metcalfe, Ryan[3]; Frederiksen, Morten[1]

[1]Aarhus Universitet, Ecoscience, [2]Aarhus Univerisitet, Ecoscience, [3]KIMO Danmark

Havfugle er anerkendt som vigtige indikatorer for havmiljøets tilstand og er prioriteret inden for EU's og Danmarks havstrategi, der omfatter biodiversitet, fødenetværk, forurening og marint affald (D1, D4, D8, D10), samt under OSPAR, HELCOM og i Arktis. Alligevel oplever flere arter af havfugle, der i store tal også fouragerer i de danske farvande markante tilbagegange. Disse farvande udgør vitale fødesøgningsområder for bl.a. alkefugle, rider, mallemukker og suler, men arterne udsættes for en række samtidige presfaktorer. Blandt de væsentligste trusler er klimaændringer og ekstreme vejrhændelser, ændringer i fødenet, sygdomme, interaktioner med fiskeri og offshore-aktiviteter samt forurening fra miljøfarlige stoffer og marint affald, især plast.
SUPRE-projektet (Seabirds Under Pressure) har til formål at styrke forståelsen af, hvordan disse trusler påvirker havfugle i danske farvande, og at bidrage til udviklingen af målrettede løsninger. Et centralt element er etableringen af et landsdækkende citizen science-baseret overvågningsnetværk, koordineret af Dansk Ornitologisk Forening DOF) i samarbejde med lokale frivillige "strandvogtere."
Fokus i projektet er i første omgang at få mere systematiske registreringer af ilanddrevne fugle, der kan levere data om forekomst og dødsårsager. Disse data suppleres med forskning i havfuglenes eksponering for miljøgifte (fx kviksølv, PFAS, olie og plast) samt populationsgenetik hos følsomme nøglearter.
En væsentlig dimension af SUPRE er inddragelse af interessenter. Gennem samarbejde med myndigheder, erhverv og civilsamfundet vil projektet identificere praktiske løsninger til at reducere havbaserede kilder til forurening og øge bevidstheden om betydningen af at beskytte havfugle og havmiljø.

P2: 12 WANTED: Your observations of interactions between wild animals and plastic litter !

Strand, Jakob[1]; Matos, Diana; Dietz, Rune; Sonne, Christian; Vorkamp, Katrin[2]

[1]Aarhus Universitet, Ecoscience, [2]Aarhus University, Environmental Sciences

Plastic pollution is increasingly recognized as a threat to Arctic and SubArctic ecosystems, affecting wildlife across terrestrial, freshwater, and marine environments. While much attention has been directed toward quantifying plastic loads, less is known about the direct interactions between wildlife and plastic debris, particularly in high-latitude regions. To address this knowledge gap, the citizen science project ***Plastics & Wildlife in the Arctic, SubArctic and Northern Europe*** (https://www.inaturalist.org/projects/plastics-wildlife-in-the-arctic-subarctic-and-northern-europe) invites contributions from nature enthusiasts, hunters, fishermen, schools, researchers, and citizens at large.
This initiative is part of the Horizon Europe ArcSolution project and focuses on instances of harmful and non-harmful interactions of wildlife with plastic litter. This include observations such as entanglement in nets, lines, or packaging; ingestion of plastics; use of plastic items as nesting material; biofouling of organisms attached to litter; and other direct interactions. Observations can easily be reported via the user-friendly iNaturalist mobile app or web platform, with or without photographic evidence.
Contributions may be identified at species level or broader taxonomic categories, ensuring accessibility for both experts and non-experts.
Incidences of wildlife interacting with plastic debris will be more likely in urban areas and at pollution hotspots such as landfills. However, they can also occur in remote areas, e.g. on shorelines or in bird colonies. All observations are relevant for the project. However, we are not interested in observations of animals caught in e.g. active hunting and fishing gear and neither bycatches - only if remains are left behind as litter in the environment.
To harmonise reporting, contributors are asked to provide additional metadata including animal condition, type of interaction, litter category, and location details. This systematic approach enables the compilation of harmonised datasets across a broad geographic range, with information on the most frequently impacted species and types of impacts. Moreover, public participation fosters awareness of the impacts of plastic litter on Arctic biodiversity. Ultimately, this initiative contributes to improved knowledge on the ecological consequences of plastic pollution, as also addressed by the Arctic Monitoring and Assessment Programme (AMAP), strengthening both scientific understanding and societal engagement in protecting fragile northern ecosystems.

P2: 13 The history of the MarinePlastic research centers!

Kristian Syberg, Jakob Strand, Annemette Palmqvist, Steffen Foss Hansen, Nanna Hartmann, Jes Vollertsen

Marine plastic pollution represents one of the most pressing environmental challenges of our time, with an estimated 4–12 million tons of plastic entering the oceans annually. In response, the VELUX Foundation has funded two major interdisciplinary research initiatives in Denmark: **MarinePlastic** and its successor **MarinePlastic II**. These centers unite leading Danish researchers to address the complex dynamics of plastic pollution across its lifecycle—from production and use to environmental degradation and impact to policy responses.

MarinePlastic I (2019–2023) laid the foundation by investigating the sources, distribution, and ecological impacts of plastic debris, including microplastics. It emphasized the need for robust scientific data to inform societal solutions and policy development. The center adopted a life-cycle approach and engaged with stakeholders to ensure the relevance and applicability of its findings. The participants of the center united around flagship projects, including a nationwide citizen science project that mapped plastic litter throughout the Danish realm and an expedition that made a comprehensive monitoring microplastic in Kattegat, including assessment of surface water, water column, biota and sediment.

Building on this success, **MarinePlastic II** (2024–2027) build on the outcome of MP1 and focused the research into three core research areas: (1) the role of science in shaping regulations and enabling a transition to a circular economy; (2) the development of advanced methods for detecting and monitoring micro- and nanoplastics; and (3) the assessment of environmental and ecotoxicological impacts of nanoplastics and associated chemical additives.

MarinePlastic II aims to strengthen Denmark's international research profile, generate groundbreaking knowledge, and propose actionable solutions to mitigate marine plastic pollution. Through interdisciplinary collaboration and stakeholder engagement, the centers contribute to global efforts such as the EU Marine Strategy Framework Directive and the UN Plastic Treaty negotiations.

Marine restoration in a Danish context

P2: 14 Fiskehotellet: Målrettede rev til ferskvandsfisk i brakvand

Andersen, Lars Emil Juel[1]; Christian Svendsen, Jon

[1]DTU Aqua

I samarbejde med Foreningen Køge Bugt Stenrev er projektet "Fiskehotellet" udviklet som et målrettet tiltag til at styrke specifikke fiskearter i Køge Bugt. Området er karakteriseret ved lav salinitet og fungerer som opvækstområde for arter som rimte (*Leuciscus idus*), aborre (*Perca fluviatilis*) og havørred (*Salmo trutta*). Disse arter er tæt knyttet til vandløbene i oplandet, herunder Tryggevælde Å, Køge Å og Vedskølle Å, hvor fiskene reproducerer. Meget tyder på at arterne kan have gavn af flere levesteder og skjulmuligheder i kystnære brakvandsområder, hvor fiskene ofte bruger omkring halvdelen af deres liv.. Et centralt problem er her prædation fra især skarv og sæl, som kan reducere overlevelsen.

Fiskehotellet adskiller sig fra tidligere restaureringsprojekter, der primært har haft fokus på at øge den generelle biodiversitet. Fiskehotellet tager udgangspunkt i konkrete arter og deres udfordringer – i dette tilfælde behovet for bedre levesteder i kystzonen. Det er særligt relevant i en dansk kontekst, hvor der allerede er investeret betydelige midler i restaurering af ørredens levesteder i vandløbene. Ørreden indgår desuden i EU Vandrammedirektivet som indikatorart for økologisk tilstand, hvor de fleste vandløb fortsat ikke lever op til direktivets krav.

Effekten af de udlagte rev undersøges ved hjælp af et BACI studiedesign (Before-After Control-Impact) med replikater, hvor både før- og efterundersøgelser inkluderer kontrolområder og rev-områder. Monitoreringen udføres ved snorkeltransekter i mørke, hvor fiskenes naturlige aktivitetsmønstre øger sandsynligheden for at observere deres brug af de nye habitater.

Projektet bidrager med vigtig viden om, hvordan målrettet habitatforbedring i kystnære brakvandsområder kan understøtte fiskebestande, heriblandt ferskvandsfisk. Vores nyskabende resultater informerer desuden fremtidige tiltag i danske farvande, hvor behovet for kombinerede løsninger – med fokus på både biodiversitet, prædations-pres og arter af særlig forvaltningsmæssig betydning – er stigende.

