Norwegian Institute for Water Research

International Symposium on Synthesis Research in Aquatic Ecosystems

11-12 June 2025, Copenhagen, Denmark

Programme and abstracts

Norwegian Institute for Water Research STI

Title	Pages	Date
International Symposium on Synthesis Research in Aquatic Ecosystems	17	12.06.2025

This programme has been quality assured according to NIVA's quality system and has been approved by:

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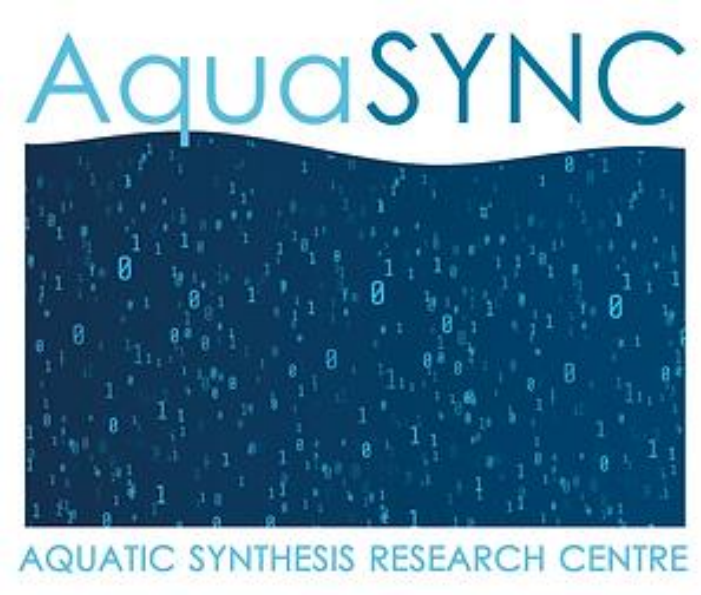

Keywords: Synthesis research, aquatic ecosystems, freshwater, marine
Emneord: Synteseforskning, akvatiske økosystemer, ferskvand, hav

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Welcome

Welcome to Copenhagen, Denmark and welcome to the first 'International Symposium on Synthesis Research in Aquatic Ecosystems', organized and hosted by AquaSYNC.

The symposium takes place at:

The Royal Danish Academy of Sciences and Letters
H.C. Andersens Boulevard 35
1533 Copenhagen V

More information can be found here: https://royalacademy.dk/?lang=en

The organizers of the symposium look forward to highlighting synthesis research in both marine and freshwater ecosystems. From reading the symposium programme, we are convinced that you will have two interesting days and intense days ahead of you. We hope that you will listen to interesting presentations and have fruitful discussions with colleagues from other countries.

The symposium is organized by AquaSYNC and has thus received direct financial from the Norwegian Institute for Water Research (NIVA).

We hope that you enjoy the symposium and have a pleasant stay in Copenhagen.

AquaSYNC
AQUATIC SYNTHESIS RESEARCH CENTRE

More information about AquaSYNC can be found here: https://www.aquasync.dk/

1 Programme including abstracts

The first International Symposium on Synthesis Research in Aquatic Ecosystem is anchored in seven keynote presentations, four invited presentations and a number of contributed presentations.

The keynotes to be presented at the symposium are:

1. Jill Baron, JPC: What is synthesis research? Examples from the John Wesley Powell Center
2. Jesper Andersen, AquaSYNC and NIVA Denmark: AquaSYNC and the Ecosystem Approach
3. Benjamin Halpern, NCEAS: NCEAS as an innovator of team science
4. Johnny Reker, EEA: Marine Messages III: Informing policy and providing solutions to resolve the crisis in Europe's seas
5. Marten Winter, sDIv: Synthesis science: Do we still really need it?
6. Søren L. Nielsen, Ocean Institute: The Ocean Institute – an end-user of 'synthesis research'
7. Nikolai Friberg, ECOS-AU: Underpinning upscaling of nature-based solutions (NbS) with ecological data: why, how and what?

The four invited presentations are all anchored in the work of past or ongoing Synthesis Working Groups supported by AquaSYNC:

1. Stefano Larsen, FMACH: Global export of biomass and contaminants from water to land by aquatic insects
2. Helene Frigstad, NIVA: Multiple stressors in Skagerrak: an ecosystem in a squeeze
3. Daniel Perkins, Brunel: Human footprints on stream size structure: consistent impacts across latitudes?
4. Samuli Korpinen, SYKE: Relative sensitivity of marine species and habitats to human activities

Thew symposium is organised with the following six sessions are:

- An opening session
- A session presenting the outcomes of four AquaSYNC Synthesis Working Groups
- A session focusing on freshwater synthesis research
- A session focusing on marine synthesis research
- A session focusing on solutions and perspectives
- A wrap up and closing session

The outline programme is presented at the following page.

Time	Wednesday 11/6	Thursday 12/6
09:30 10:00	*Registration with coffee & tea*	KN4: Johnny Reker, EEA P9: Nanna Meilholm & Marie N. Jørgensen, UniCPH **S5**
10:30 11:00 11:30	**OPENING** KN1: Jill Baron, JPC KN2: Jesper H. Andersen, AquaSYNC **S1**	*Coffee & tea break with refreshments* P10: Mats Lindegarth, UGOT and SÌME P11: Jacob Carstensen, AU P12: Dorte Krause-Jensen, AU
12:00 12:30	*Lunch*	*Lunch*
13:00 13:30 14:00 14:30	P1: Stefano Larsen, FMACH P2: Helene Frigstad, NIVA P3: Daniel Perkins, BU P4: Samuli Korpinen, SYKE **S2**	KN5: Marten Winter, sDiv KN6: Søren L. Nielsen, Ocean Institute KN7: Nikolai Friberg, AU **S6**
15:00	*Coffee & tea break with refreshments*	*Coffee & tea break with refreshments*
15:30 16:00 16:30 17:00	P5: Ignassi Arranz, Universidad Rey Juan Carlos P6: Rolf D. Vogt, NIVA P7: Sofie Mentzel & Jannicke Moe, NIVA P8: Jukka Arrovita, SYKE **S3**	**WRAP UP, NEXT STEPS & CLOSING**
17:30 18:00	KN3: Benjamin Halpern, NCEAS (online) **S4**	
18:15- 21:00	***SYMPOSIUM DINNER***	

For more information about the titles and contributors, please confer with the detailed programme on the following pages.

1.1 Wednesday 11 June

09:30-10:30 **Registration with coffee and tea**

10:30-10:40 **Welcome and opening of the symposium**

10:40-11:25 **What is synthesis research? Examples from the John Wesley Powell Center**
Jill S. Baron
Synthesis Oversight Contributors: Marten Winter, sDIV and Ben Halpern, NCEAS

Scientific synthesis integrates diverse data and knowledge to increase the scope and applicability of results and yield novel insights or explanations within and across disciplines. The demand for synthesis comes from the pressing societal need to address grand challenges related to global change and other issues that cut across multiple societal sectors and disciplines and from recognition that substantial added scientific value can be achieved through the synthesis-based analysis of existing data. Demand also comes from groups of scientists who see exciting opportunities to generate new knowledge from interdisciplinary and transdisciplinary collaboration, often capitalizing on the increasingly large volume and variety of available data. While synthesis activities can take place anywhere, synthesis centers offer a unique amalgam of culture, infrastructure, leadership, and support that facilitates creative discovery on issues crucial to science and society. The John Wesley Powell Center for Earth System Science and Analysis is the only member of the Synthesis Center Consortium to support scientific advances for all Earth and Environmental Sciences. The scientific productivity of groups addressing hazards, water resources, energy and minerals, and environmental health, disciplines that were naïve to the idea of collaborative synthesis as a way of conducting science, has been remarkable. However, ecological themes, especially those related to climate change, make up most of the more than 80 Working Groups hosted since 2009. Examples from synthesis of freshwater ecology will be presented, along with examples of cross-synthesis center collaboration and co-sponsorship.

11:30-12:00 **AquaSYNC and the Ecosystem Approach**
Jesper H. Andersen

The Aquatic Synthesis Research Centre (AquaSYNC) was established in January 2022. AquaSYNC is supported by the Norwegian Institute for Water Research (NIVA), Aarhus University (ECOS-AU), and the Swedish Institute for the Marine Environment (SIME-UGOT). As a synthesis centre, our focus is on collaborative research through the initiation of synthesis working groups (SWGs) and analyses of so-called 'Big Data'. We also support activities related to the development, testing, and application of multi-metric indicator-based assessment tools (MIBATs), which are frequently employed in the context of Integrated Assessment. To date, AquaSYNC has initiated eight SWGs, developed and tested several MIBATs, and contributed to two Integrated Assessments. AquaSYNC and the supported SWGs are tasked with addressing the challenges faced by aquatic ecosystems and, consequently, the implementation of the Ecosystem Approach (EA). The EA is significant within a European context, and this presentation will outline the origin of the concept and its connections to Ecosystem-Based Management (EBM) and the Ecosystem-Based Approach to Management (EBAM).