P2: 15 Koblet model og GIS-værktøj til vurdering af pelagisk og bentisk primærproduktion ved reduktion af landbaseret næringsstofbelastning til Vejle Fjord

Lees, Mikkel Keller[1] Kadri Kuusemäe[2], Anders C. Erichsen[2], Mogens R. Flindt[1] & Paula Canal-Vergés[1]

[1]Syddansk Universitet, Biologisk Institut

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Intensivt landbrug gennem de seneste årtier har øget næringsstofbelastningen i estuarier og kystvande og derved markant forringet de økologiske forhold. Dette studie præsenterer et GIS-baseret værktøj, der anvender højopløselige data fra en mekanistisk biogeokemisk model til at kvantificere de økologiske gevinster af næringsstofreduktion i et dansk estuarie. Tre reduktionsscenarier (30 %, 50 % og 70 % reduktion i kvælstof- og fosfortilførsler) blev simuleret for at vurdere effekterne på primærproduktion, vækstdynamikker og økosystemtjenester.
Resultaterne viste en markant eutrofieringsgradient, hvor koncentrationerne af opløst uorganisk kvælstof (DIN) faldt eksponentielt fra hovedudløbet mod den ydre fjord. Modellen beskrev tydeligt responsen på næringsstofreduktioner, herunder en kraftig nedgang i planteplanktonproduktionen og et skift fra pelagisk til bentisk domineret primærproduktion. Lysforholdene ved bunden blev forbedret, hvilket skabte betydelige arealer egnede til naturlig eller assisteret genetablering af ålegræs. Inden for den relativt korte simuleringsperiode var potentialet dog begrænset, idet kun beskedne stigninger i biomasse og produktion blev registreret. Den begrænsede respons skyldtes dels et højt organisk indhold i sedimentet som kun ændres over en meget lang tidsskala, og dels en meget lav initial biomasse af ålegræs som er en vigtig faktor i vækstkinetikken.
Det konkluderes at næringsstofreduktioner væsentligt forbedrer vandkvaliteten og accelererer regimeskiftet mod bentisk kontrollerede systemer. Dette understreger, at reduktion af næringsstofbelastningen er en forudsætning for at opnå god økologisk tilstand (GES). Imidlertid reagerer sedimentkarakteristika langsommere, hvilket begrænser den fulde effekt af reduktionerne. Desuden understøttes reetableringen af ålegræs ikke tilstrækkeligt som et resultat af for lave initialbiomasser. Derfor er assisterede marine restaureringsforanstaltninger nødvendige for at fremskynde genopretningen og sikre opfyldelse af Vandrammedirektivets (WFD) målsætninger. Her peges i særlig grad på Sandcapping og assisteret ålegræs reetablering ved udplantning.

P2: 16 High-density sediment mapping reveals challenges in quantifying ecosystem functions in restored eelgrass

Frederik H. Hansen, Rune C. H. Steinfurth, Mogens R. Flindt [1]

[1]University of Southern Denmark

SDU have restored a large-scale eelgrass bed in Horsens Fjord covering 4000 m^2 through the TRANSPLANT project. The eelgrass bed was transplanted in 2017 and in 2019 it already had shoot densities comparable to nearby natural populations (Lange et al. 2022). The introduction of eelgrass has caused an accretion of organic material in the sediment and thus has provided an ecosystem function of burial of nutrients. However, in the published literature there is not a consensus on how to quantify this ecosystem function. Sediment cores are often used but the appropriate depth of sediment, the necessary number of replicates, and the use of a comparable control sites are all parameters that are not consistent across the literature. For that reason, we at SDU have collected 62 sediment cores in a grid-pattern to map the heterogeneity of the sediment both in the restored meadow and the surrounding bare bottom which will act as the control. This poster will present the first results from several sediment parameters such grain size, LOI and nutrients. GIS-tools have been used to analyze these data and create map material that provides a better visual understanding of how the accretion functions and the primary drivers/limiters of this ecosystem function.

P2: 17 Fra midte til kant: Transektundersøgelse af artsrigdommen i et diffust stenrev i Gyldensteen Kystlagune

Kiilerich, Karoline; Kristensen, Erik; Quintana, Cintia

Syddansk Universitet

Når to forskellige habitater mødes, er der ofte en overgangszone, hvor der findes en højere biodiversitet og artsrigdom. Dette kan skyldes en gradient af biologiske og fysiske forhold, som derved kan understøtte flere forskellige arter og deres behov. To forskellige habitater i det marine miljø, kan fx være stenrev og barbund. Sådan to tilstødende habitater kan findes i den genetablerede Gyldensteen Kystlagune, da der i 2022 blev anlagt to diffuse stenrev på hver ca. 1 ha med tilgrænsende sandkapper til hvert stenrev. For at undersøge, om der var en højere artsrigdom af dyr og alger i yderkanterne af stenrevene end inde midt i, blev der i efteråret 2024 taget prøver af fastsiddende dyr og alger fra stenene i tre transekter på hvert stenrev så hver prøve havde forskellige afstande til afgrænsningen af stenrevene. Denne poster vil komme ind på, hvilke faktorer, der kan have haft indflydelse på artsrigdommen og den rummelige fordeling af arter i de diffuse stenrev i Gyldensteen Kystlagune.

P2: 18 Designing with dispersal: Connectivity Informed Site Selection

Gaia Grieco, Janus Larsen, Vibe Schourup-Kristensen, Charlotte H. Clubley, Ange Pacifique Ishimwe, Marie Maar

Department of Ecoscience, Aarhus University,

Bivalve beds play an important role in coastal ecosystems, and understanding factors that influence their persistence and recruitment is therefore critical, especially given the strong impact of human activities on these habitats. Marine mussel bed restoration projects have therefore gained momentum in recent years. However, bivalve bed restoration success critically depends on well-planned site selection that optimises larval connectivity to ensure recruitment and long-term population viability. Here, we present a comprehensive connectivity analysis to determine recruitment and potential restoration of blue mussel (*Mytilus edulis*) reefs, exemplified for Roskilde Fjord, Denmark. Hotspots for potential new blue mussel reefs were first identified based on habitat suitability and environmental conditions and then overlapped with site selection guidelines. A biophysical model was then used to predict larval dispersal. Graph theory metrics were used to characterise the connectivity patterns in the basin. This analysis showed that carefully planned reef placement can improve the survival of the mussel population by achieving more homogeneous connectivity and increasing inter-site connections. Modelling of the external larval supply demonstrated minimal recolonisation potential from outside the system, highlighting the critical importance of internal connectivity for recruitment. While reducing nutrient loads in the basin is still a major concern, our results provide quantitative evidence-based guidance for optimising bivalve recruitment. Moreover, integrating biophysical modelling with network analysis provides an improved framework for identifying sites with a higher chance of establishing new bivalve reefs through enhanced larval connectivity, with broader applications for potential marine restoration efforts in semi-enclosed coastal systems worldwide.

Greenland's coastal ecosystems in a changing climate

P2: 19 From studying microscopic algae to understanding food webs in Greenland's fjords

Vonnahme, Tobias; Schleijpen, Lisa; Meire, Lorenz; Gaber, Hannah; Juul-Pedersen, Thomas; Zwerschke, Nadescha; Maier, Sandra; Nordberg Nilsson, Karoline; Langley, Kirsty; Raundrup, Katrine; Jacobsen, Ida; Lopez-Blanco, Efren

Invisible to the naked eye microscopic microalgae form the base of marine food webs. In various fjords around Nuuk, we found complex and variable dynamics and environmental drivers of these essential organisms across years, seasons, and locations. Influences range from land and glaciers to the seafloor, shelf, and distant offshore waters. Understanding these drivers then allows us to study how microalgae affect higher trophic levels of direct economic or societal importance. Scallops for example, rely directly on a microalgae diet. A growth model demonstrated that scallop production in Kangerluarsunnguaq only used a fraction of local microalgae production, suggesting additional grazers or microalgae loss to the shelf or seafloor. For other commercially important species like cod and snow crabs, which don't directly consume microalgae, comprehensive food web models are essential to understand how microalgae impact these predators. Our study highlights the importance of microalgae in Greenland's marine ecosystems and economy and suggest ways to link them via food web models.

P2: 20 Center for ice-free Arctic research

Rysgaard, Søren

The Arctic Ocean, despite its relatively small size, receives about 11% of the world's river runoff. This, combined with freshwater from increasing melting of sea ice and Greenland's glaciers, is leading to rapid freshening of the region. This accumulation of freshwater alters the physical and biogeochemical dynamics of the ocean and can potentially disrupt the thermohaline circulation, which plays a critical role in regulating global climate. Freshening also affects marine ecosystems, but predicting the overall impact is diffucult due to the complexity of the processes involved.