12:00-13:00 **Lunch**

13:00-13:30 **Global export of biomass and contaminants from water to land by aquatic insects**
Stefano Larsen, Jakob Wolfram, Darin Kopp, Jeff Wesner, Jeff Muehlbauer, José M.A. Martinez, Afroditi Grigoropoulou, Johanna Kraus & Ralf Schulz

The production of anthropogenic chemicals has increased sixfold in the last decades and represent major drivers of global change. Streams and rivers receive contaminants from the watershed but also export them back to land via the bioaccumulation and emergence of adult aquatic insects. This flux of contaminants can offset the benefits of transported subsidies and increase the exposure of terrestrial consumers. Here, leveraging extensive dataset on in-stream insect production and contaminants concentration, we provide the first global estimates of biomass and contaminant fluxes from water to land. Rivers export an average of ~2240 mg of dry-mass/m2/y of adult aquatic insects. That translates to ~1000 mg of carbon/m2/y, which is similar to previous estimates. GAM models accounting for precipitation and temperature as well as the total river surface areas on Earth estimate that the global flux of adult aquatic insects is ~1.7 million metric tons of dry mass and ~0.7 million metric tons of carbon. We then combined these mass estimates with predictions of multiple contaminant tissue concentrations derived from predicted aqueous concentrations. The results suggest global export of ~0.5 metric tons of Hg, 5 metric tons of Pb, and 0.13 metric tons of herbicides, from water to land.

13:30-14:00 **Multiple stressors in Skagerrak: an ecosystem in a squeeze**
Helene Frigstad, Jesper H. Andersen, Trine Bekkby, Richard Bellerby, Jacob Carstensen4, Tove Gabrielsen, Linus Hammar, Ashley Hemraj, Dag O. Hessen, Johanna M. Aarflot, Even Moland, Ciaran Murray, Andy Stock, Geir Systad, Finn-Arne Welzien & Paula Ramon

Over the past decade, significant progress has been made in understanding the effects of multiple anthropogenic stressors on marine ecosystems. The methodology developed by Halpern et al. (2008) has been a catalyst for numerous studies from local to international scales and has in recent years evolved from a mapping tool to an analytic instrument, including scenarios of climate change. The objective of SWG MultiStress Skagerrak is to provide a comprehensive understanding of the potential interactions between stressors and ecosystem components in the Skagerrak, a regional sea under increasing anthropogenic pressure and with high economic importance, shared by Norway, Sweden and Denmark. The work of the SWG is organized into three tasks 1) cumulative impact assessment (CIA) for the open parts of Skagerrak, 2) CIA with higher spatial resolution for the Oslofjord, and 3) a literature review of the Skagerrak ecosystem. We aim to provide a baseline for effects of multiple stressors and identify potential hotspot areas of anthropogenic influence, in addition to exploring how combined stressors will evolve with climate change and/or future management scenarios. The presentation will highlight the first results from the working group, including temporal and spatial trends in eutrophication status of the Oslofjord and the baseline results for cumulative impacts for the open Skagerrak.

14:00-14:30 **Human footprints on stream size structure: consistent impacts across latitudes?**
Dan Perkins, Ignasi Arranz, Andrew Edwards, Ioar De Guzman, Vojsava Gjoni, Dean Jacobsen, Pavel Kratina, Aitor Larranaga, Ciarán Murray, Justin Pomeranz, Jes J. Rasmussen, Victor Saito, Francisco Valente & data contributors

Human activities are driving major shifts in the structure and functioning of freshwater communities worldwide. Yet, it remains unclear how consistently these impacts manifest across regions, particularly between the well-studied Global North and the rapidly transforming landscapes of the tropics. Community body size distributions offer a powerful, integrative lens for detecting anthropogenic effects, as they reflect shifts in food web structure and ecosystem functioning. Here, we present findings from a global analysis of

stream community size spectra (AquaSYNC SWG003), spanning gradients of human pressure and latitude. We compiled a dataset comprising tens of millions of individual body size measurements for macroinvertebrates and fish, collected from thousands of stream sites across six continents. Size spectrum parameters shifted consistently along a human footprint index, indicating a disproportionate decline in larger-bodied organisms relative to smaller ones. Notably, these effects intensified toward the tropics, where trophic downgrading and species loss were more pronounced. Our findings provide new global-scale insights into freshwater community responses to human disturbance and underscore the heightened vulnerability of tropical ecosystems to ongoing environmental change.

14:30-15:00 **Relative sensitivity of marine species and habitats to human activities**
Samuli Korpinen, Jesper H Andersen, Jacob Carstensen, Elena Gissi, Benjamin Halpern, Linus Hammar, Niko Kallio, Ciaran Murray, Vanessa Stelzenmueller & Andy Stock