The Center for Ice-free Arctic Research (CIFAR) aims to investigate the consequences of melting ice and increased freshwater influx in the Arctic and I will provide an overall presentation of the center activities as well as a few new result from the first field campaigns. The CIFAR program (focused on the Arctic's East Greenland region) aims to understand how the loss of ice and freshening will change ocean properties, marine biogeochemistry, and ecosystems. One of its key projects is to study the patterns and impacts of freshwater runoff from glaciers, which affects coastal water quality and biogeochemical cycles. Another focus is on the exchange of freshwater between fjords and the coastal shelf, which influences marine biological productivity and nutrient distribution.

CIFAR will also investigate how the loss of sea ice and increased freshening will alter primary production and marine food webs. As ice loss changes light and nutrient availability, it may shift the composition of primary producers and alter the structure of marine ecosystems. Moreover, the freshening of surface waters could lead to a decline in nutrient availability, potentially limiting biological production in some areas.

By combining field data, satellite observations, and modeling, CIFAR will provide a comprehensive understanding of how freshwater input, ice loss, and biogeochemical changes will reshape the Arctic Ocean. This research is critical not only for predicting the future of the Arctic but also for understanding the broader implications for global climate and the livelihoods of coastal communities in the region.

P2: 21 From Fjords to Slopes: Long-Term Dynamics of Greenland's Marine Ecosystems

Juul-Pedersen, Thomas[1]; Vonnahme, Tobias[1]; Merz, Alenya Silvia[2]; Mortensen, John[1]; Lee, Craig[3]; Azetsu-Scott, Kumiko[4]; Ostermann, Else[1]; Hammer, Katharina Lysgård[1]

[1]Greenland Climate Research Centre, [2]University of Groningen, [3]University of Washington, [4]Fisheries and Oceans Canada

The marine ecosystems of Greenland, spanning from glacially influenced fjords to offshore continental slopes, represent dynamic environments of both local and global significance in a rapidly changing climate. Fjords serve as convergence zones where glacial discharge, terrestrial runoff, and oceanic processes interact to shape circulation, nutrient dynamics, and phytoplankton production. These processes sustain productive food webs that support fish, seabirds, and marine mammal species critical for local fisheries and subsistence hunting. Meanwhile, Greenland's offshore continental slopes function as

biological hotspots, where dynamic oceanographic conditions and nutrient availability extend productive seasons and sustain rich fisheries vital to both the economy and society.

Phytoplankton biomass and production in high-latitude waters are often underestimated due to limited *in situ* data and the depth constraints of remote sensing products, leaving major gaps in our understanding of their true productivity. Despite their central role in marine food webs, plankton communities in both fjord and offshore systems remain understudied, and the ecological links between coastal and offshore ecosystems are still poorly understood, even as growing evidence highlights their strong interdependence.

Ongoing monitoring and research are beginning to bridge these knowledge gaps. Here, we highlight two multidecadal studies from a fjord and an offshore ecosystem along West Greenland. By linking insights from fjord and continental slope ecosystems, this work underscores the central role of phytoplankton in sustaining biodiversity, marine carbon cycling, and fisheries across Greenland's coastal and offshore waters, while emphasizing the urgent need to understand how climate-driven freshwater inputs and oceanographic changes will reshape these vital ecosystems.

P2: 22 Small-scale eddy dynamics on the East Greenland Shelf from SWOT (Fresh4Bio)

Andersen, Ole Baltazar

The recently launched Surface Water and Ocean Topography (SWOT) mission provides Sea Surface Height (SSH) observations over a 120 km wide swath at 250 meters resolution throughout the worlds oceans every 20 days. This presents a unique opportunity to map small mesoscale and submesoscale ocean dynamics that are not currently resolved by nadir altimetry. This is especially important in the Arctic, where the typical scale of mesoscale motion shrinks to ranges between 5-60 km, and where many observational studies are limited by the presence of sea ice and/or clouds. In the Fresh4Bio project, we derive high-resolution (2 km) maps of ocean topography, geostrophic current, and relative vorticity on the East Greenland Shelf from April 2023 to September 2025 by assimilating SWOT and nadir altimetry data in a 1.5-layer quasi-geostrophic model. During the winter period, we applied a sea-ice filter to enhance the SWOT spatial-temporal coverage. SWOT provides an efficient way to map rapidly evolving small-scale structures and reveal previously unresolved processes in the marginal ice zone (see figure). The SWOT derived dataset agrees well with Sentinel 2 & 3 derived chlorophyll a and surface temperature, in the position and structure of fronts and eddies. A case study of a 20-km cold-core eddy with elevated chlorophyll-a, detected simultaneously in SWOT-assimilated maps and optical remote sensing data, demonstrates the potential for coupled physical–biological studies of small eddies in the Arctic. This eddy was unobserved in conventional altimetry from the DUACS multimission maps.

Marin Biodiversitet

P2: 23 Bird modelling Saare Liivi Estonia

Bjerregård, Emil Blicher

The Saare Liivi Offshore Wind Farm (OWF) in the Gulf of Riga, will comprise up to 120 turbines with a capacity of 1.2 GW. The project area coincides with important wintering grounds for two vulnerable sea duck species: the long-tailed duck (*Clangula hyemalis*) and the velvet scoter (*Melanitta fusca*). Both are known to be sensitive to disturbance and habitat displacement caused by offshore wind.
Our approach was inspired by the Dutch KEC4 framework (*Kader Ecologie en Cumulatie 4.0*), which provides a holistic methodology covering all stages from data acquisition and modelling to cumulative assessment. While this study represents an application of such principles in the Baltic context, it highlights both the need for international harmonisation of methods and the potential of advanced modelling frameworks to improve confidence in seabird impact assessments.
This EIA focused on quantifying displacement and evaluating its potential ecological consequences. Based on aerial surveys (2022 to 2024), species distribution was modelled using Generalized Additive Models (GAM), combined with distance sampling and GIS analyses, forming a comprehensive displacement modelling framework. Displacement rates were informed by the best available evidence and applied within the development footprint and surrounding buffer zones to estimate potential habitat loss and disturbance.
To evaluate the longer-term consequences, a Population Viability Analysis (PVA) was conducted. Since evidence-based mortalities caused by displacement are not available, assumptions had to be made. We followed the KEC4 approach calculating conservatively with a 10 % mortality for all displaced birds. The approach incorporated age-structured demographic data and simulated population dynamics over

multiple generations, allowing assessment of both project-specific and cumulative impacts. The PVA indicated that, although the species are likely to be displaced from parts of the development area, the overall population is expected to remain robust. Cumulative effects from additional regional developments were identified as more pronounced but still within a range suggesting population persistence.
The study demonstrates how combining displacement modelling with population-level analyses provides a robust framework for assessing ecological consequences of offshore wind development. It illustrates the value of applying integrated approaches inspired by frameworks such as KEC4 to improve confidence in seabird impact assessments and support decision-making in the planning of offshore wind energy projects.

P2: 24 Findes der landskaber på havet – og bør vi beskytte dem?

Struve Olsson, Anke

Begrebet *landskab* forbindes traditionelt med landjord, men kan det også anvendes i en marin kontekst? Mange forbinder havlandskaber med romantiske malerier af skibe på åbent hav, men spørgsmålet er, om landskabstilgangen også kan anvendes videnskabeligt i forhold til havet – både over og under overfladen.

I denne poster undersøger vi, hvordan landskabsbegrebet kan overføres fra land til hav. Vi ser på, om metoder til landskabskortlægning og -analyse kan anvendes i en marin kontekst, og hvordan både natur- og kulturbetingede elementer bidrager til det marine landskabs karakter. Det omfatter både det visuelle og rumlige udtryk over havoverfladen og det undersøiske landskab.

På land beskyttes særligt karakteristiske landskaber gennem kommuneplanlægning og landskabsudpegninger. Havets landskaber – og samspillet mellem hav og kyst – har derimod begrænset opmærksomhed og ingen tilsvarende beskyttelse for arealer på havet. Samtidig kan nye anlægsprojekter her ændre den landskabelige oplevelse markant, både til søs og fra land. Da planloven ikke gælder for havet, rejser det spørgsmålet: Bør vi indføre en form for landskabsbeskyttelse til havs af udvalgte særlig karakteristiske landskaber?

P2: 25 Creating habitats for blue biodiversity in Danish harbours with 3D printed concrete

Parkinson, Joseph William; Parkinson, Joseph William; Jacobsen, Lars Magnus Wulf[1]; McLaverty, Ciaran[2]; Fonseca, Rute A.R.[3]; Macnaughton, Martin[4]; Kunther, Wolfgang

[1]Technical University of Denmark, [2]University of Exeter, [3]University of Copenhagen, [4]Sund & Bælt Holding A/S

The status of marine ecosystems in Danish waters is one of decline. Human and climate pressures in Danish waters are contributing factors to marine biodiversity loss. Historically, the removal of hard substrate, such as boulder extraction for construction purposes, has exacerbated biodiversity decline through loss of habitat. The homogenous nature of marine infrastructure, not least the removal of natural and spatially complex coastal habitats, lends to low biodiversity environments [1]. By introducing habitat heterogeneity to anthropogenically influenced coastal environments, such as ports, it is hoped biodiversity loss can be mitigated. Enhancing hard substrate habitat restoration with biologically driven and nature inclusive design could potentially lead to improvements in biodiversity status. Concrete 3D printing is a technology with the capabilities to establish biologically enhanced design of hard substrate. By creating varying surface rugosities and structural complexities, concrete modules can be designed and submerged to fill and utilise vacant structural space created by sheet-piling seawall structures. The idea is to create conditions and new habitats for recruiting marine ecosystem-engineering species, such as macroalgae, bivalves and mobile species to colonise and create functional and interactive biodiversity at the reef sites. In this project, 64 reef modules with three biologically enhanced designs have been submerged at four reef sites along the seawall at the Port of Korsør, Zealand, Denmark. Early monitoring results from ecosystem development will be presented to determine whether nature inclusive concrete can establish improvements in biodiversity compared to homogenous seawall infrastructure, and reference sites. A combination of ROV, video, image analysis and applied eDNA methodologies will form the basis of a comprehensive monitoring program. Sampling will take place on a spatial and temporal scale to understand succession, connectivity and interactions in the community to determine the suitability of concrete substrate as a viable reef material for improving biodiversity.

P2: 26 Marin geodiversitet i lavvandede kystnære områder i Lillebælt

Larsen, Mette[1]; Andersen, Mikkel Skovgaard[1]; Larsen, Isak Ring[1]; Nielsen, Nina Lei Juul[1]; Hansen, Lars Øbro[1]; Blok, Carlette Neline[1]; Al-Hamdani, Zyad[1]; Ernstsen, Verner Brandbyge[1]

[1]GEUS

Geodiversitet bliver ofte karakteriseret som fundamentet for biodiversitet, men koblingen går begge veje med en mere eller mindre dynamisk interaktion. En økosystembaseret forvaltning forudsætter derfor integration og dermed kortlægning og monitering af både geo- og biodiversitet. En fladedækkende højopløselig kvantificering og kortlægning af geodiversitet er derfor central med henblik på optimeret forvaltning (Ernstsen et al., 2017).
GEUS udfører for Miljøstyrelsen kortlægning af havbunden i lavvandede kystnære områder i dele af Lillebælt. Projektets formål er at forbedre data, information og viden om Lillebælt med henblik på at optimere naturforvaltningsgrundlaget, herunder også at bidrage til at kunne kortlægge potentialet for naturgenopretning i området. Projektet omfatter bl.a. kortlægning af havbundens batymetri, morfometri, morfologi, substrattyper og naturtyper samt menneskelig påvirkning. Kortlægningen er baseret på flybåren scanning (grøn lidar og RGB) i kombination med groundtruth data, bl.a. ROV-videoer. Flybåren havbundskortlægning er state-of-the-art i lavvandede kystnære områder og muliggør en fladedækkende og detaljeret (højopløselig og højpræcis) 3D kortlægning af havbundsoverfladen med en sømløs overgang til land på tværs af kystlinjen. De indsamlede data vil bidrage til på sigt at kunne opstille geologiske og geomorfologiske konceptuelle modeller for området, hvilket er vigtigt med henblik på bæredygtig naturforvaltning i dynamiske hav- og kystområder og i forhold til inddragelse af effekter og konsekvenser af klimaforandringer i lavvandede dynamiske hav- og kystområder. Vi præsenterer resultater fra kortlægningen med eksempler på forskellige komponenter af geodiversitet.

P2: 27 Environmental DNA Approaches for Bycatch Assessment in Pelagic Fisheries

Strand, Nina[1]; Maggini, Sara[1]; Wullf Jacobsen, Lars Magnus[1]; Eg Nielsen, Einar[1]

[1]DTU Aqua

Reliable estimation of bycatch is crucial for sustainable fisheries management and biodiversity conservation. Yet current monitoring approaches—such as fishermen logbooks, 3rd party observer programs, and manually sorting and counting fish – the so-called "bucket method"—are limited by small sample sizes, high costs, and reliance on visual identification by different observers with variable levels of expertise. Even a few percent of bycatch in landings of several thousand tonnes can represent a substantial biomass of non-target species. In this study, we developed and tested environmental DNA (eDNA) approaches, including droplet digital PCR (dPCR) and metabarcoding, to assess catch composition in a pelagic fishery of blue whiting (*Micromesistius poutassou*). Controlled experiments with known species mixtures of blue whiting with primary bycatch species were first used to evaluate DNA-to-biomass conversion, followed by application to industrial-scale landings.
Our results show that eDNA-based methods provide higher taxonomic resolution and reproducibility compared to the bucket method, while also detecting rare bycatch species that would remain undetected by visual subsampling. Metabarcoding identified a multitude of mesopelagic species, most of which are currently pooled into the group *"lanternfish"* by third-party observers, masking important aspects of biodiversity in bycatch data. By revealing both small, rare taxa and large, low-abundance individuals, eDNA substantially improves the detection of biodiversity within catches. Metabarcoding in particular revealed the presence of low-abundance taxa of ecological concern, underscoring the potential of eDNA to improve the precision of bycatch estimates and support more comprehensive ecosystem-based fisheries management.

P2: 28 Integrating Ecological and Genomic Diversity for Climate Resilient Marine Spatial Planning

Yazici, Tunca Deniz[1]; Bekkevold, Dorte[2]; Hemmer-Hansen, Jakob[2]

[1]DTU Aqua – National Institute of Aquatic Resources, [2]DTU Aqua - National Institute of Aquatic Resources

Rising temperatures, ocean acidification, deoxygenation, and changing sea levels severely stress marine environments. These stressors, compounded by anthropogenic activities such as pollution, habitat destruction, and overfishing profoundly threaten marine biodiversity and disrupt essential ecosystem functions, including food provision, carbon cycling and climate regulation. The resulting loss of biodiversity weakens the resilience of marine systems, undermining their ability to adapt to further change.

Considering these threats on the oceans, habitat restoration and conservation of biodiversity is vital. However, managers face the challenge of prioritizing areas and species for protection in the face of complex and interacting threats. Addressing this challenge requires an evaluation of the current and potential impacts of climate change. To evaluate those impacts, our understanding of climate change vulnerability must grow not only on species but also on the community and ecosystem levels.

We tackle the question of how biodiversity can be preserved in a changing climate through spatial planning and habitat restoration. We use an ecosystem engineering species, sugar kelp (*Saccharina latissima*), both as target species, and as ecosystem indicator. We investigate its genomic diversity and climate change vulnerability where we will combine this information with an evaluation of sugar kelp associated community diversity through eDNA data from a range of locations. We will make predictions of species and population vulnerability to future climate change through genome scans, genotype-environment associations and connectivity assessments.

P2: 29 How to "B-USEFUL" in marine biodiversity conservation: from monitoring to decision-making

Martin Lindegren

DTU Aqua

We are currently experiencing a rapid and accelerating loss of marine biodiversity worldwide which threatens not only unique habitats and species, but also key ecosystem functions and services essential for our well-being (e.g., food provisioning and climate regulation). Tackling the "biodiversity crisis" requires well-informed science advice allowing managers to devise conservation actions for biodiversity protection and restoration, including Marine Protected Areas (MPAs) and other Nature-Based Solutions (NBS). However, to ensure that such actions are efficient meeting global and regional policy targets (e.g., the EU Biodiversity Strategy 2030), it is of paramount importance to improve our capacity to map and assess the status of biodiversity in space and time, as well as anticipating the risk and responses of biodiversity to human impacts (e.g, climate change and overexploitation). This requires appropriate monitoring programs and state-of-the-art models capable of generating new process knowledge while representing multiple aspects of biodiversity. Such improved knowledge and tools may in turn allow managers to evaluate and select actions achieving conservation targets (e.g., MPAs), while minimizing trade-offs with other maritime sectors (e.g., fishing and offshore energy). In this poster, I will provide an overview of an ongoing EU funded project entitled "B-USEFUL" showcasing research and visions towards improved monitoring, modelling and management of marine biodiversity in European waters and beyond

P2: 30 Habitat succession on project implemented rockwork – innovation biodiversity monitoring

Yi Mei Tan, Dora Szekely, Verena Schrameyer, Ole B. Brodnicke, Lars O. Mortensen, Sofia Ferreira, Sanne Lina Niemann

DHI A/S

As part of the Fehmarnbelt Fixed Link Project, rubble mound breakwaters ("rockworks") have been constructed for land reclamations and work harbours, creating new marine habitats. These structures may partly compensate for habitat loss and provide additional biodiversity capacity.