Impacts of human activities have increased in world oceans which has initiated several attempts to determine sustainable levels of activities. Models estimating human impacts on marine ecosystems have hugely improved but they still cannot fully grasp the ecosystem dynamics. A main challenge is to define how to estimate the cumulative impacts of human activities on the biodiversity and ecosystem functioning. To simplify such a model, scientists have selected key ecosystem components and estimated their sensitivity via elicitation of expert knowledge. In AquaSYNC synthesis working group #1 the objective has been to analyze these expert-based sensitivity estimates and conclude their robustness. A key research question was whether the experts agree on the sensitivity of species and habitats against human activities and consequent pressures. In addition, it was analyzed whether regional differences or survey methods would cause differences for the sensitivity. The working group outcome was published and many of the sensitivities were confirmed. First of all, it was found that there is high agreement of the high sensitivity of many components against demersal trawling, fisheries in general, climate change, hazardous substances as well as many sea-floor damaging activities. Looking from the ecosystem point of view, especially estuaries, corals and macroflora indicated high sensitivity to some activities are pressures. Secondly, the analysis showed true tolerance of ecosystem components to many activities and pressures. The working group also concluded that there is a great need for improving the expert elicitation methods in marine ecology: differences between the survey methods prevented conclusions for a number of ecosystem components.

15:00-15:30 Coffee & tea break with refreshments

15:30-16:00 **Building global individual body size datasets in aquatic biodiversity to tackle global research questions**
Ignasi Arranz Urgell

Body size is a key ecological trait that reflects biological rates at individual, population and community levels including metabolic rates, demographic effects, biotic interactions and energy fluxes. Temperature-size rules predict that warming reduces organism's body size through increasing metabolic rates. However, previous experimental, and empirical studies found that temperature-related shrinking in body size is not a universal response but depends on the ecological context. This controversy shows that we are still lacking a clear understanding on how warming acts on body size and on the role played by external factors including habitat complexity, human footprint, and biological invasions, among others. Therefore, future research is needed to disentangle the relative effects of climatic and non-climatic factors in modulating body size shifts in real-world ecosystems. In this talk, we present a comprehensive compilation of new datasets of individual body size in

the aquatic biota, developed through the collaboration of hundreds of researchers and stakeholders across all continents. The datasets came from two projects. The first, MacroSize, aims to determine the macroecological patterns of body size structure at both temporal and spatial scales under the global change impacts including climate warming, pollution, habitat fragmentation and biological invasions. The second project, SexSize, focuses on uncovering the evolutionary and environmental drivers of the intraspecific differences in body size males and females. The datasets roughly encompass 150,000 sampling surveys in 100,000 georeferenced sites, spanning from the 1950s to present. Each record contains information on individual body size, sampling date and methodology. These databases include over 400 marine and freshwater species mostly comprised of teleost fish, together with elasmobranchs, crustaceans, and cephalopods. In this talk, we would also discuss key challenges in assembling large-scale datasets, knowledge gaps, explore ways to enhance dataset accessibility, and outline future research directions.

16:00-16:30 **Post-Acid Rain Recovery with Increasing Calcium Concentrations**
Rolf David Vogt

This study assesses long-term trends in surface water chemistry using data from the Norwegian national monitoring and the ICP Waters programs that originally focused on the effects of reduced sulphuric acid deposition. As was anticipated, in acid-sensitive regions heavily effected by acid rain, the widespread and substantial decline in sulphate concentrations has led to a corresponding decrease in calcium concentrations. Conversely, in regions less impacted by acidification, calcium concentrations are increasing in a large number of sites, largely in response to rising bicarbonate levels. At these sites, the increase in bicarbonate contributes to a higher acid neutralizing capacity (ANC), which more than offsets the decline in sulphate. The most likely drivers of this increase in bicarbonate include a warming climate, which promotes longer growing seasons and increased biomass production, thereby enhancing soil respiration and CO2 exchange (i.e., CO_2 pump). This process increases weathering rates and the release of base cations such as calcium. As the decline in acid deposition has stabilized and surface water pH increases above 5.6 in formerly strongly acidified areas, similar increases in calcium concentrations may eventually be observed there as well. However, statistically separating the effects of acid rain recovery from those of climate change on water chemistry remains a significant challenge. The observed calcium trends may have ecological implications. Interestingly, in regions most severely impacted by acidification, no significant correlation was found between the declining calcium concentrations and biodiversity indices. In contrast, in less-affected regions, strong negative correlations were observed - contradicting conceptual expectations and highlighting the need for further investigation into how aquatic ecosystems responds to changing chemical conditions.

16:00-17:00 **ENCORE: a probabilistic framework for ENvironmental CO-exposure and Risk Estimation**
Jannicke Moe, Karel P.J. Viaene, Karel Vlaeminck, Jos Van Gils, Merete Grung, Samantha Martins, Sophie Mentzel, Anders L. Madsen, Luka Snoj, Gašper Šubelj, Frederik Verdonck

EU's Chemicals Strategy for Sustainability aims to incorporate "combined exposure" risks, stemming from unintentional chemical mixtures in the environment, into regulatory risk assessments. A Mixture Allocation Factor (MAF) has been proposed to lower all safety limits for single chemicals. However, recognising the shortcomings of MAF for the management of co-exposures of environmental relevance, CEFIC-LRI called for a project ECO66 for next generation risk assessment methods supporting the identification of environmental co-exposures of potential concern. The resulting project ENCORE (ENvironmental CO-exposure and Risk Estimation, 2025-2027) aims to develop a probabilistic modelling framework to identify priority chemicals for co-exposure risk at the watershed

level across Europe. The ENCORE framework builds upon an environmental fate model originally developed in the EU project SOLUTIONS for large-scale European domains, but is adaptable to specific regions, such as the Rhine and Danube river basins. In chemical risk modelling, epistemic uncertainty and natural variability are both unavoidable. ENCORE will develop a probabilistic framework to allow for integration of multiple sources of information, as well as uncertainty from both exposure and hazard information throughout the risk model. More specifically, Bayesian network (BN) methodology will be used to update prior probabilities from process-based simulation data with new evidence from monitoring data. By integrating national chemical use and emission information with local monitoring data, ENCORE aims to improve the accuracy of model predictions for specific watersheds. For this purpose, key data sources include the pan-European publicly available datasets Waterbase Emissions (WISE-1) and Waterbase Water Quality (WISE-6), hosted by the European Environment Agency (EEA). Furthermore, BN models will be developed for case studies for efficient exploration of alternative emission scenarios, alternative approaches to mixture risk characterisation, and other modelling aspects. Ultimately, ENCORE aims to prioritize high-risk co-exposure chemicals by accounting for spatial and temporal exposure patterns across large regions of Europe.

17:00-17:30 **Assessment of the status of freshwater biodiversity using monitoring data**
Jukka Aroviita

Biodiversity in freshwaters has declined globally more than in any other ecosystem. Despite the decline, systematic data-driven assessments of freshwater biodiversity are lacking, hindering effective management. We used past 20-year monitoring and survey data of benthic invertebrate, diatom, phytoplankton and macrophyte communities from >2500 streams and lakes to assess status of freshwater biodiversity in Finland. We used multi-taxon distribution models to estimate taxon frequencies expected in near-natural reference conditions and then compared observed frequencies from monitoring data to the expected frequencies to derive estimates of regional biodiversity status. We found significant, up to 50% declines in regional biodiversity with often marked declines in common taxa. We observed both losses and gains of taxa which varied among regions, land use types, water body types and biotic community groups. This type of multi-taxon assessments of biodiversity provides key information for more effective implementation of policies (e.g. EU Water Framework Directive, and Nature Restoration Law) aiming to halt freshwater biodiversity loss.

17:30-18:00 **NCEAS as an innovator of team science**
Benjamin Halpern

The National Center for Ecological Analysis and Synthesis (NCEAS) first opened its doors 30 years ago, launching a major shift in the culture and practice of ecological and environmental science. One of the key innovations at that time was the idea of bringing together teams of diverse experts across career stages and disciplines to share ideas and data during several one-week meetings, what is often called a working group. NCEAS has since hosted nearly 400 working groups. I will share more of this history, the lessons learned over the years on how to run and support an effective working group, and new directions and innovations happening at the Center to help groups be even more productive. As a participant in more than 25 of these groups that have been focused on marine ecology and conservation, I will also share personal perspectives on the successes, challenges, and evolution of working groups from an ocean perspective.

18:15-21:00 SYMPOSIUM DINER

1.2 Thursday 12 June

09:30-10:00 **Marine Messages III: Informing policy and providing solutions to resolve the crisis in Europe's seas**
Johnny B. Reker

Marine Messages III presents a comprehensive assessment of the state of Europe's seas, evaluating the impact of human activities on marine ecosystems and identifying solutions to restore ecosystem health, particularly for food provision and climate resilience. Drawing on advanced datasets and integrated indicator-based assessment tools, the report distinguishes between 'problem areas' and 'non-problem areas' across key domains such as biodiversity, contamination, and eutrophication. The findings reveal that large areas of Europe's seas remain 'problem areas' due to intense human pressures that undermine environmental objectives. Mapping human activities across marine regions, the assessment ranks key pressures—fishing, pollution (nutrients and contaminants), seabed disturbance, noise, and climate change—as primary factors preventing good environmental status. Despite decades of vision-setting, including legal and policy frameworks aiming for clean, healthy, and productive seas, the analysis underscores a persistent implementation gap. Progress has been made, but not at the pace or scale required to meet agreed goals. Additionally, increasing pressures from climate change further amplify risks to marine ecosystem structure, function, and service provision. Current measures are insufficient to manage these compounding stressors. The report concludes that restoring ecosystem resilience must now be a core priority. Without resilient marine ecosystems in good environmental status, climate impacts risk becoming irreversible, leading to significant losses in biodiversity and services such as food provision and coastal protection. Marine Messages III is both a warning and a call to action: restoring the resilience of Europe's seas is essential to safeguard their ecological integrity and secure the benefits they provide to society in the face of accelerating climate change.

10:00-10:30 **Eutrophication in Danish Coastal Waters: Exploring Long-Term Temporal and Spatial Trends**
Marie Neel Jørgensen & Nanna Meilholm

Danish coastal waters were severely affected by eutrophication in the 1980s, prompting the implementation of nutrient mitigation efforts. The aim of this study was to explore the recovery of Danish coastal waters via the multi-metric HELCOM Eutrophication Assessment Tool (HEAT) and report on the distinct trends for seven selected indicators of eutrophication: dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorous (DIP), chlorophyll a, light penetration depth, eelgrass main depth limit, Danish Quality Index (DKI), and bottom water oxygen concentration. Based on data from an extensive monitoring programme, we report on the temporal and spatial trends of eutrophication in 109 Danish coastal waterbodies from 1980-2023. The analysis revealed that although improvement has been observed in several Danish coastal waterbodies, eutrophication continues to affect large areas in recent years. The national eutrophication status showed improvements until approximately 2010, from where a stagnation in status was observed. The same trend was observed for national averages of winter DIN and DIP, while for other indicators the average remained relatively stable throughout the study period e.g. oxygen concentrations, eelgrass depth limits, and DKI. For the indicators chlorophyll a and light penetration depth, the averages showed signs of recovery until 2012 and 2021 respectively, from where a degradation of these indicators was observed. These findings suggest that mitigation efforts towards nutrient reduction have played a pivotal role in driving Danish coastal waters towards recovery, however, current mitigation efforts appear insufficient to ensure that Danish coastal waters are classified as 'not affected by eutrophication'.

10:30-11:00 Coffee & tea break with refreshments

11:00-11:30 **From research to decision support: lessons from the implementation of national Swedish research effort on water quality criteria**
Mats Lindegarth, Ciaran Murray & Jacob Carstensen

In 2009 the Swedish Environmental Protection Agency (SEPA) launched the six-year research programme WATERS, on the Swedish WFD assessment criteria in coastal and inland waters. Due to changes in the Swedish environmental governance system, the program was later jointly funded and audited by the newly formed Swedish Agency for Water and Marine Management (SwAM) and SEPA. The consortium consisted of eleven academic and consultancy partners and was instructed to develop close communication with relevant stakeholders, mainly those from the public sector engaged in water management. The main objectives of the programme were to develop more sensitive and robust indicators in surface waters, and to develop a harmonised approach to assess uncertainty, reference and class boundaries and integrated assessments in accordance with to the WFD definitions. As in most research programmes the efforts were successful to a varying degree. Several new and modified indicators were suggested, however, some of them needed additional operationalisation, and a concept for a harmonised assessment including confidence in classification and integration among quality elements was proposed, including a prototype aggregation tool. The concept was based on well-known methods for partitioning of variability using mixed linear models, Monte Carlo simulations and a mathematically stringent implementation of existing assessment criteria. The proposed methods were arguably scientifically well-founded, but without further support, they were clearly too complex for safe implementation at the practical level. Part of the consortium therefore proposed further long-term development work, in collaboration with the end-users to develop an online-tool and a workflow that connects with monitoring databases, implements the data-driven calculations and delivers an automated initial classification including confidence assessments. The system provides a very efficient, transparent and repeatable support for the practicing expert and good basis for national and EU reporting. In this presentation we give a brief introduction to the programme, assessment method and tool. We also reflect upon the many challenges associated with knowledge transfer between academia and management, and in particular the operationalisation of complex ecological concepts and statistical approaches into useful governance tools.

11:30-12:00 **The synergies of human pressures driving coastal acidification**
Jacob Carstensen & Carlos M. Duarte

Increasing CO2 in the atmosphere has led to a gradual and predictable decrease in pH in the open ocean, but coastal acidification is more variable, exhibiting rates more than one order of magnitude higher than ocean acidification. We analysed 83 ecosystems around the world with long-term monitoring data to describe the seasonal and long-term changes in pH, and to investigate the potential drivers of these variabilities. Spatial and temporal decoupling of production and respiration in coastal ecosystems can lead to seasonal and long-term changes in pH exceeding 1 unit. Largest excursions in pH are observed in stratified and high-latitude systems, where the metabolic imbalance is most pronounced. Enhanced nutrient input from land, stimulating ecosystem productivity and thus raising pH levels, can counteract ocean acidification in shallow and well-mixed coastal systems, whereas eutrophication and ocean acidification are synergistic pressures in stratified systems where bottom waters may display low pH and high pCO2. Coastal oligotrophication resulting from nutrient management can amplify the effect of rising CO2 in the atmosphere on pH in the euphotic zone but may also alleviate acidification in

bottom waters of stratified systems. Ecosystem management needs to consider the balance between the negative consequences of eutrophication and acidification.

12:00-12:30 **Challenges for carbon crediting in *Zostera marina* (eelgrass) meadows**
Dorte Krause-Jensen, Carmen Leiva-Duenas, Catherine E. Lovelock & Hilary Kennedy

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 carbon (OC) stocks and accumulation rate (CAR) and have experienced major global declines in response to pressures. However, their role in climate change mitigation and carbon crediting potential vary among and within seagrass species and habitats. Here we address the potential for carbon crediting in meadows of *Zostera marina* (eelgrass), the most widely distributed seagrass species, through a review of soil OC stocks, CAR, sources and stability (mineral associated organic matter - MAOM) of the organic matter inputs. 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 a wide range of values, with median stocks 40% lower and CAR 50% lower than the median values for *P. oceanica* and median eelgrass CAR only 28% of the Tier 1 emission factor for seagrass used in the IPCC guidelines. The OC stocks under eelgrass vegetated patches 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 mineral-protected fraction (a requirement of some carbon market methodologies). These features may partly be due to strong spatial heterogeneity and temporal dynamics of eelgrass meadows, general eelgrass traits as well as export of eelgrass carbon beyond the meadows. We discuss how the findings inform the implementation of methodologies used in carbon crediting projects for restoration of eelgrass meadows and encourage the valuation of these meadows for all the ecosystem services they provide.

12:30-13:15 Lunch

13:15-13:45 **Synthesis science: Do we still really need it?**
Marten Winther

In my talk I'll present some synthesis collaboration methods or modes of operation synthesis centres have used over the last decades to advance our knowledge. I'll use some examples from sDiv (www.idiv.de/sdiv), the centre showing successful data synthesis examples but also challenges and opportunities in this field. Based on the extensive experience of 13 years sDiv and the many interactions with other centres and centre leaders, I'll present some recommendations how to do successful collaborative synthesis science, either in teams or as an individual. As a last and hopefully also interesting discussion point, I'll present some own reflections and ideas where the future of synthesis science could be. What do we need in future to successfully tackle the growing complex grand scientific and societal challenges?

13:45-14:15 **The Ocean Institute – an end-user of 'synthesis research'**
Søren Laurentius Nielsen

The Ocean Institute is an independent, knowledge-based, and solution-oriented think tank that facilitates collaboration between businesses, NGOs, and decision-makers who want to contribute to a clean and healthy ocean. Our work is centered around collecting and processing knowledge, insights, and experiences from Danish and international research related to the ocean, to support the most influential agents of change in the transition toward a sustainable relationship between marine life and humans. We strive to

facilitate collaboration and joint solutions among all actors who wish to contribute to securing a healthy ocean. The Ocean Institute bridges diverse interests in the marine habitat with the aim of paving the way for business innovation and transition, as well as political decisions that can establish new frameworks for the protection and use of the ocean. By employing people with different professional backgrounds, we aim to embrace the nuances of changing the current state of the marine environment. Our work not only supports key decision-makers but also helps build strong public awareness of the ocean's importance to humanity — highlighting its challenges and solutions to make the necessary transition inevitable. To produce our analyses and reports we obviously rely heavily on data and analyses from high quality research. We make our own syntheses based on this and especially focusses on combining data and viewpoints from different fields - natural science as well as social science, including economy. Our purpose is to make both consequences of action and lack of action clear. A particularly important aspect of our work is to emphasize the importance of analyses of cumulative effects and the necessity of an ecosystem-based approach, where analysis of cumulative effects is crucial. I my talk, I will give examples of our work with an emphasis on our use of synthesis research to highlight cumulative effects.

14:15-14:45 **Underpinning upscaling of nature-based solutions (NbS) with ecological data: why, how and what?**
Nikolai Friberg

Global ambitions about restoring degraded ecosystems in the coming decades, and the recent adoption of the restoration law by EU Member States, means that a substantial upscaling of restoration efforts are needed sooner rather than later. Nature-based solutions should play a key role in achieving targets and they were highlighted in a resolution from the Kunming-Montreal Biodiversity Framework as a mechanism to curb biodiversity declines and tackle the nature crisis. The advantage of a wider use of NbS, as defined by UNEA, is that also address other societal challenges such as climate change, thereby making them more multifaceted than nature conservation and restoration. This should facilitate uptake by society with the potential of improving biodiversity across ecosystems at a scale that have not been achieved by more conventional conservation efforts in the past decades. However, my view is that the current research on NbS is not drawing sufficiently on the large body of existing ecological knowledge and data, which limits the scope of projects that are conducted in terms of benefits to biodiversity. Ecological theory and related data on biodiversity-ecosystem functioning should underpin the next generation of NbS to ensure that our degraded ecosystems are recovered. In my talk, I will address some key science questions in relation to NbS that could be explored by using existing data, as well as the potential use of new sampling technologies in the context of NbS.

14:45-15:15 Coffee & tea break with refreshments

15.14-16:00 **Wrap up, next steps and closing**
Jesper H. Andersen

2 Publication of Symposium Proceedings

We aim to publish Symposium Proceedings as a so-called Research Topic with the title 'Synthesis Research in Aquatic Ecosystems'. The Research Topic is linked to two Frontiers journals:

- Frontiers in Marine Science, section 'Marine Ecosystem Ecology', link: https://www.frontiersin.org/journals/marine-science and
- Frontiers in Freshwater Science, section 'Aquatic Population Health and Diseases', link: https://www.frontiersin.org/journals/freshwater-science).

Guest editors of the Research Topic are:

- Helene Frigstad, Norwegian Institute for Water Research (NIVA), Norway
- Daniel Perkins, Brunel University of London, United Kingdom
- Jacob Carstensen, Aarhus University, Denmark
- Jesper H. Andersen, NIVA Denmark Water Research, and AquaSYNC, Denmark

The expected number of papers in the Research Topic on 'Synthesis Research in Aquatic Ecosystems' is 12-14 covering different types such as an Editorial, original research papers, reviews, short notes and opinion papers. More information about the Research Topic is available here:

- https://www.frontiersin.org/research-topics/70229/synthesis-research-in-aquatic-ecosystems

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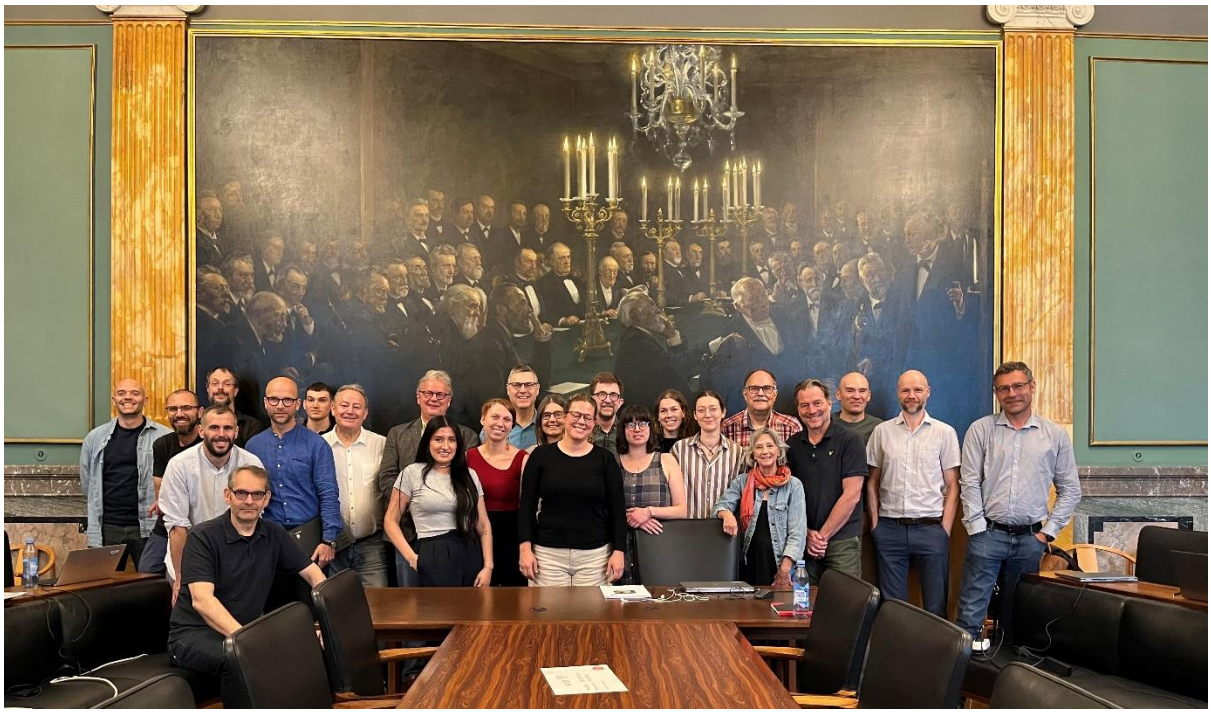

Norwegian Institute for Water Research STI

We are Norway's premier research institute in the fields of water and the environment. We are experts on ecosystems in both freshwater and marine environments, from mountains, lakes and rivers, to fjords, coasts and oceans. We develop science-based knowledge and solutions to challenges related to the interaction between water and climate, the environment, nature, people, resources and society.