This monitoring program assesses the development of flora on the rockworks and the state and recovery of benthic flora at adjacent seabeds—key habitat components that support species diversity, primary production, and ecosystem balance.

Traditional methods (video transects, biological sampling) are applied to evaluate biomass dynamics compared with pre-construction baselines. In parallel, innovative tools (eDNA sampling, hyperspectral scanning) capture taxonomic diversity and ecosystem functioning.

Biodiversity is further assessed using compound metrics such as the Biodiversity State Indicator and 3D benthic cover. Connectivity modelling extends these findings by estimating the broader biodiversity footprint of the new habitats.

Overall, the innovation monitoring campaign will be able to pinpoint potential positive effects of project-related implementation of rockwork and inform future projects on innovation biodiversity monitoring techniques. Results show that large marine areas connected to the local monitoring sites are positively effected after 3 years of establishment. eDNA results show a complex ecosystem structure and utilisation of transient species indicating a positive development of the new habitat.

Scherfig – Poster II: 31-44

The North Atlantic: Impacts on Climate and Ecosystems

P2: 31 Reversible weakening of the Atlantic Meridional Overturning Circulation under global warming, stabilisation, and cooling

Schiller-Weiss, Ilana[1]; Guo, Chuncheng[1]; Andres Concha Bernales, Jorge[1]; Mahmood, Rashed[1]; Olsen, Steffen M.[1]; Tian, Tian[1]; Yang, Shuting[1]

[1]Danish Meteorological Institute

The Atlantic Meridional Overturning Circulation (AMOC), a key component of the climate system, has long been considered vulnerable to irreversible weakening or tipping under anthropogenic forcing, but its resilience remains debated. Here we use EC-Earth3-ESM-1, one of the few CO2-emission driven Earth system model with an interactive Greenland Ice Sheet (GrIS) that produces realistic historical meltwater fluxes, to assess AMOC reversibility under idealised CO2 emission pathways that generates linear warming (at 0.2 K/decade), followed by stabilisation at various global warming levels (GWLs) and cooling. Across experiments, the AMOC weakens quasi-linearly with warming and up to ~7 K without collapse, remains stable during stabilisation, and recovers promptly during cooling, despite continued GrIS meltwater input. In contrast, GrIS mass loss accelerates during warming and persists under all stabilisation pathways, with only partial recovery during cooling from lower GWLs. These results reveal a divergence in resilience: while the AMOC strength remains reversible even under realistic GrIS meltwater forcing, the GrIS faces long-term vulnerability, underscoring the urgency of rapid emission cuts to limit both AMOC weakening and irreversible GrIS loss.

P2: 32 Historiske forbrugsstrukturer og deres indvirkning på marine miljøer: forbruget af laks i 1700- og 1800-tallet

Bøgeskov, Camilla[1]

[1]Aalborg Universitet

Det er bredt anerkendt, at vor tids forbrugsmønstre udgør en stor trussel for adskillige marine miljøer. Måske knapt så åbenbart er, at nutidens forbrugsstrukturer har rødder tilbage til de kulturelle og teknologiske udviklinger, der prægede europæiske samfund i 1700- og 1800-tallet. For forbruget af marine ressourcer betød dette, at kulturelle forandringer skabte en øget efterspørgsel på friske, ukonserverede produkter, hvorefter teknologiske fremskridt muliggjorde masseforsyning, der kunne imødekomme den markant stigende efterspørgsel.
I denne proces, som strakte sig over et par århundrede, er forbruget af laks (*Salmo salar*) særligt interessant at følge, da et fokus herpå tydeligt viser de gradvise trin, processen indebar, og hvordan det øgede, moderniserede forbrug, indvirkede på fiskeriet og bestandene.
Indtil slutningen af 1700-tallet havde den eftertragtede laks overvejende været centrum for lokalt, elitært forbrug, men som samfundsstrukturerne ændredes og innovative opfindelser muliggjorde øget holdbarhed, blev den transportmæssige rækkevidde betydeligt udvidet. Fra 1860'erne steg forbruget af laks markant, og da laks kunne blive transporteret til fjerntliggende og udenlandske markeder i fersk tilstand, blev det et produkt af kommerciel værdi.
Dette skete imidlertid samtidig med, at industrialiseringen satte sit præg på det europæiske landskab. Vandløbsreguleringer og forurening sammenholdt med det intensiverede fiskeri, pressede laksebestandene, og allerede i 1880'erne begyndte diskussioner om lakseopdræt i dambrug og genudsætningsforsøg. Mindre end 100 år efter, at laksen fik sit kommercielle gennembrud, var bestandene i mange tidligere lakserige områder mindsket betragteligt, og flere steder, som f.eks. i Gudenåen og Rhinen, ophørte kommercielt fiskeri fuldstændigt. Denne undersøgelse demonstrerer således, hvordan vejen op til den moderne verdens forbrugsmønstre kan spores gennem lakseforbugets udviklingen fra 1750-1900.
Grundlaget for undersøgelsen er systematisk indsamling af annoncer i de to store aviser Københavns Adresseavis og Berlingske fra de første gang udgives i henholdsvis 1759 og 1749 til år 1900. Herved har det været muligt at spore repræsentationen af fersk og konserveret fisk samt følge produkternes prisudvikling. Ugentlige udgivelser af danske og norske fiskeritidsskrifter fra 1882-1900 har været værdifulde kilder til omkringliggende omstændigheder vedrørende fiskeri, transport og markeder samt aktuelle diskussionspunkter for samtidens fiskeriengagerede.

P2: 33 Reconstructing Historical Trophic Levels of Fish Using Otolith Isotopes

Digre, Sander[1]; Grønkjær, Peter

[1]Aarhus University

Over the past 15 years, several demersal fish populations in Faroese waters have remained at historically low biomass levels, including Atlantic cod (*Gadus morhua*). This decline in biomass has been attributed to multiple interacting drivers, including phytoplankton dynamics, ocean temperature, fishing pressure, and current systems, all of which can impact population growth. Changes in diet as a response to changes in environmental and oceanographic conditions could be an explanation for the observed biomass decline. Understanding how environmental variability affects fish population growth, and through which pathways, is crucial for predicting population trajectories and developing effective conservation strategies.

To investigate long-term dietary shifts, we will analyse the isotopic values of carbon and nitrogen of proteins embedded in 667 otoliths of Atlantic cod (*Gadus morhua*), ranging from 1951 to 2025. Otolith protein isotopic signatures provide a proxy for trophic position and dietary sources. This fine-scale resolution enables us to reconstruct temporal trends in trophic position and identify environmental and anthropogenic factors associated with dietary change. This approach offers new insights into how oceanographic variability influences the feeding ecology of Atlantic cod in the Faroese region.

P2: 34 Seasonal and interannual variability in pH and dissolved oxygen concentration in the Atlantic Water inflow north of Svalbard

Hollænder, Anna[1,2]; Renner, Angelika[2]; Jones, Elizabeth[2]; Stedmon, Colin[1]; Mourgues, Claire[2]; Chierici, Melissa[2]; Foss, Øyvind[3]

[1]Technical University of Denmark, [2]Institute of Marine Research, [3]Norwegian Polar Institute

The slope area north of Svalbard is a key gateway between the North Atlantic and the Arctic Ocean. The inflow of Atlantic Water is a major source of heat and nutrients and strongly influences biological productivity and the marine ecosystem. At the same time, Atlantic Water is rich in anthropogenic CO_2 and characterised by low pH, potentially affecting acidification and thus marine organisms in the Arctic. While recent efforts have increased our understanding, there remains large uncertainty around seasonal processes and the interplay between physics, biogeochemistry and biology especially in winter due to a lack of observations.

Here, we present time series observations of pH and dissolved oxygen concentrations near the surface and at the bottom from moored sensors placed in the Atlantic Water inflow on the continental slope north of Svalbard in 2019-2020 and 2021-2022.

We find high seasonality in the near-surface layer both in dissolved oxygen and pH whereas the bottom layer is more stable. Variability in pH is mostly driven by the strength of the Atlantic Water inflow and water mass present both near the surface and at depth. In contrast dissolved oxygen near the surface is strongly influenced by both physical processes including Atlantic Water inflow, sea ice presence and air-sea interaction, but also biological activity such as the spring bloom and respiration and degradation of organic matter. In the deep layer gradual respiration is counteracted by periodic ventilation events linked to the inflow of more oxygen-rich Atlantic origin waters.

The strong influence of Atlantic Water on pH and dissolved oxygen at the Svalbard slope highlights how changes in North Atlantic circulation and water mass properties have cascading effects on the biogeochemistry of this Arctic sentinel region. Concurrently, the pronounced difference between the two years of pH and dissolved oxygen, and the interplay between various advective and local biogeochemical processes, highlight that no single driver fully explains the observed variability. This complexity underlines the urgent need for longer time series and sustained year-round observations to robustly identify the processes shaping the biogeochemistry in the Arctic-Atlantic transition zone, and how these may evolve under future climatic change.

P2: 35 The ESA ARCFRESH and FRESH4BIO Arctic Freshwater projects

Andersen, Ole Baltazar

The ARCFRESH project is supported by ESA to study how the Arctic freshwater system is undergoing major changes, with implications for ocean circulation, sea level, and ecosystem resilience. However, large-

scale and long-term assessments of Arctic freshwater fluxes remain limited due to sparse in situ records and methodological inconsistencies. Here we present results from the ArcFresh project (ESA Cross-ECV), which integrates seven ESA CCI Essential Climate Variables together with the Sea Level Budget X-ECV to provide consistent estimates of freshwater storage and fluxes across the Arctic.
We combine multi-mission satellite altimetry, sea surface salinity, sea ice, glacier and ice sheet mass balance, river discharge, and precipitation–evaporation to estimate pan-Arctic and sub-regional freshwater budgets and fluxes through the major Arctic gateways. Advanced EO-driven methods allow us to extend freshwater flux records over two decades (2003–2022), enabling the study of both long-term trends and extreme events. Rigorous uncertainty propagation ensures that derived fluxes and budgets can be robustly compared across regions and time.
By delivering homogenized, observation-driven estimates of freshwater changes both within the Arctic and across its boundaries, this work advances understanding of how Arctic freshwater dynamics interact with large-scale ocean circulation, with implications for the Atlantic Meridional Overturning Circulation (AMOC), Northern Hemisphere climate, and Arctic marine ecosystem.
The overall aim of ESA Fresh4Bio is to advance the current state of knowledge of the impact of the Arctic freshwater export and Greenland ice discharge on modulating the water column structure and phytoplankton dynamics on the East Greenland Shelf (EGS) Fresh4Bio aims to advance on understanding the effects of freshwater export on the water column structure and, further, on the onset of phytoplankton communities in East Greenland. As one of the first results from the Fresh4Bio project, we present results from a high-resolution (2 km) maps of ocean topography, geostrophic current, and relative vorticity on the East Greenland Shelf from April 2023 to September 2025 by assimilating SWOT and nadir altimetry data in a 1.5-layer quasi-geostrophic

Hav og Klima

P2: 36 Exploring the potential of the Copernicus Marine Service

Huess, Vibeke[1]; Ringgaard, Ida[1]

[1]DMI

EU's Copernicus Marine Service provides a vast amount of ocean information spanning from in-situ and satellite observations to model simulations and to derived products such as ocean monitoring indicators. The geographical coverage is global; with addition of higher resolved model products on the European regional scale. The temporal coverage is constantly increasing in time with inclusion of more historical observations and extending of model simulations longer back in time. DMI is heavily involved in the Marine Service as data provider of both observations and model products. We will present the different available data types and the usability of the variety of products; with focus on the relevant long term model reanalysis products that can be used for climate and climate change investigations.

P2: 37 Linking carbonate chemistry and biological time series to understand ocean acidification impacts in natural environments

Suhareva, Natalija[1]; Hansen, Per Juel[1]; Isensee, Kirsten[2]; Dupont, Sam[3]; Widdicombe, Stephen[4]; Enevoldsen, Henrik Oksfeldt[5]

[1]University of Copenhagen, Department of Biology, Marine Biological Section, Helsingør, [2]Intergovernmental Oceanographic Commission of UNESCO, Paris, [3]University of Gothenburg, Department of Biological and Environmental Sciences, Fiskebäckskil, [4]Plymouth Matine Laboratory, Plymouth, [5]Intergovernmental Oceanographic Commission of UNESCO, Helsingør

Ocean acidification (OA) caused by anthropogenic CO_2 emissions is reshaping marine ecosystems by altering seawater chemistry and putting pressure on biological processes. Traditionally, scientists have studied the biological impacts of OA through two main approaches: by taking advantage of variations in the ocean's carbonate system and by running controlled experiments in the field and the laboratory.
While informative, these are not enough to capture the ecological complexity[1]. Recognizing the urgency of this issue, IOC UNESCO has initiated a project funded by the Velux Foundation to develop a comprehensive framework for understanding the biological impacts of OA across natural environment over time.
We performed a global overview of available in situ time series including both carbonate system observations and biological records. The study illustrates how diverse data sources (in situ observations, reanalysis products, and remote sensing datasets) can be combined to investigate biological responses to OA. It discusses benefits and limitations of each time series type, along with a set of best practices that can help researchers identify the most suitable datasets for OA impact assessment. This compilation is

supported by a user-friendly tool that streamlines data preparation and selection. This approach allows for a systematic evaluation of these trade-offs, guiding researchers toward robust and reproducible analyses.
In support of the general approach, the study presents a series of case studies illustrating how the methodology can be applied across different ecosystems and available time series. It highlights a detailed Danish coastal case study, where long-term trends in carbonate chemistry and biological traits reveal a shift in direction over time. This example underscores the importance of sustained observations to detect non-linear changes and identify potential tipping points in ecosystem responses.
Together, these results provide a pathway toward globally comparable OA impact assessments, integrating chemical and biological observations in a way that supports both science and policy.

P2: 38 Et århundrede præget af klimaanomalier og krisetid - ekstreme vejrfænomeners betydning for de nordøstlige Atlanterhavsfiskerier i det 17. århundrede

Dahl, Johannes Rom[1]

[1]Trinity Centre for Environmental Humanities, Trinity College Dublin

Det 17. århundrede beskrives ofte som en periode præget af en generel krisetilstand, udløst af en række faktorer, herunder militære konflikter, dybtgående strukturelle omvæltninger og betydelige klimatiske udsving, bredt kendt som den lille istid. Fiskerierne i det nordøstlige Atlanterhav afspejlede denne generelle krise, idet fangsterne i en række af de største europæiske fiskerier stagnerede eller endog faldt markant i denne periode. For at forstå i hvilken udstrækning dette fald var drevet af klimaforandringer og miljømæssige chok, præsenteres en database med et bredt udvalg af materiale vedrørende storme samt stormfloders intensitet og udbredelse i det nordøstlige Atlanterhavsområde. Samtidig præsenteres en model til evaluering af hyppighed og intensitet af storme og stormflodshændelser langs det bredere nordøstlige Atlanterhavs kyster i den tidligt moderne periode.

Modellen bygger på en database, der kombinerer information og data fra en række kilder, herunder historiske vidnesbyrd af både beskrivende og kvantitativ karakter samt videnskabelige studier og paleoklimatiske proxydata. Kombinationen af disse forskellige kilder muliggør en undersøgelse af mønstre i historisk stormaktivitet og stormflodsintensitet med særligt fokus på, hvilken påvirkning disse vejrfænomener havde på kystsamfund og fiskeri. Desuden giver denne tilgang mulighed for at validere eller afvise de beskrivelser, som findes i kilder af mere anekdotisk karakter, såsom vejrdagbøger og kronologier. Dette sikrer, at sådant materiale kan inddrages i analysen og bidrage med værdifulde detaljer om specifikke vejrbegivenheder samt give indsigt i, hvordan disse hændelser påvirkede livet langs kysterne.

Afslutningsvis præsenteres resultaterne af, hvordan storme og stormfloder kan have bidraget til krisen i det 17. århundredes nordøstlige Atlanterhavsfiskerier med afsæt i udsving i historisk fangst- og eksportdata og beskrivelser fra kildematerialet der danner grundlag for stormflodsdatabasen.

P2: 39 Assessing the adaptive use of littoral marine resources in the North Atlantic during the late Little Ice Age (1650-1850 CE)

Dahl, Johannes Rom[1]; Chapple, Sophia[1]; Devitt, Cianna[1]

[1]Trinity Centre for Environmental Humanities, Trinity College Dublin

The late Little Ice Age (1650-1850 CE) was a period of profound climatic variability for the coastal communities of North Atlantic Europe. Serial weather crises, longer, cooler springs and winters, and unprecedented storm surges characterised the time for many of Europe's littoral populations. Drawing together multiple lines of archival evidence and historical data, we aim to investigate the role of marine harvesting across a range of Atlantic ecologies, illustrating the significance of this response in light of climatic anomalies.

This poster will showcase research from several research streams to elucidate our common research findings on Atlantic coastal resilience during the LIA. This first section will constitute a regional study, examining how land and maritime regimes in operation in Argyll and its adjacent islands interacted with one another during the period, especially in terms of the effects of climatic adversity and the development of commercially-driven systems of exchange. As the region witnessed an above-average incidence of storms, lower sea-surface temperatures, prolonged winters, and shorter growing seasons, we have sought to assess how resource use, both on land and at sea, was altered to adapt to these shifts. Moreover, the analysis highlights how shifting demands from seaborne commerce reconfigured subsistence economies and terrestrial regimes of tenure and exploitation. Building on the evidence presented in the first section, the next part will explore the nature of seaweed harvesting across the North

Atlantic, with a particular emphasis on the diverse social and ecological functions of macroalgae in Atlantic coastal communities during a period of climatic anomalies and amid the simultaneous emergence of the inter-Atlantic commercial kelp industry. This section will draw together archival evidence from Scottish, Irish and Scandinavian collections, including the Soundtoll registers, to trace shipments of macroalgae-based commodities through Atlantic waterways.

Assembled together, these accounts reveal both the collective adaptive capacities of coastal communities. While not losing sight of local trajectories, this poster aims to draw attention to the common undercurrents that have affected Atlantic coastal life, influenced by large-scale environmental, economic and social change.

P2: 40 Mapping the Meadows: Future Distribution of Eelgrass Under Climate Change

Staehr, Sanjina[1]; Holbach, Andreas; Ringgaard, Ida; Göke, Cordula; Payne, Mark; Poropat, Lea; Stæhr, Peter

[1]Aarhus University

Eelgrass (*Zostera marina*) meadows are essential marine habitats that support biodiversity, enhance water quality, and stabilize sediments. Their distribution is highly sensitive to environmental changes, including those driven by climate change. In this study, we applied a Species Distribution Model (SDM) developed using three key environmental parameters- average summer light availability at depth, high sea bottom temperature, and the Maximum Exposure Index (MEI), to project the future distribution of eelgrass in Danish marine waters.

We integrated climate projections data from the Danish Meteorological Institute (DMI), including changes in sea temperature, wind patterns, and sea level rise, under two scenarios (RCP 4.5 and RCP 8.5) for mid-century (2041–2070) and end-century (2071–2100). Sea level rise projections were used to estimate changes in underwater light conditions due to increased depth.

Preliminary results suggest that eelgrass habitat may expand under certain future conditions. However, this potential is likely constrained by additional stressors, such as epiphyte overgrowth, anoxia, and physical disturbance from more frequent storms, not yet represented in the model. Despite these uncertainties, our results provide one of the first nationwide predictions of eelgrass distribution under climate change in Denmark.

The pelagic ecosystem: Environmental drivers and structuring processes shaping spatial and temporal dynamics across scales

P2: 41 Genetic differentiation along steep environmental gradients in northern European waters: Processes behind local adaptation in the plankton

Jaspers, Cornelia[1]; Pujolar, José Martin; Gawinski, Christine[2]; Majaneva, Sanna[3,4]; Lehtiniemi, Maiju[5]; Hinrichsen, Hans-Harald[6]

Aim
To quantify the connectivity and degree of population differentiation of a planktonic model species along an extreme environmental gradient to understand source-sink dynamics and processes leading to local adaptation.
Location
Baltic Sea/North Sea.
Taxon
Jellyfish *Aurelia aurita*.
Methods
Levels of genetic connectivity and population differentiation were analysed combining molecular data with 40-years of Lagrangian stepping-stone drift-route simulations. Drifters represented different *A. aurita* life-stages that were followed throughout 40 consecutive life-cycles from four empirically-confirmed start locations. Suitable habitat for polyp recruitment was parameterized from high-resolution bottom topography maps to allow for stepping-stone range expansion across the Baltic Sea, along with physiological experiments.
Results
Molecular and drift analyses revealed large degree of isolation with two major clusters in the Baltic Sea in i) low saline central-eastern and ii) intermediate saline south-western areas, respectively. Additionally, molecular analyses confirmed the southern North Sea as independent cluster with limited connectivity to

the Baltic Sea, and the Skagerrak/central North Sea as transition zone between both regions. Lagrangian simulations suggested only one seeding-event from this transition zone (Skagerrak) into the Baltic Sea throughout the investigated 40-year period. Further, a 2.5-fold lower genetic diversity in the low saline Baltic, relative to the high saline North Sea, confirmed limited current gene flow. Significant correlation between haplotype frequency, salinity and isolation-by-distance (IBD) for Baltic Sea samples were detected along with high physiological fitness of northern Baltic individuals at low salinities.

Main conclusions

Limited connectivity with the North Sea leads to population differentiation of *A. aurita* in the Baltic Sea. Further, active recruitment at low salinities point to local adaptation in the Baltic Sea. Local adaptation is likely widespread among Baltic species with marine origin, leading to concerns for biodiversity conservation and ecosystem management of the Baltic Sea under continued freshening as salinity will become an important global change stressor.

P2: 42 Does maternal size structure affect larval viability in marine fish? Insights into maternal effects on larval survival using stable isotopes

Kolodzey, Stina[1]; Grønkjær, Peter[1]

[1]Aquatic Biology, Aarhus University

One of the most pervasive effects of decade long overexploitation of marine fish is the truncation of size distributions in affected populations. Today, many populations of commercially important species, such as Atlantic cod (*Gadus morhua*), consist of smaller individuals than just a few decades ago. Concurrently, a general decline in recruitment has been observed with severe consequences for population growth and productivity. These observations have led to the formulation of the Big Old Fat Fecund Females (BOFFF) hypothesis, which states that older, larger females contribute disproportionally more to the recruitment because of their increased mass-specific fecundity and production of more viable offspring. The first part of the hypothesis has been tested and confirmed, while the considerably more challenging test of superior offspring survival is hindered by the inability to link individual offspring caught in the open sea to the size of the mother. Here we present the design, methodology and progress of our ongoing project, aiming to use size-specific natural biochemical markers (stable isotopes) to link maternal size to larval viability. Larvae are provisioned with the maternal isotopic signature via nutrient transfer from maternal gonads to the eggs/larvae. The objectives are to (1) confirm the size-effect on maternal gonadal isotopic signature, (2) assess size-dependent stable isotope transfer in laboratory experiments, (3) assign wild-caught larvae to the size of its mother using stable isotope profiles, and (4) use a simple model to estimate the effect of population size truncation on larval viability. Data obtained in this project will advance our understanding of how size truncation affects larval viability and thereby recruitment. This knowledge can support decision making and fisheries management and place its coordinators and the EU at the forefront of international efforts for understanding the impacts of fishing on our marine resources. Although data collection and analysis are ongoing, this poster will outline our framework and discuss the expected insights into maternal effects and recruitment in cod of the eastern Baltic Sea.

Co-existence at sea – opportunities and challenges

P2: 43 Kampen med og mod havet – historiske perspektiver på havmiljø, bosætning, turisme, fiskeri og naturbevaring ved Harboøre og Agger Tange, 1825-2025

Andersen, Camilla[1]; Andersen, Mette Lund[2]; Bloksgaard, Anders[3]; Gardiner, Jake Hubert[3]; Jørgensen,, Michael Riber[4]; Knudsen, Inger Bjørn[2]; Knudsen, Line Vestergaard[5]; Poulsen, Bo[6]

[1]Museum Mors, [2]Lemvig Museum, [3]Limfjordsmuseet, [4]Museum Thy, [5]Aalborg Universitet, [6]Aalborg University

Med udgangspunkt i vores nye bog, *Kampen mod Havet – Limfjordstangen 1825-2025*, er det dette indlægs tese, at man kan øge denne generelle offentligheds "ocean literacy" gennem formidling af miljøhistorisk forskning.

Vi har valgt at afrapportere to miljøhistoriske forskningsprojekter i form af denne flerforfattede bog, der med udgangspunkt i et helt særligt sted i Nordvestjylland, fortæller om stedets mennesker og deres liv tæt sammenvævet med natur og miljø igennem 200 år. Gennembruddet af Limfjordstangen i 1825 skabte direkte forbindelse mellem Limfjorden og Nordsøen og fungerer som udgangspunkt for bogens fremstilling.

I 1800-tallet var fiskeriet ved Limfjordstangen præget af kombinationsnæring, mobilitet og lokal tilpasning. Havfiskeri fra åbne både, ålefiskeri med pulsvod i Limfjorden og strandbaserede fangstmetoder afspejlede en praksis, hvor erfaring og fleksibilitet var centrale; men fra omkring forrige

århundredeskifte blev områdets fiskeri og hele erhvervsliv industrialiseret og koblet til globale markeder, hvilket medførte en intensivering af fiskeriet og en gradvis udtømning af lokale bestande.
I det 20. århundrede accelererede udviklingen med ståltrawlere, fiskemelsfabrikker og kvotesystemer, hvilket førte til en koncentration af kapital og en dramatisk ændring i fiskeriets sociale og økologiske struktur. Samtidig blev havet genstand for politisk regulering og teknologisk kontrol – fra kystsikring og sluseplaner til meteorologisk risikohåndtering.
Vi peger således på, at nutidens udfordringer – havstigninger, erosion og biodiversitetstab – kræver en ny forståelse af havet, ikke som fjende, men som medspiller. Oplægget argumenterer for, at historisk viden om tilpasning, erfaring og lokal praksis er uomgængelig for fremtidens forvaltning af marine ressourcer og kystmiljøer. På den måde håber vi at bogen bibringer en bredere forståelse af, hvordan kampen med og mod havet har formet – og fortsat former – liv, landskab og læring langs den danske vestkyst.
Bogen, der er på 352 sider, udkommer i starten af november 2025 på Gads Forlag / Nord Academic, og er resultatet af et længerevarende forskningssamarbejde mellem, Lemvig Museum, Limfjordsmuseet, Museum Thy, Museum Mors og Aalborg Universitet i regi af Center for studier i Kulturarv.

Formidling af havforskning – at oversætte videnskab til handlemuligheder

P2: 44 Fra forskning til forandring: Potentialet i målrettet havforskningsformidling

Brokjær, Signe

Effektiv formidling af havforskning er afgørende, hvis vi skal skabe reelle forandringer i havmiljøet. Det handler ikke kun om at dele viden, men om at engagere og aktivere mennesker, så de forstår og handler på de udfordringer, havet står overfor.

I dette oplæg præsenterer vi erfaringer fra Hovedet i Havet og Kend Dit Hav, to store formidlingsprojekter forankret på Aarhus Universitet, der har gjort havforskningen tilgængelig for tusindvis af børn, unge og voksne over hele landet. Vi viser, hvordan forskningsbaserede aktiviteter kan skabe nysgerrighed og handlekompetence – fra skoleelever, der undersøger havbunden på skibe, til lærerstuderende, der får konkrete redskaber til at integrere havet i undervisningen og politikkere der selv kommer ud og sanser havmiljøet de lovgiver om.

Vi deler kvantitative resultater, der dokumenterer vores impact: antal deltagere, events, lærere uddannet og elever nået. Vi diskuterer også kvalitative indsigter om, hvordan formidling kan ændre både forståelse og adfærd – og hvorfor det er vigtigt, at forskere aktivt tager ejerskab over kommunikationen af deres resultater.

Oplægget fremhæver de fire centrale fokusområder i Kend Dit Hav:

- Læreruddannelser – styrker kommende læreres evne til at undervise i havets natur og udfordringer.
- Skibsbaseret undervisning – giver elever og lærere hands-on oplevelser med havforskning til søs.
- Forskningsformidling – gør kompleks havforskning tilgængelig og nærværende.
- Events – bringer havet ind i byrum, festivaler og konferencer og når nye målgrupper.

Oplægget viser, hvordan strategisk forskningsformidling kan være en katalysator for større samfundsmæssig forståelse af havets tilstand – og et konkret bidrag til at løse de udfordringer, vi står overfor.

P2: 45 Følelsesporno eller højt lixtal - hvordan balancerer man høj opmærksomhedsværdi med effektiv engagementsskabelse og seriøs forskningsformidling?

Forsberg, Søren[1]; Mouritsen, Lone Thybo[1]

[1]Kattegatcentret

Kattegatcentret er et statsanerkendt zoologisk anlæg, har en af Danmarks største naturvidenskabelige skoletjenester, åbnede i 2024 Danmarks første særudstilling om det dårlige danske havmiljø, vandt i 2025 Naturmødets pris som Danmarks Bedste Naturformidling og deltager som formidlingspartner i nationale og internationale forskningsprojekter.
Derfor er lødig forskningsformidling meget højt prioriteret i Kattegatcentret.
Men hvordan undgår man, at viden og budskaber drukner i faglige detaljer, lange tekster og svære ord, så folk vælger formidlingen fra, intet lærer og ikke forstår, hvor vigtigt det er at passe bedre på havet?
Kattegatcentret deler erfaringer fra udstillinger, formidling og undervisning, hvor følelser, sanselighed og involvering bruges til at skabe nysgerrighed, engagement og viden hos børn, unge og voksne. På en

måde som: 1) er tro mod fagligheden uden at kvæle modtageren i detaljer, 2) fanger opmærksomheden hos både de særligt interesserede og dem, der bare er på "pomfrit-besøg", og 3) bruger følelser til at røre gæsterne og skabe engagement uden at forfalde til følelsesporno.

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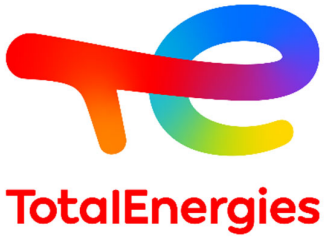

Tilskud

Derudover takker arrangørerne DCH – Dansk Center for Havforskning, der har ydet støtte til Havforskermøde 2026.

Arrangører er Aarhus Universitet og Tænketanken HAV

Program:

Tirsdag 20. januar

Start	Slut	Damgaardssalen (220 pers)	Jorn (240 pers)	Øresundssalen (70 pers)	C13	Scherfig
10:00	10:10	Velkomst	Velkomst			
10:10	10:30	Keynote: Jacob Carstensen	Keynote: Jacob Carstensen			
10:30	10:40	Pause (10 min)			Poster I: 1-30	Poster I: 31-48
10:40	12:10	Succesthistorier fra 50 års natur og miljøforvaltning	Marine Biogeochemistry I	Marine birds in Danish waters I		
12:10	13:10	Frokost (60 min)				
13:10	13:30	Keynote: Outi Tervo (Stream)	Keynote: Outi Tervo (stream)			
13:30	13:40	Pause (10 min)				
13:40	15:10	Sensing the Sea - advancing marine monitoring I	Marine Biogeochemistry II	Marine birds in Danish waters II		
15:10	15:30	Kaffepause (20 min)				
15:30	17:00	Sensing the Sea - advancing marine monitoring II	Marine Biogeochemistry III	Marine Mammals in a Changing Seascape		
17:00	18:30				Postersession I	
18:30		Middag				

Onsdag 21. januar

Start	Slut	Damgaardssalen (220 pers)	Jorn (240 pers)	Øresundssalen (70 pers)	C13	Scherfig
08:30	08:50	Keynote: Poul Holm	Keynote: Poul Holm			
08:50	09:00	Pause (10 min)			Poster II: 1-30	Poster II: 31-44
09:00	10:30	Coastal Fish and their Habitats in Denmark I	Oceanografiske ekstremer og impacts	Increasing Gender Equality in Marine Research		
10:30	10:50	Kaffepause (20 min)				
10:50	12:20	Coastal Fish and their Habitats in Denmark II	Development of digital twin of ocean (DTO)	Co-existence at sea – opportunities and challenges		
12:20	13:10	Frokost (50 min)				
13:10	13:30	Keynote: Cornelia Jaspers (Stream)	Keynote: Cornelia Jaspers (stream)			
13:30	13:40	Pause (10 min)				
13:40	15:10	Marine virkemidler som driver for et godt havmiljø	Ocean prediction and coastal modelling	Pollution effects - assessment and monitoring		
15:10	15:30	Kaffepause (20 min)				
15:30	17:00	Non-indigenous marine species	Beskyttede havområder - effektive værktøjer?	Miljøfarlige stoffer og plastik i havmiljøet		
17:00	18:30				Postersession II	
19:00		Festmiddag				

Torsdag 22. januar

Start	Slut	Damgaardssalen (220 pers)	Jorn (240 pers)	Øresundssalen (70 pers)	C13 (48 pers)
08:30	08:50	Keynote: Camilla Snowman Andresen	Keynote: Camilla Snowman Andresen		
08:50	09:10	Keynote: Ditte Mandøe Andreasen	Keynote: Ditte Mandøe Andreasen		
09:10	09:20	Pause (10 min)			
09:20	10:50	Marine restoration in a Danish context I	Greenland's coastal ecosystems	Marin biodiversitet	
10:50	11:10	Kaffepause (20 min)			
10:50	12:40	Marine restoration in a Danish context II	The North Atlantic: Impacts on climate and ecosystems	Green solutions or green washing?	Benthic fauna communities
12:40	13:30	Frokost (50 min)			
13:30	15:00	Marine restoration in a Danish context III	Hav og klima	Nyt om forskningsprogrammer - finansiering og infrastruktur	The pelagic ecosystem

Kort over Konventum: