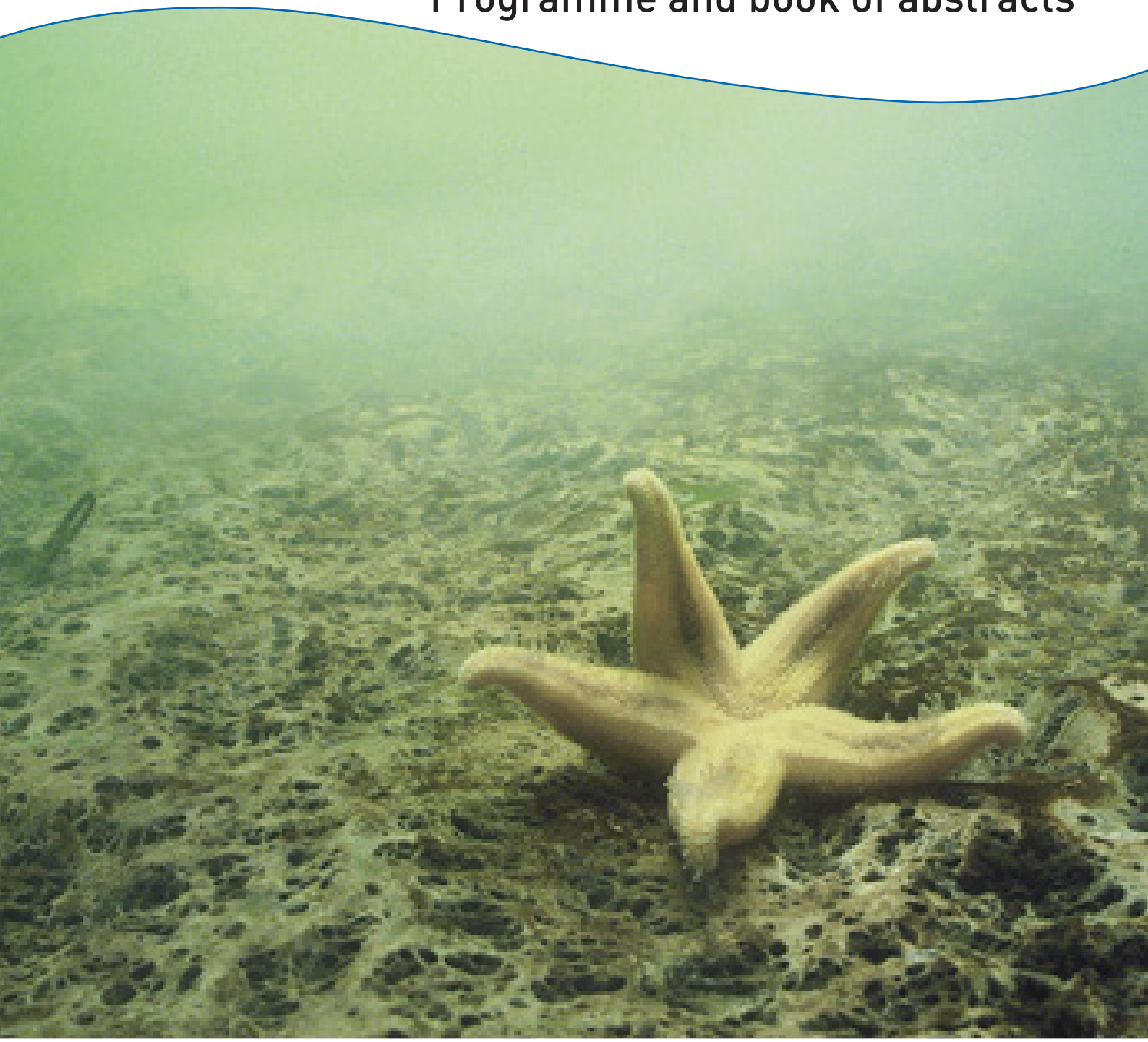
NIVA Denmark

4th International Symposium on Research and Management of Eutrophication in Coastal Ecosystems: Programme and book of abstracts



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Summary

EUTRO 2018, or in full 'The Fourth International Symposium on Research and Management of Eutrophication in Coastal Ecosystems', follows up on 3 earlier symposia and celebrates the 25-year anniversary of the first symposium, which took place in 1993. Presentations at EUTRO 2018 will in particular focus on: 1) Land use and nutrients: Loads, concentrations, availability, limitation and dynamics, 2) Phytoplankton and HABs, 3) Benthic communities, 4) Monitoring, remote sensing and modelling, 5) Assessment and management tools and 6) Mitigation, oligotrophication and recovery.

Four keywords	Fire emneord
1. Eutrophication	1. Eutrofiering
2. Research	2. Forskning
3. Management	3. Forvaltning
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This programme is quality assured and approved by

Project Manager

Research Manager

EUTRO 2018

4th International Symposium on Research and Management of Eutrophication in Coastal Ecosystems: Programme and book of abstracts

18-20 June 2018
Nyborg, Denmark

Welcome

Welcome to Nyborg, and welcome to EUTRO 2018, the Fourth International Symposium on Research and Management of Eutrophication in Coastal Ecosystems.

The organizers of EUTRO 2018 look forward to helping to highlight the causes, effects and consequences of coastal eutrophication. From reading the Symposium Programme and abstracts, we are convinced that you have three interesting and intense days ahead of you.

We hope that you will have fruitful discussion with colleagues and will also be able to strengthen contacts with scientists from other countries. The latter is important, since eutrophication is a large-scale problem not only restricted to national waters.

EUTRO 2018 is organized jointly by NIVA Denmark and Aarhus University, and has received financial and various types of support from the Danish Environmental Protection Agency, the Swedish Agency for Marine and Water Management, University of Southern Denmark, and Hotel Nyborg Strand.

We hope that you enjoy EUTRO 2018 and have a pleasant stay in Nyborg.

Jesper H. Andersen
NIVA Denmark

Jacob Carstensen
Aarhus University

Marianne Holmer
University of Southern Denmark

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1 Background

In 1993, Denmark hosted "International Symposium on Nutrient Dynamics in Coastal and Estuarine Environments". The 1993 symposium was organised by the Danish Marine Research Programme (managed by the Danish Environmental Protection Agency) in collaboration with the European Commission, Directorate-General for Science, Research and Development. The Symposium Proceedings were published as OPHELIA vol. 41 and 42 and some of the papers, especially Nixon (1995) "Coastal marine eutrophication: a definition, social courses, and future concerns" and Duarte (1995) "Submerged aquatic vegetation in relation to different nutrient regimes" are highly cited. For more information about the Danish Marine Research Programme, please see Bondo-Christensen *et al.* 1998.

A follow up symposium was organised in 2006 by the Danish Environmental Protection Agency, Fyn County, the Swedish Environmental Protection Agency and DHI Denmark. The institutions joined forces to organize a symposium focusing on both science and management of coastal eutrophication. The motivation for a follow-up symposium focusing on both science and management was a common regional and international interest in the effects of nutrient loading and the critical processes in eutrophication in coastal and estuarine environments. Symposium Proceedings were published as HYDROBIOLOGIA vol. 629 “Eutrophication in Coastal Ecosystem” (see Andersen & Conley 2009).

A third symposium was organised in 2010 by ICES, NOAA and DHI Denmark, almost 17 years after the first symposium and four years after the second symposium, as the problems associated with eutrophication were still far from being solved despite the adoption of several updated nutrient management strategies (i.e. the EU Water Framework Directive (Anon. 2000), the EU Marine Strategy Framework Directive (Anon. 2008), and the HELCOM Baltic Action Plan (HELCOM 2007)). For a synthesis of EUTRO 2010, please see Fulweiler *et al.* (2012).

Today, almost 25 years since the first Symposium the problems associated with eutrophication are as pronounced as ever. There has been a major development in scientific knowledge and in the conceptual understanding of nutrient enrichment and eutrophication in coastal waters. New questions and challenges have emerged - especially in relation to modelling and management of coastal eutrophication and the importance of climate change. However, the challenges related to nutrient enrichment and eutrophication is still far from being solved. Hence, EUTRO 2018 aims to focus on:

1. Setting the scene: What is coastal eutrophication?
2. Presentation and discussion of scientific results in relation to specific eutrophication issues, e.g.:
    - Causative factors and direct and indirect eutrophication effects
    - Climate and physical control on the biogeochemical dynamics and eutrophication status of the coastal zone
    - Effects of eutrophication of biological quality elements, and
    - Monitoring, modelling and assessment of eutrophication
3. Presentation and discussion of evidence-based or ecosystem-based nutrient management strategies and polices
4. Next steps: From eutrophication to oligotrophication in a changing climate

2 About Hotel Nyborg Strand

EUTRO 2018 will take place at Hotel Nyborg Strand in Nyborg, Denmark.

Nyborg City is at the hub of Denmark, with easy access from all parts of the country. Nyborg Strand is situated at the water's edge, with a very fine view to the Great Belt Bridge and with a lovely beech wood as its next-door neighbour. Both the centre of Nyborg and the railway station are within walking distance of the hotel - and the mo-torway is only a few minutes' drive away:

- Nyborg Railway Station: 1 km
- Motorway E20, exit 45: 1 km
- Nyborg Centre: 1,5 km
- Odense Centre: 35 km
- Copenhagen Airport: 100 km

Hotel Nyborg Strand is a convention and conference hotel with a location right next to beach and close to the historical town centre of Nyborg which makes it ideal for a symposium of 3 working days in a relaxed atmosphere with state-of-the-art conference facilties.

At Hotel Nyborg Strand, you have free wireless access to the internet..

The EUTRO 2018 Symposium Secretariat will be open:

- Sunday, 17 June: 18:00 – 22:00
- Monday, 18 June: 08:00 – 19:00
- Tuesday, 19 June: 08:00 – 19:00
- Wednesday, 20 June: 08:00 – 15:00

Please do not hesitate to contact the EUTRO 2018 Symposium Secretariat or the staff at Hotel Nyborg Strand if you need any help or additional information.

3 Programme (including abstracts)

The 4th International Symposium on Research and Management of Eutrophication in Coastal Ecosystems is anchored in 1) seven keynote presentations, 2) a total of xx oral presentations, 3) two thematic workshops and 4) a Symposium Summary.

The keynotes to be presented at EUTRO 2018 include:

1. **COASTAL MARINE EUTROPHICATION: THE DAMAGE, THE DANGER AND THE DISRUPTIONS** by Carlos M. Duarte, KAUST, Saudi Arabia
2. **THE GLOBAL EXPERIENCE IN ABATING COASTAL EUTROPHICATION: BARRIERS AND BRIDGES** by Donald Boesch, UMCES, USA
3. **PHYTOPLANKTON DYNAMICS AND FOOD WEB EFFICIENCY IN RELATION TO CHANGING NUTRIENTS AND CLIMATE REGIMES** by Monika Winder, SU, Sweden
4. **SUBMERGED AQUATIC VEGETATION IN RELATION TO CHANGING NUTRIENT AND CLIMATE REGIMES** by Marianne Holmer, SDU; Denmark
5. **CONTRIBUTIONS OF MACROFAUNAL COMMUNITIES TO ECOSYSTEM FUNCTION ACROSS GRADIENTS OF EUTROPHICATION** by Alf Norkko, TZS/HU, Finland
6. **EUTROPHICATION SCIENCE IN A CHANGING WORLD: WHAT HAVE WE LEARNED AND WHERE TO GO FROM HERE?** by Jeremy Testa, UMCES, USA
7. **FROM BLOOM TO DOOM - 30 YEARS OF MANAGING EUTROPHICATION IN THE NORTH AND BALTIC SEAS** by Ulrich Claussen, UBA, Germany

Themes for oral presentations at EUTRO 2018 include:

1. Phytoplankton and harmful algae blooms (session 1; number of presentations: 4)
2. Assessment and management tools (session 2, parts I, II and III; number of presentations: 14)
3. Benthic communities (session 3: number of presentations: 4)
4. Land-use and nutrients: (session 4; number of presentations: 7)
5. Mitigation, oligotrophication and recovery (session 5; parts I and II; number of presentations: 8)
6. Monitoring, remote sensing and modelling (session 6, parts I and II; number of presentations: 8)
7. Selected contributed oral presentations in relation to the themes covered by keynote 6 and keynote 7 (number of presentations: 4)

Two thematic workshops are organizxzed as part of EUTRO 2018 with the following focus:

1. **FROM MONITORING DATA TO INTEGRATED ASSESSMENTS**
2. **STEPS TOWARD A HARMONIZED ASSESSMENT OF EUTROPHICATION IN EUROPE'S SEAS**

The Symposium Summary, which will compiled and bresented by the Three Wise Ladies, has the followoing title:

- **UNDERSTANDING EUTROPHICATION: HOW FAR HAVE WE COME AND WHERE DO WE GO FROM HERE?** By Robinson W. Fulweiler (BU, USA), Dorte Krause-Jensen (BIOS/AU, Denmark) & Katherine Richardson (UniCPH, Denmark)

An outline programme is presented on the following page:

	MONDAY 18/6		TUESDAY 19/6		WEDNESDAY 20/6
07:00	Breakfast		Breakfast		Breakfast
09:00	OPENING		Keynote 3		Keynote 6
	Keynote 1		Keynote 4		Keynote 7
	Keynote 2		Keynote 5		
10:00	Session 1	Session 2	Session 5	Session 6	Session 7
11:00					
12:00					Lunch
13:00	Lunch		Lunch		
14:00	Session 3	Session 2 *Cont.*	Session 5 *Cont.*	Session 6 *Cont.*	Symposium Summary by 'Three Wise Ladies'
15:00					CLOSING
16:00	Session 4	Session 2 *Cont.*	Workshops		
17:00					
19:30	Dinner		Symposium Dinner		

MONDAY 18 JUNE 2018

09:00 – 10:50: Opening of EUTRO 2018

Plenary Session in Sal J
Chair: **Jesper Andersen**

09:00 – 09:10 Welcome address

Jacob Carstensen, Aarhus University (EUTRO 2018 Scientifc Committe chair)

09:10 – 09:25 Opening Address

Mats Svensson, Swedish Agency for Water and Marine Management

09:25 – 10:50 KEYNOTE 1 AND KEYNOTE 2

09:25 – 09:30 Intro

09:30 – 10:15 **KN1: COASTAL MARINE EUTROPHICATION: THE DAMAGE, THE DANGER AND THE DISRUPTIONS**

Carlos M. Duarte[1,2]
[1] *Red Sea Research Center, King Abdullah University of Science and Technology, Kingdom of Saudi Arabia*
[2] *Arctic Research Center, Aarhus University, Denmark*

The longevity, now a quarter of century of history, of the EUTRO symposia series signals at the reality that eutrophication has become a chronic problem across the world's coastal waters. Opening symposium themes evolved from defining eutrophication and identifying drivers (1993 Symposium, Nixon 1995), to expectations of the capacity to manage the problem, with the symposium opening addressing, in a sign of optimism, oligotrophication (2006 Symposium, Nixon 2009). Failure to realize recovery across eutrophied marine ecosystems reverted attention to the complexity of responses (2010 Symposium, Cloern). A quarter of century later the title I was suggested for my talk reveals the mind set of current thoughts on eutrophication, where eutrophication damages to ecosystems add to danger of disruption by compounding with other growing pressures. Indeed, concerns on eutrophication as a main vector of damage to coastal ecosystem has been superseded by concern on the dangers derived from human CO2 emissions and associated ocean impacts: warming, acidification and deoxygenation. Here I summarize the synergies between eutrophication, warming and global trends toward acidification and deoxygenation of coastal ecosystems. I then argue that since eutrophication management is actionable at the watershed scale, this remains one of the effective strategies to manage the dangers of disruption of coastal ecosystem derived from warming, acidification and deoxygenation, which can only be mitigated at the global scale.

10:15 – 10:45 KN2: THE GLOBAL EXPERIENCE IN ABATING COASTAL EUTROPHICATION: BARRIERS AND BRIDGES

Donald F. Boesch
University of Maryland Center for Environmental Science, Annapolis, Maryland, USA

Over the past 30 years concerted efforts have been taken to reverse nutrient-driven eutrophication in coastal waters in many parts of the world. Almost always, this has

proven a more recalcitrant challenge than anticipated, with ecosystem improvements only recently beginning to emerge. Barriers and bridges to progress are evaluated for efforts to abate coastal eutrophication in Europe, North America, Japan and Australia. Political and social commitment and support is essential, as is a governance framework that ensures accountability. Reduced nutrient loadings from point sources have improved environmental quality and ecosystem health where such sources dominate and, where they do not, are practically required in order to enable reductions from diffuse sources. Emission controls intended to improve air quality have surprisingly also reduced loadings of nitrogen in some cases. Reducing diffuse nutrient loads from agriculture has been most stubborn because of increasing industrialization, political and economic barriers, and lack of innovation in integrating nutrient conservation and agricultural production. And, even where there have been concerted control efforts, nutrient loads from stormwater runoff have continued to grow as a result of land development. Scientific research and monitoring conducted in conjunction with abatement efforts have improved understanding of: effectiveness of management actions, legacy lags, multiple nutrient limitation, ecosystem hysteresis, living resource consequences, and climactic influences that can guide more effective and efficient abatement actions.

10:45 – 11:15 BREAK (tea & coffee)

11:15 – 13:00 SESSION 1: PHYTOPLANKTON AND HARMFUL ALGAE BLOOMS (HABs)
Room: 20+21
Chair: **Michelle Devlin**

11:15 – 11:20 Intro

11:20 - 11:40 **The usefulness of Phaeocystis blooms as an indicator for eutrophication**
Theo Prins[1] & Anouk Blauw[1]
[1] *Deltares, Delft, The Netherlands*

Blooms of the haptophyte Phaeocystis globosa are a common phenomenon in the southern North Sea. In the 1970s and 1980s, observations of increased blooms in the western Dutch Wadden Sea coincided with high riverine N and P loads to the coastal waters. This led to the recognition of Phaeocystis as a major indicator of eutrophication in Dutch coastal waters. In 1990, a phytoplankton monitoring program was started in all Dutch coastal and marine waters. Several indicators describing blooms of Phaeocystis were developed and used in eutrophication assessments for OSPAR and for the Water Framework Directive (WFD). In the last decades, riverine loads of N and P have shown significant decreases. This has resulted in decreasing concentrations of nutrients and chlorophyll in coastal waters, but the indicators that are used to describe Phaeocystis blooms for the OSPAR assessments (maximum cell number) and for the WFD assessments (frequency of blooms) do not show as clear response to this reduction in nutrient loads. We have analysed the 25-year data set from the phytoplankton monitoring program. The developments in Phaeocystis blooms in relation to environmental conditions will be presented, and we will discuss the applicability of Phaeocystis indicators for the assessment of eutrophication in the Dutch part of the North Sea.

11:40 - 12:00 **Impacts of harmful algal blooms on cycling of carbon and nutrients in a microtidal estuary**

Anderson, I.C, Brush M.J., Reece, K.S. & Song, B.K.
Biological Sciences, Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, Virginia

Increased frequency and intensity of harmful algal blooms represent a form of eutrophication, since they result in an increase in the rate of supply of organic matter to an ecosystem. Although nutrient enrichment is often the cause of eutrophication, other environmental conditions may be responsible. The lower York River estuary in Virginia, USA, annually experiences intense harmful algal blooms, which appear to be unrelated to increased external nutrient loading. The dominant bloom-forming organisms are Cochlodinium polykrikoides and Alexandrium monilatum, which over the last 5 – 10 years have occurred in sequence during late summer/early fall, and have the potential to affect carbon and nutrient cycling in the estuary. Data collected during the bloom period from late July to mid-September, 2016 and 2017 demonstrate a peak in C. polykridoides (67,000 cells ml-1) in mid-August and A. monilatum (66,000 cell ml-1) in late August. Concentrations of pCO2 and DIC were inversely related and highly correlated with chlorophyll a, whereas DOC and DIP were directly related to chlorophyll a. Net community production and respiration measured in the light and dark on samples from within intense bloom areas were 8-fold higher than in samples from outside bloom patches. Next generation sequencing analysis of 16S rRNA genes showed increases in heterotrophic bacterial communities during the blooms, likely in response to the DOC released from the two dinoflagellate species. We expect that the trophic state of the estuary will be in near metabolic balance except during bloom periods with dynamic shifts on short temporal and spatial scales.

12:00 - 12:20 **Use of Pulse-shape recording flow cytometry for monitoring phytoplankton: challenges and perspectives**

Lumi Haraguchi, Hans H. Jakobsen & Jacob Carstensen
Aarhus University, Department of Bioscience, Frederiksborgvej 399, DK-4000 Roskilde, Denmark

Climate change and anthropogenic pressures are drivers of phytoplankton community composition, and consequently ecosystem functioning and health. Thus, phytoplankton monitoring programs are essential to assess ecological status of aquatic ecosystems. Even though long-term time series of phytoplankton provide valuable information, current monitoring programs sample with bi-weekly or monthly frequency, which represents a coarse time scale for organisms with life cycles of days. Challenges to implement higher frequency sampling strategies are mainly associated with cost increase, as traditional phytoplankton counts are time consuming and demand highly skilled taxonomists. The use of in flow systems (i.e. flow cytometers) to analyse phytoplankton has increased in research, and have high potential for monitoring purposes as well. Pulse-shape recording flow cytometer (PFCM) is a flow cytometer designed specifically for phytoplankton counts, analysing a broad size range (0.5-1000 µm), in few minutes. A two-year time series with approximately daily sampling at a single point of Roskilde Fjord demonstrate phyto-plankton variations at different time scales. The PFCM results are in agreement with microscopy samples obtained from a nearby monitoring station, highlighting the

importance of small-sized organisms and seasonal pattern with cryptophyte dominance during spring shifting to dominance of dinoflagellates and diatoms over summer and autumn. However, the PFCM data also reveal high importance of picophytoplankton and oscillations occurring within time spans of days, suggesting that blooms and abrupt community shifts can easily be missed from weekly sampling.

12:20 – 12:40 **Linking eutrophication pressures and phytoplankton community responses through a new Phytoplankton Tool**

Sorcha Ní Longphuirt[1], Georgina McDermott[1], Shane O'Boyle[1], Robert Wilkes[1] & Dagmar B. Stengel[2]

1 Environmental Protection Agency, Ireland

2 Botany and Plant Science , School of Natural Sciences , Ryan Institute, National University of Ireland Galway, Ireland

Increased nutrient delivery to estuarine systems results in elevated growth of primary producers evidenced by high chlorophyll concentrations and increased frequency of phytoplankton blooms. However shifts in nutrient loads to estuarine ecosystems can also cause modifications in the structure of phytoplankton communities which can have adverse impacts right through the food web. Acknowledging these modifications is imperative if response mechanisms are to be fully understood. In this study Ireland's current Water Framework Directive (WFD) tool for determining the status of phytoplankton communities was built upon to encompass not only biomass and blooming frequency but also community structure (diversity and evenness) and phytoplankton abundance. This method allows for comparison with site- and date- specific environmental data which could give an indication of cause and effect relationships. The newly developed Index performed well against current EPA methods to determine ecological status. Furthermore, it had a better agreement with other physico-chemical and biological WFD parameters. The inclusion of community structure in the tool acknowledged the disturbance nutrient imbalance can cause to some systems even when frequent blooms are not evident. A principal components analysis captured the relationship between physico-chemical parameters and the Index allowing for a more detailed look at the impact of disturbance on the system. Development of the Index will allow not only for compliance with WFD requirements, but is a method to determine the status of Irish estuarine phytoplankton communities over spatial and temporal timelines in line with changes in physiochemical parameters.

11:15 – 13:00 SESSION 2: ASSESSMENT AND MANAGEMENT TOOLS (PART I)

Room: 22+23

Chair: **Mark Brush**

11:15 – 11:20 Intro

11:20 – 11:40 **Monitoring and modelling of opportunistic green algal blooms for the Water Framework Directive**

Robert Wilkes, Georgina McDermott, John Keogh, Shane O'Boyle and Sorcha Ní Longhpuirt
Ecological Monitoring and Assessment Unit, Environmental Protection Agency, Ireland

Large accumulations of macroalgae, primarily green algae, in transitional and coastal waters have long been an issue in Ireland. Regular monitoring of these green tides has been ongoing since the implementation of the Water Framework Directive (WFD) monitoring programme in 2006. This biological quality element is now used to assign ecological status in Ireland's waters and is a key factor driving status in areas classified as less than good status. Areas affected by this phenomenon are mostly along the south and east coasts of Ireland but these issues are now also seen in other locations. The data from this programme is also used to assess eutrophication conditions under the MSFD and for the identification of problem areas for OSPAR commitments. As a key indicator of eutrophication this monitoring will inform measures to improve water quality. Modelling tools have been developed to estimate the reductions in nutrient loading needed to improve status. These models can assist in the development of catchment-wide measures that will address issues at the land-sea interface and allow us to reach our WFD objectives.

11:40 – 12:00 **Living up to expectations under two EU Directives: A tool to score nature management status for submerged vegetation dependent bird-guilds in Danish wetlands affected by eutrophication**

Preben Clausen, Thorsten J.S. Balsby, Ole Roland Therkildsen, Thomas Eske Holm & A.D. Fox
Department of Bioscience, Aarhus University, Grenåvej 14, DK-8410 Rønde, Denmark

We developed an assessment system to score ecological and management status (relative to a historically best situation) of Special Protection Areas (SPA's) designated under the EU Birds Directive for their importance to staging populations of herbivorous waterbirds in Denmark. Danish experimental and empirical studies demonstrate that sufficient food supplies, as well as shooting-free reserves for quarry species determine the maximum numbers of herbivorous birds a shallow-water wetland can support. Thus, large seagrass beds with high plant densities within a reserve support many more birds than small beds lacking reserve protection status. Based on a 50-year historical reference period, we identify when the designated SPA's had a plentiful food resource and supported the most numerous herbivorous bird-guild under favourable reserve management, and use this guild composition as target bird numbers. From knowledge about the birds daily energy expenditure, food selection and digestion rates, we estimated the total food resource required to support the energetic needs of the target bird-guild. The system then scores contemporary site quality by combining assessment of seagrass area, seagrass density, and 'reserve match' (the extent of spatial overlap between reserves and seagrass beds) into a five score category from poor to high nature management status, equivalent to the rating system proposed under the Water Framework Directive (WFD). Eutrophication processes have occasionally denied herbivorous waterbirds the feeding resources they formerly enjoyed in Danish fjord systems including within SPAs, but recoveries have also occurred, and the system successfully

distinguishes between poor and good status. A rich seagrass community is also recognised as ranking among the highest levels of ecological assessment under the WFD, hence the assessment system builds linkages to establish favourable status for herbivorous waterbirds and their food supply under two EU Directives.

12:00 – 12:20 **Assessing trans-boundary nutrient modelling results including WFD reduction scenario within an OSPAR frame**

Hermann Lenhart[1] & Fabian Große[2]
[1] Scientific Computing Group, Department of Informatics, Universität Hamburg, Hamburg, Germany; [2] Department of Oceanography, Dalhousie University, Halifax, Canada

The trans-boundary nutrient transport (TBNT) tagging approach allows for the tracing of elements from individual sources, like the nutrient input from rivers, through the biogeochemical cycles of an ecosystem. Hence, it facilitates the practical application of the source-oriented approach of OSPAR by the quantification of the influence of individual sources on selected regions, e.g. areas characterised as eutrophication problem areas. With the European Union's Water Framework Directive (WFD) reduction measures presently under debate, the question arises how the planned measures will alter the contributions from different countries to these problem areas. A reduction scenario is run with the ecosystem model ECOHAM, based on the proposed WFD reductions levels from the North Sea member states as reported to OSPAR. First, the effects of this WFD reduction on the dissolved inorganic nitrogen and Chlorophyll-a concentrations will be compared to a reference simulation. Second, the changes in the relative contributions, e.g. for the German Exclusive Economic Zone (EEZ), will be analysed. These analyses reveal that – despite a general reduction of anthropogenic nutrient loads – the relative contributions increase for countries with only low reduction targets, minimising the local effects of the reduction efforts of other member states in their own EEZs.

12:20 – 12:40 **Signature patterns of chlorophyll a variability in the Greater North Sea**

Xavier Desmit & Dimitry Van der Zande
DO Natural Environment, RBINS, Brussels, Belgium

The greater North Sea comprises a high diversity of marine systems within a relatively small geographical area: shallow and well-mixed systems, stratified systems, continental shelf, margin and deep ocean. Across these systems, different seasonal and interannual patterns of chlorophyll a (Chl) variability may be observed. Characteristic features of the Chl dynamics are used to identify typical areas across the studied domain. Remote sensing observation of Chl (ENVISAT-MERIS) offers a comprehensive picture of the spatial dynamic of surface phytoplankton biomass over almost a decade (2003-2011). The Cloern and Jassby (2010) method of Chl signal decomposition was applied to every pixel separating the Chl signal into four components: 1) the grand mean, 2) the interannual, 3) the seasonal and 4) the residual components for the considered 9-years period. The method assumes no trend a priori over the considered period and the standard deviations for each component are compared in a relative fashion to describe the local dynamics of Chl. The pixel-wise calculated components are represented in individual maps to depict the spatial patterns of chlorophyll a variability and outline areas of high or low seasonal and interannual variability. Subsequently the decomposed Chl signal is used

in a K-means cluster analysis to classify areas in the greater North Sea. These areas correspond to different categories of Chl dynamics for the considered period 2003-2011, providing a governance tool for policy makers. It is also shown how these areas directly reflect physical features of the sea, suggesting invariant structure of phytoplankton dynamics.

12:40 – 13:00 **Use of Ocean Color data to assess phytoplankton response to nutrient pressure under EU Directives**

Ana C. Brito[1,2], Paloma Garrido-Amador[3] , Carla Gameiro[1,4], Maria Teresa Cabrita[4,5] & Marta Nogueira[4]

[1] MARE – Marine and Environmental Sciences Centre, Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal; [2] Departamento de Biologia Vegetal, Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal; 3 Max Planck Institute for Marine Microbiology, Bremen, Germany; 4 IPMA – Instituto Português do Mar e da Atmosfera, Lisboa, Portugal; [5] CEG/IGOT-ULisboa – Instituto de Geografia e Ordenamento do Território, Universidade de Lisboa, Lisboa, Portugal

The Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD) aim at evaluating the ecological and environmental status of European coastal waters. This is a rather complex task and requires the use of long-term time-series to assess the effect of anthropogenic pressure on biological communities and the whole ecosystem. Due to their importance as primary producers, phytoplankton are a key component of marine ecosystems. Moreover, by having a fast response to nutrient changes, these microalgae are considered particularly important for the evaluation of ecosystem health. In this study, a phytoplankton database containing in-situ chlorophyll a measurements were used to validate the CMEMS' chlorophyll a product obtained through the application of OC5CI algorithm for the western Iberia region. These satellite data were then used to calculate the chlorophyll a 90th percentile, which is considered an appropriate indicator of coastal phytoplankton blooms. The highest annual values of chlorophyll a 90th percentiles (up to ~4-5 mg.m-3) were observed in the northern Portuguese coastal zone and Galicia, from Peniche to Finisterra. Nutrient and oxygen observations were also used to identify the areas with the highest anthropogenic influence. The effective use of satellite remote sensing for monitoring the water quality of marine waters is of outstanding importance.

13:00 – 14:00 LUNCH

14:15 – 15:40 SESSION 2: ASSESSMENT AND MANAGEMENT TOOLS (PART II)

Room: 22+23

Chair: **Autumn Oczkowski**

14:15 – 14:20 Intro

14:20 – 14:40 **IOC, FAN, FLU & RIM: incoherent acronyms to assess coastal eutrophication coherently**

Eva Flo & Jordi Camp
Institut de Ciències del Mar – Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain

Multiple approaches to assess coastal eutrophication have been proposed. However, there are some methodological gaps regarding its risk and impact assessment, for which we present some solutions. First, the index of chlorophyll-a (IOC) is proposed, which is based on this parameter and on salinity and allows an evaluation of the biological state of coastal waters and thus of their eutrophication impact. Second, the Phosphate-Ammonium-Nitrite (FAN) and FLUviality (FLU) indexes are described, which rely on a previous study of the NW Mediterranean. This study demonstrated that the main pressures that trigger the production of chlorophyll-a on coastal waters are nutrient-rich continental inflows and distinguished between their urban vs. fluvial-agricultural origins. The FAN index mainly reflects phosphate, ammonium, and nitrite levels and thus describes a gradient related to urban pressures into coastal waters. The FLU index is an indicator mostly of silicate and nitrate levels but also of freshwater inputs (inversely related to salinity); as such, it describes a gradient related to pressures deriving from fluvial and agricultural sources. Together, the two indexes enable an assessment of the physicochemical state of coastal waters and thus of their eutrophication risk. In addition, they provide for the distinction and quantification of the respective continental pressures. Finally, an integrated assessment based on the three indexes is proposed through the Risk-Impact-Management table (RIM). This table offers insights into the risk, impact, and continental origins of coastal water eutrophication and thus elucidates which actions should be implemented and where, being an essential cornerstone for management.

14:40 – 15:00 **Aggregation rules influence assessment results: Kattegat case study**

Philip Axe
Swedish Agency for Marine and Water Management, SE-404 39 Göteborg, Sweden

The revised Commission Decision 2017/848 guides EU member states when assessing Good Environmental Status under the Marine Strategy Framework Directive. Eutrophication is assessed based on a suite of three obligatory, primary criteria complemented by a further five voluntary, secondary ones. In coastal waters, these criteria are to be used in accordance with the requirements of the Water Framework Directive. No explicit guidance is given as to how these criteria are to be aggregated. Aggregation rules typically used in the Regional Seas Conventions differ slightly, and also differ from the guidance used under the Water Framework Directive (WFD). Guidance is also lacking in how assessment results should be aggregated over time in order to produce an assessment to cover a 6 year management cycle. The Kattegat, between Sweden and Denmark, lies in both the HELCOM and OSPAR Convention areas. It is a historically eutrophic region which has benefitted from substantial nutrient input reductions in recent years. As a result, it is close to having non-problem status. It was assessed using both the (HELCOM) HEAT3 and (OSPAR) COMP assessment frameworks. Coastal waters were assessed according to WFD rules but also using the assessment levels of the WFD aggregated according to HEAT3 and COMP. Being close to the Problem/Non-Problem boundary resulted in aggregation rules having an impact on the final status. Not achieving good status requires

Member States to implement legally binding Programmes of Measures, so choice of aggregation rules has consequences.

15:00 – 15:20 **The use of pressure response relationships between nutrients and biological quality elements as a method for establishing nutrient supporting element boundary values for the Water Framework Directive: Coastal and transitional waters**

Salas Herrero, F.[1], Teixeira, H.[2] & Poikane, S.[1]
[1] Joint Research Centre, European Commission, Ispra, Italy; [2] Department of Biology & CESAM, University of Aveiro, Aveiro, Portugal

A huge variability exists in nutrient concentrations boundaries set for the Water (WFD) and the Marine Strategy (MSFD) Framework Directives, as revealed by a survey to EU Member States. Other relevant aspects showed similar inconsistency, namely the nutrient parameters and metrics used, the time of year assessed and the reference conditions established. The Working Group on Ecological Status (ECOSTAT), as part of the Common Implementation Strategy for the WFD, agreed to address the topic of wide variations in the concentration of boundaries set by the Member States and the need of establishing appropriate nutrient boundaries to achieve good ecological status. Different statistical approaches have been proposed in the Best Practice Guide (BPG, Phillips et al. 2017) to establish suitable nutrient boundaries. Intercalibrated results from the WFD for the biological quality element phytoplankton were used for deriving nutrient boundaries in coastal and transitional waters, applying the BPG. Overall, the statistical approaches proved adequate for coastal lagoons, but are not always robust to allow deriving nutrient boundaries in other water categories such as estuaries in transitional waters or some coastal water types. The datasets available for analysis provided good examples of the most common problems that might be encountered in these water categories. Similar issues have been found in freshwater environments (Phillips et al. 2016), for which solutions are proposed in the Best Practice Guide and which are demonstrated here for coastal and transitional waters.

15:20 – 15:40 **LUSI: determining land pressures and their link with coastal eutrophication**

Eva Flo, Esther Garcés & Jordi Camp
Institut de Ciències del Mar – Consejo Superior de Investigaciones Científicas (ICM-CSIC), Barcelona, Spain

Human activities on land result in the high-level production of nutrients that, when they reach coastal waters, drive the eutrophication process in those waters. Here we present the Land Uses Simplified Index (LUSI), an easy-to-use tool for assessing continental pressures on coastal waters, as it indirectly estimates continental nutrient loads and concentrations. It is based on systematic information describing both the land uses that influence coastal waters (urban, industrial, agricultural and riverine) and the morphology of the coastline. The latter determines the degree of coastal water confinement and therefore the likelihood that continental nutrient-rich freshwater inflows will be diluted. A low LUSI value indicates coastal waters that are not or only slightly influenced by continental pressures, and a high LUSI value coastal waters strongly influenced by continental pressures. An additional and important feature of LUSI is that it allows the establishment of pressure-impact relationships based on the chlorophyll-a concentration as a proxy of the eutrophication impact. For instances, this relationship for the NW Mediterranean has been established as

chlorophyll-a concentration = 0.12 * LUSI + 0.22 (p = 8.14*10−8, R2 = 82%). By providing insights into which land uses trigger the ongoing eutrophication process in coastal waters, the LUSI aids in the design of measures aimed at remediating the environmental damage caused by human activities.

14:15 – 15:40 SESSION 3: BENTHIC COMMUNITIES
Room: 20+21
Chair: **Jouni Lehtoranta (to be confirmed)**

14:15 – 14:20 Intro

14:20 – 14:40 **Alterations between sugar kelp and turf/filamentous algae in Norway, regime shifts or flips back and forth between different opportunistic seaweed species?**
Hartvig Christie, Guri S. Andersen, Trine Bekkby, Camilla W. Fagerli, Janne K. Gitmark & Eli Rinde
Norwegian Institute for Water Research (NIVA), Oslo, Norway

Following the disappearance of sugar kelp (Saccharina latissima) in southern Norway around year 2000, previous kelp forest areas were observed completely overtaken by filamentous algae (turf algae) loaded with sediments. Large areas, estimated to about 90% of the total sugar kelp forests on the Skagerrak coast (South) and about 50 % on the southwestern (SW) coast, were affected. Turf algae had taken over the hard bottoms mainly in inshore waters. This large spatial scale change was reported as a possible irrevocable regime shift, not caused by a single factor, but rather multiple stressors where eutrophication and ocean warming were suggested to be the most important. More recently, observations of flips back and forth in dominance between sugar kelp and turf algae at several areas within both the S and SW coast has been observed on temporal scales spanning from seasons to years. Hence, the regime shift hypothesis can be questioned. Different experiments and field observations indicate that sugar kelp has a high dispersal potential, colonization rate, and growth rate, and it seems that this species has opportunistic traits in the sense of ability to rapid colonize available substrate. However, if the coverage of turf/sediment is persistent, the possibilities for sugar kelp recolonization will most likely be minor, and a persistent regime shift may occur. Here, we will elucidate the stability properties within these rocky shores. We will discuss data from the recent years to shed light on both prerequisites and drivers of either irrevocable regime shifts or dynamic changes between sugar kelp and ephemeral algae.

14:40 – 15:00 **The combo index – for monitoring eutrophication related problems of macroalgae in the sublittoral zone**
Hege Gundersen, Janne K. Gitmark & Mats Walday
Norwegian Institute for Water Research (NIVA), Oslo, Norway

Monitoring of rocky shores using WFD biological quality elements often results in Good or High ecological status, even in areas where the overgrowth of macroalgae by turf algae is known to be a significant problem. The reason is that the existing biological quality elements are designed to monitor the littoral conditions, while turf algae is mainly a sublittoral phenomenon. The rapid growth of opportunistic filamentous algae is related to the eutrophication of coastal areas, and is a major threat to kelp forests in the North Sea and Skagerrak. It has previously been reported of annual

growth of turf algae that has affected Saccharina latissima in southern Norway and western Norway in recent years, while Gitmark et al. (2016) showed that also the larger Laminaria hyperborea is affected. We suggest to develop a “combo index” for Norway, which combines the investigation of lower growth limit for macroalgae and red algae with the depth distribution of turf algae, using underwater camera.

15:00 – 15:20 **Variability in Danish eelgrass carbon and nitrogen stocks – implications for climate change- and eutrophication mitigation from an ecosystem service perspective**

Theodor Kindeberg[1], Dorte Krause-Jensen[2], Mogens Flindt[1], Emilia Röhr[3] & Marianne Holmer1

[1] Department of Biology, University of Southern Denmark, Odense, Denmark; [2] Department of Bioscience, Aarhus University, Silkeborg, Denmark; [3] Environmental and Marine Biology, Åbo Akademi University, Åbo, Finland

Seagrass ecosystems provide an array of ecosystem services ranging from habitat provision to erosion control, but are threatened by human activities such as eutrophication, land-use changes and overfishing. From a climate change and eutrophication perspective, these systems also cycle carbon and nutrients of which a fraction is buried and stored in the underlying sediment over relevant timescales and thus provide important ecosystem services. Eelgrass (Zostera marina) is an omnipresent seagrass species along the Danish coastline, and its function as a carbon and nutrient sink has been shown to be significant in some areas. However, the spatial variability of these functions, and the drivers behind them, are not fully understood. Here we compile existing datasets on particulate organic carbon (POC) and nitrogen (PON) in the top 10 cm of eelgrass sediments from >50 locations in Denmark. Furthermore, we assess the vertical variability in depth profiles of POC along with stable isotopes (□13C and □15N) in deeper sediment cores and evaluate the possible mechanisms behind the observed variability. Finally, we discuss the effect of eutrophication on carbon burial capacity, which has been shown to be both negative (due to decreased seagrass productivity and/or seagrass loss) and positive (due to increased burial of sestonic particles) in certain areas, and the implication for the ecosystem services of Danish eelgrass meadows.

15:20 – 15:40 **Benthic fauna early colonization and bioturbation after a eutrophication event in a newly flooded coastal lagoon: an ecosystem functioning approach**

Cintia O. Quintana, Thomas Valdemarsen, Sandra W. Thorsen & Erik Kristensen

Department of Biology, University of Southern Denmark

In March 2014, Gyldensteen coastal lagoon in northern Fyn, Denmark was created by flooding 214 ha of agricultural land in a coastal realignment project. In the first year, nutrients mainly derived from agricultural activities fueled the primary production and blooms of macroalgae in the lagoon causing eutrophication and hypoxia. In the following two years, nutrient concentrations in the water decreased markedly (65%) with no development of algal blooms, allowing improvement of ecological conditions. The pioneering benthic community inside the lagoon consisted in typical opportunistic species and it was structurally different from the marine community outside the lagoon. The dominant species in all stations was the polychaete Nereis diversicolor with average abundance of 1604 ind m-2. We investigated how this dominant species influenced benthic fluxes of CO2. We estimated that after flooding and colonization by N. diversicolor, organic carbon degradation in the lagoon was

increased up to 220%. Early colonizing polychaetes can thus modify soils and play an important role in restoring ecological conditions and in successional developments in newly flooded coastal ecosystems.

15:45 – 16:15 BREAK (tea & coffee)

16:15 – 18:00 SESSION 2 continued: ASSESSMENT AND MANAGEMENT TOOLS (PART III)
Room 22+23
Chair: **Philip Axe**

16:15 – 16:20 Intro

16:20 – 16:40 **Utilising eutrophication assessment directives from freshwater to marine systems in the Thames and Liverpool Bay, UK**
Naomi Greenwoord[1], Michelle Devlin[1], Mike Best[2] & Lenka Fronkova[1]
1 Centre for Environment, Fisheries and Aquaculture Science. Lowestoft. UK;
[2] Environment Agency, Peterborough. UK

Assessment of eutrophic conditions are part of several European Directives, including UWWTD, Nitrates Directive, WFD, MSFD and the OSPAR comprehensive procedure, typically using a set of primary indicators (nutrients, chlorophyll and dissolved oxygen) and other secondary information (including phytoplankton species distribution). Each directive typically relates to a set of geographical or political boundaries, that do not always represent an appropriate ecological boundary. These assessments are therefore not coordinated across a river basin and do not most efficiently serve to support improvements in water quality through the river basin management plans. We present recent work that has been undertaken for two case studies, the Thames and Liverpool Bay in the UK, which have historically received significant anthropogenic nutrient inputs. Individual eutrophication indicators are tested across a salinity gradient, and assessments applied within an ecological typology or through a salinity gradient. Use of fully integrated datasets over these ecological gradients is required, utilising several disparate data sources from different agencies. Data sources included the use of new technologies such as satellites together with SmartBuoys, freshwater inputs, ecosystem modelling, and traditional methods such as ship surveys. The paper presents the outcomes of an assessment applied across freshwater to marine scale. We discuss the benefits of such an approach including a more holistic understanding of the impact of anthropogenic nutrient inputs along the river continuum.

16:40 – 17:00 **Assessment of eutrophication status based on sub-halocline oxygen conditions in the Gulf of Finland (Baltic Sea)**
Stella-Theresa Stoicescu, Urmas Lips & Taavi Liblik
Department of Marine Systems, Tallinn University of Technology, Tallinn, Estonia

Sub-halocline oxygen conditions in the deep basins of the Baltic Sea depend on natural forcing and anthropogenic impact. HELCOM has a long tradition of characterizing the status of the seabed and deep-water habitats by estimating “the extent of anoxic and hypoxic bottoms”. An eutrophication-related indicator “oxygen debt” has been used in the recent HELCOM assessments and a more sophisticated “oxygen consumption” indicator has been introduced. We describe the oxygen conditions in

the Gulf of Finland (GoF) in 2014-2017 based on observations at profiling stations where vertical profiles of temperature, salinity, and oxygen were acquired up to 8 times a day. The applicability of high-frequency data from a fixed automated station and the three possible oxygen indicators for the status assessment were tested. The results show that the GoF bottom area affected by hypoxia varied in large ranges with a seasonal maximum in autumn (> 25% of bottoms were hypoxic in autumn 2016). The "oxygen debt" indicator is the simplest and the assessment results are less influenced by the wind-induced changes in hydrographic conditions. For the status assessment based on "oxygen consumption" indicator, a rough oxygen budget, where the contributions of advection and mixing are included, was formulated. We concluded that all three indicators have their advantages and methodological challenges. To increase the confidence of eutrophication assessments both high-frequency profiling should be implemented in the monitoring programmes and more accurate estimates of changes due to physical processes are required.

17:00 – 17:20 **Mapping eelgrass beds with orthophotos**

Sarah B. Ørberg[1], Geoffrey B. Groom[2], Ane Kjeldgaard[1], Jacob Carstensen[3], Michael B. Rasmussen[1], Preben Clausen[2] & Dorte Krause-Jensen[1]

[1] Aarhus University, Department of Bioscience, Silkeborg, Denmark; [2] Aarhus University, Department of Bioscience, Kalø, Denmark; [3] Aarhus University, Department of Bioscience, Roskilde, Denmark

Mapping the distribution of eelgrass is important for optimal management of eelgrass meadows, a key organism in coastal ecosystems. The many ecosystem functions and services that eelgrass beds provide, scale directly with their distribution area. We have evaluated the potential in using orthophotos, that Aarhus University has bought for other purposes, to map and quantify eelgrass distribution. Based on photos from the summers of 2012, 2014 and 2016, in combination with monitoring data on eelgrass, we developed image analysis techniques applied to RGB color bands and analyzed orthophotos from selected, important eelgrass areas in Denmark: Nibe-Gjøl Bredninger in Limfjorden, Saltholm incl. the Amager coast facing Saltholm, the Southfunen Archipelago and Roskilde Fjord. The analysis displayed good precision with less than 5% uncertainty, validated by ground truth monitoring data. Good measures of eelgrass distribution areas and patterns will contribute to a better understanding of the ecosystems services and the socioeconomic value of eelgrass meadows at larger scales. We show that mapping eelgrass distribution by image analysis of orthophotos serves as a readily applicable method. Orthophotos are often available in relatively long continuous time series, offering the opportunity to observe longterm patterns in distribution and how they may be affected by different levels of environmental status in associated water bodies.

17:20 – 17:40 **Microbial genetic indicators of Baltic Sea environmental status: the BONUS Blueprint project**

Deniz Bombar[1], Anders Andersson[2], Christoph Humborg[3], Jarone Pinhassi[4], Kaarina Sivonen[5], Klaus Jürgens[6], Veljo Kisand[7], Åke Hagström[4] & Lasse Riemann[1]

[1] University of Copenhagen (UCPH), Copenhagen, Denmark; [2] KTH Royal Institute of Technology (KTH), Stockholm, Sweden; [3] Stockholm University (SU), Stockholm, Sweden; [4] Linnaeus University (LNU), Kalmar, Sweden; [5] University of Helsinki (UH), Helsinki, Finland; [6] Leibniz Institute for Baltic Sea Research Warnemünde (IOW), Warnemünde, Germany; [7] University of Tartu (UT), Tartu, Estonia

The BONUS Blueprint project ran between 2014 and 2018 with the overarching objective to recommend new, genetic indicators for evaluating Baltic Sea environmental status. The key result of this project is that retrieval, sequencing and analysis of environmental DNA or RNA samples can be done in a relatively streamlined and cost-efficient manner, producing taxonomic and functional information about pelagic microbial communities which correlate well with different environmental conditions and anthropogenic pressure scenarios. For example, specific and reproducible changes were seen in the meta-omics profiles, and specifically in abundances of transporter genes, in response to simulated enrichments with humic or agricultural riverine dissolved organic matter. We further highlight the capacity of genetic indicators for assessing potential future changes in the interplay between pelagic nitrogen fixation and denitrification, processes which are of great relevance for the future eutrophication status of the Baltic Sea. The strength of using genetic information in monitoring of environmental status is that even small numbers of samples yield vast amounts of information that can be exploited in different ways depending on the scenario in question. With sophisticated data-processing pipelines in place, such analyses can become applicable for common monitoring practice.

17:40 – 18:00 **Eutrophication in the Arabian Gulf – a case study and ongoing issues**

Michelle Devlin[1], Brett Lyons[2] & Will Le Quesne[1]

[1] Centre for Environment, Fisheries and Aquaculture Science. Lowestoft, Pakefield Rd NR32 OHT, UK; [2] Centre for Environment, Fisheries and Aquaculture Science. Weymouth, Barrack Rd, DT4 8UB, UK

Assessment of eutrophic conditions is a common management tool, providing information on primary indicators (nutrients, chlorophyll and dissolved oxygen) and other secondary information (including phytoplankton species distribution). Typically, when applying the assessments in Europe, it has been difficult to fully assess a shift in a reference or baseline state given that the anthropogenic changes have been occurring prior to any established monitoring program. The assessment of eutrophic conditions in the Arabian Gulf offers a scenario in which the rapid urbanisation in recent decades has caused significant and measurable changes from a pre-industrial condition. In this talk, we present the long-term data available from the Arabian Gulf, with a focus on the changes in Kuwait marine waters, where a long-term water quality monitoring program provides a unique perspective of a changing eutrophic state. The analysis of long term water quality and phytoplankton data show the changes that have occurred through major shifts in the Shatt Al Arab River flow and associated pollutant loads, along with significant discharges of coastal sewage pollution. We present an overview of a possible eutrophication assessment framework for Kuwait with possibilities for the wider Gulf region, drawing on the

lessons learnt through the application of the European Water Framework Directive and the OSPAR comprehensive procedure. We will present how this assessment framework can contribute to wider State of the Marine Environment Reporting.

16:15 – 18:20 SESSION 4: LAND-USE AND NUTRIENTS: LOADS, CONCENTRATIONS, AVAILABILITY, LIMITATION AND DYNAMICS
Room: 20+21
Chair: **Cintia Quintana**

16:15 – 16:20 Intro

16:20 – 16:40 **Freshwater discharge and terrestrial DOM as a drivers of marine productivity: challenging the role of mineral nutrients**
Johan Wikner[1,2], Agneta Andersson[1,2] & Ulf Båmstedt[1,2]
[1] Department of Ecology and Environmental Science, Umeå University, Umeå, Sweden
[2] Umeå Marine Sciences Center, Umeå Universitey, Hörnefors, Sweden

Phosphorus and nitrogen limitation have been the prime focus for controlling marine productivity and thereby measures to mitigate eutrophication. However, field as well as experimental studies have observed marked effect of organic carbon discharged by rivers. To better understand the mechanism behind the influence of riverine discharge on the coastal zone we investigated the interacting effects of different mixing depths and a realistic increase of allochthonous dissolved organic carbon (DOC) on the ratio of heterotrophic to autotrophic production (i.e. trophic balance). This was evaluated in a mesocosm study with a stratified water column. An autumn plankton community from the northern Bothnian Sea showed significantly decreased phytoplankton production (P) and somewhat increased bacterial production (B) with added DOC. In addition, increased mixing depth further reduced phytoplankton production. Addition of DOC shifted the system towards net heterotrophy irrespective of mixing depth, but with a stronger effect with a deep mixed layer (B/P quotient from 0.42 to 1.24). Without DOC addition there was no significant effect of the mixing depth. Our results corroborate field observations that organic carbon have an influence of coastal marine productivity exceeding that of concomitant discharge of mineral nutrients. The importance of organic C for marine productivity is well established in the northern Baltic Sea, but few similar reports are available from other marine areas.

16:40 – 17:00 **Sources of phosphorus to the surface layer of a Baltic estuary**
Jakob Walve, Maria Sandberg, Ulf Larsson & Ragnar Elmgren
Department of Ecology, Environment and Plant Sciences, Stockholm University, Stockholm, Sweden

The response of coastal waters to anthropogenic nutrient loads depends on the nutrient sources and the nutrient uptake by primary producers. An analysis of nutrient sources is complicated by variations in freshwater and seawater flushing rates and nutrient concentrations, and by nutrient recycling from the sediments. We used a mass-balance box-model to calculate long-term and seasonal water exchange and phosphorus (P) turnover in the stratified Stockholm inner archipelago, once heavily loaded with nutrients from untreated sewage. After a drastic P load reduction in the early1970s and further reductions in the 1990s, treated sewage now contri-

butes only ~12% of the observed P concentration. The sediments are a net P sink in spring but a net P source in summer and autumn, when P sedimented with the spring bloom is recycled. We see no indication of a remaining legacy internal P load from the previous high P loading. Most of the P uptake by the spring phytoplankton bloom comes from recent inflows of freshwater and seawater. Recycled P from the sediments is also a significant source for the spring bloom, while the sewage contribution is small. Thus, P inputs with freshwater and seawater are now the major drivers of the P cycle of the Stockholm inner archipelago. Yearly variations in freshwater flushing influence P concentrations, with higher values in dry years, when dilution of P inputs from sediments and sewage is low.

17:00 – 17:20 **Influence of allochthonous dissolved organic matter on pelagic basal production in a northerly estuary**

Agneta Andersson
Department of Ecology and Environmental Science, Umeå University, Umeå, Sweden

Phytoplankton and heterotrophic bacteria are key groups at the base of aquatic food webs. In estuaries receiving riverine water with a high content of coloured allochthonous dissolved organic matter (ADOM), phytoplankton primary production may be reduced, while bacterial production is favoured. We tested this hypothesis by performing a field study in a northerly estuary receiving nutrient-poor, ADOM-rich riverine water, and analyzing results using multivariate statistics. Throughout the productive season, and especially during the spring river flush, the production and growth rate of heterotrophic bacteria were stimulated by the riverine inflow of dissolved organic carbon (DOC). In contrast, primary production and photosynthetic efficiency (i.e. phytoplankton growth rate) were negatively affected by DOC. Primary production related positively to phosphorus, which is the limiting nutrient in the area. In the upper estuary where DOC concentrations were the highest, the heterotrophic bacterial production constituted almost 100% of the basal production (sum of primary and bacterial production) during spring, while during summer the primary and bacterial production were approximately equal. Our study shows that riverine DOC had a strong negative influence on coastal phytoplankton production, likely due to light attenuation. On the other hand DOC showed a positive influence on bacterial production since it represents a supplementary food source. Thus, in boreal regions where climate change will cause increased river inflow to coastal waters, the balance between phytoplankton and bacterial production is likely to be changed, favouring bacteria. The pelagic food web structure and overall productivity will in turn be altered.

17:20 – 17:40 **Phosphorus losses from an artificially drained lowland catchment and its changes along the flow path**

Monika Nausch[1], Sandra Jahn[1], Petra Kahle[2], Günther Nausch[1],Thomas Leipe[1] & Bernd Lennartz[2]
[1] Leibniz Institute for Baltic Sea Research Warnemünde, Germany; [2] Faculty of Agricultural and Environmental Sciences-University of Rostock, Germany

Phosphorus (P) is a major contributor to eutrophication of rivers, lakes and coastal ecosystems as the Baltic Sea. Most of this P is coming from diffuses sources of agricultural origin. The German catchment to the Baltic Sea is agricultural dominated. Arable land is equipped with tile-drain systems to a high degree which can be a

source introducing P from arable land to aquatic ecosystems. The objective of this study was to detect the P loads and their composition (P fractions) from a tile-drain outlet and how they vary along the flow path (ditch, brook, river). The investigations were conducted in a sub-basin of the Warnow catchment, the second largest German catchment discharging to the Baltic Sea. Samples were collected during three discharge seasons (1th November - 30th April) in 2013/2014, 2015/2016, and 2016/2017. All periods covered relative dry and mild winters. Total phosphorus (TP) concentrations in drain water ranged from 15.5 ± 3.9 µgl-1 in 2013/2014 to 34.6 ± 46.9 µgl-1 in 2015/2016. They increased along the flow path, especially in the superior brook. Thus the contribution of drain water to the P concentrations in the brook and the river Warnow seems to be low. Drain water was dominated by dissolved P (>70%) with an increase of particulate P along the flow path. In the river Warnow, dissolved inorganic P was converted into particulate organic P by the spring bloom in March and April. Clay minerals and Fe(hydr)oxides were the main carrier of particle bound inorganic P.

17:40 – 18:00 **Resolving mechanisms of N retention in coastal waters through a combined mass balance and process-oriented approach**

Mindaugas Zilius[1], M. Bartoli[2,1], Iris Liskow[3], Jolita Petkuviene[1], Diana Vaiciute[1], Irma Vybernaite-Lubiene[1], Maren Voss[3], Petras Zemlys[1] & P.A. Bukaveckas[4]
[1] Marine Research Institute, Klaipeda University, Klaipeda, Lithuania; [2] Department of Chemistry, Life Sciences and Environmental Sustainability, University of Parma, Parma, Italy; [3] Department of Biological Oceanography, Leibniz Institute for Baltic Sea Research, Rostock, Germany; [4] Department of Biology and Center for Environmental Studies, Virginia Commonwealth University

Estuaries, being situated at the interface between freshwater and marine environments, are important regulators of nitrogen (N) fluxes from land to sea. Though N cycling in estuaries has received considerable attention, there remains a need to better understand the mechanisms governing N retention and storage. As part of the BONUS COCOA project (Nutrient cocktail in coastal zones of the Baltic Sea), we investigated seasonal shifts in external vs. internal N sources, and the transition from diatom- to cyanobacteria- dominated phytoplankton communities influenced N retention within the Curonian Lagoon (SE Baltic Sea). Results show that almost all of the annual N retention was due to sediment storage following the spring diatom bloom. This period was characterized by high riverine inputs of dissolved inorganic nitrogen, high rates of assimilatory conversion to particulate nitrogen, and net retention of particulate nitrogen. By contrast, the larger cyanobacteria bloom occurring in summer was associated with low sediment N storage due to greater export of particulate fraction to the Baltic Sea and high rates of N remineralization. In addition, summertime dinitrogen fixation by cyanobacteria largely offset losses from denitrification, which occurred predominantly during winter. These findings suggest that increasing dominance by cyanobacteria in fresh–brackish waters diminishes N retention in coastal estuaries and lagoons.

18:00 - 18:20 **Assessing human contributions to production in the coastal waters of the United States using modern and archived fish tissues**

Autumn Oczkowski[1], Betty Kreakie[1], M. Nicole Gutierrez[2], Peg Pelletier[1], Emily Santos[3] & John Kiddon[1]

[1] US EPA Atlantic Ecology Division, Narragansett, RI, USA; [2] US EPA Student Contractor, Narragansett, RI, USA; [3] Humboldt State University, Arcata, CA, USA

This study assessed the degree human-associated changes in nitrogen sources have impacted coastal food webs over the past century and a half. Stable isotope values of nitrogen (δ15N) and carbon (δ13C) were used as a proxy for human influence and were measured in tissue samples of common fish species, collected in 2015, from every major estuary in the United States as part of the U.S. Environmental Protection Agency's National Coastal Condition Assessment (n=616). Samples were compared to tissues taken from fish specimens collected from 1854 through the 1990s and archived at the Smithsonian National Museum of Natural History in Washington, DC (n=237). We used random forest modeling to explore the impacts of spatial structure as well as the potential environmental drivers on isotope values. Time specific information about geographic region, fish species and life history, as well as upstream land use and human population densities were among the variables included in the model. Larger scale geographic variables were better predictors of coastal fish isotope values than either time or human influence categories. Local and regional scale differences were observed between the archived and modern fish δ15N and δ13C values and could be associated with human impact predictor variables. More impacted systems were affiliated with both higher δ15N and δ13C values; this is consistent with current paradigms. Our results suggest, however, that these paradigms are not universally applicable to all coastal waterbodies and underscore the importance of characterizing the baseline and timeline of human impacts on coastal water bodies of concern.

18:20 – 18:40 Carbon inputs and dynamics in the eutrophic estuary Roskilde Fjord

Søren Laurentius Nielsen

Department of Science and Environment, Roskilde University, Roskilde, Denmark

Depending on the relative significance of decomposition of allochthonous organic matter and in situ production of autochthonous organic matter in the estuary, estuaries can act as both sinks and sources of organic matter in global carbon cycle. The aim of this contribution is to quantify these two main sources of organic carbon to a temperate, eutrophic estuary and to analyze the implications for the carbon dynamics of the estuary. This is done based on data from a detailed seasonal study in 2008-2009, analyzing the allochthonous input to the estuary quantitatively and qualitatively, comparing this input to the primary production in the estuary. The high loadings of inorganic nutrients to the estuary mean that the estuary behave more like a reactor, converting inorganic nutrients to organic matter, than like a simple transport route of organic matter from the terrestrial ecosystems to the marine. The autochthonous to allochthonous ratio of DOC in Roskilde Fjord is approximately 20. A small amount of carbon, about 0.5 mol C m-2 year-1, is received from the surrounding landscape primarily as DOC (2% of the total carbon input). The dominating carbon source is phytoplankton primary production with about 15.9 mol C m-2 year-1 (65 %). In conclusion, any transport and conversion of terrestrial DOC components in Roskilde Fjord happen on a background of an intense marine

production and degradation, which, in this eutrophic estuary with long residence time, by far surpass the metabolism of terrestrial carbon.

19:00 – ... **DINNER**

TUESDAY 19 JUNE 2018

09:00 – 10:45 **KEYNOTE 3, KEYNOTE 4 AND KEYNOTE 5**
Plenary Session in Sal J
Chair: **Erik Bonsdorff**

09:00 – 09:30 **KN3: PHYTOPLANKTON DYNAMICS AND FOOD WEB EFFICIENCY IN RELATION TO CHANGING NUTRIENTS AND CLIMATE REGIMES**
Monika Winder
Department of Ecology, Environment and Plant Sciences, Stockholm, Sweden

Phytoplankton provide an important ecosystem service by fuelling the production at higher trophic level, and particularly so in coastal waters that are among the most productive marine ecosystems. A good understanding of the natural dynamics of phytoplankton and effects of increased nutrient loads on production, species composition and consequences for carbon transfer is important to provide the management tools to mitigate threats to coastal waters. In this talk I will show that phytoplankton annual cycles and seasonal fluctuations vary greatly from year to year and blooms can occur any time of the year, suggesting that phytoplankton biomass is regulated by multiple processes. The food quality of these primary producers characterized by essential fatty acids varies greatly across taxonomic groups and salinity gradients along the freshwater-marine continuum. This nutritional composition regulates trophic efficiencies because consumers require an adequate intake of all essential building blocks to fulfil their nutritional needs. Dense human settlements and climate change that have led to nutrient enrichment and other stressors in many coastal systems, however, threaten the production of high-quality primary production by restructuring biodiversity and often promote the formation of harmful cyanobacteria or toxic dinoflagellate blooms. To ensure continuous provision of essential compounds in coastal waters, it will be important to sustain the production of high-quality phytoplankton composition that synthesizes rich amounts of essential compounds in the face of threats from human pressures and climate change.

09:30 – 10:00 **KN4: SUBMERGED AQUATIC VEGETATION IN RELATION TO CHANGING NUTRIENT AND CLIMATE REGIMES**
Marianne Holmer
Department of Biology, University of Southern Denmark, Denmark

Submerged aquatic vegetation (SAV) is ecologically important primary producers and ecosystem engineers that play a central role in coastal habitats ranging from kelp forests to seagrass meadows, but SAV is also under global threat. One of the major challenges limiting the success of SAV conservation and restoration is the limited understanding of ecological feedback mechanisms under changing nutrient and climate regimes. Although SAV is known to be vulnerable to physical and biogeochemical changes in the marine environment, the impacts on SAV of ongoing and future anthropogenic change in nutrient and climate regimes often fail to be predicted as a result of multiple and unexpected feedbacks. In this talk, feedback mechanisms in SAV communities undergoing changes are explored with focus on responses to eutrophication, oligotrophication and climate change (e.g. sea-level rise). Status will be given on the role of top-down and bottom-up effects in SAV, critical factors for restoration of SAV under improved nutrient regimes and return of coastal lagoons after

sea-level rise. Further effects of altered nutrient and climate regimes on the ability of SAV to provide important ecosystems services such as nutrient and climate mitigation will be discussed. The review will provide suggestions for improved management of SAV habitats under changing nutrient and climate regimes.

10:00 – 10:30 **KN5: CONTRIBUTIONS OF MACROFAUNAL COMMUNITIES TO ECOSYSTEM FUNCTION ACROSS GRADIENTS OF EUTROPHICATION**

Alf Norkko[1,2]
[1] *Tvärminne Zoological Station, University of Helsinki, Hanko, Finland*
[2] *Baltic Sea Centre, Stockholm University, Stockholm, Sweden*

Soft-sediment habitats are important in the global cycles of elements and energy and the benthic fauna play pivotal roles in affecting benthic-pelagic coupling and sediment biogeochemistry. In shallow coastal seas, high levels of primary productivity feeds organic matter to the benthic system, affecting both the structure and function of macrofaunal communities. Hence eutrophication-status has a profound influence not only on benthic communities, but as a consequence, also on key processes in marine ecosystems. Despite growing insight into how macrofaunal communities affect key ecosystem processes such as organic matter mineralization, burial, and nutrient transformation pathways, our ability to generalize how biodiversity modifies ecosystem functions in real world settings is limited due to the complexity of natural ecosystems. I will provide examples from a combination of large-scale field studies and modelling efforts across the Baltic Sea, that aim to resolve how macrofaunal communities process organic matter and mediate nutrient fluxes across the sediment-water interface, while exploring how gradients in eutrophication and hypoxia modify these relationships. These studies suggest that the relationship between benthic community structure and nutrient fluxes is highly context dependent and dictated by local communities and environmental conditions. While ecological theory predicts a positive relationship between biodiversity and ecosystem functioning, our findings suggest that variation in the functional attributes of communities affect carbon- and nutrient-cycling processes more than species diversity per se does. Changes in the abundance and distribution of functionally important species due to progressing eutrophication and climate change thus has important feedbacks on the functioning of seafloor ecosystems.

10:30 – 10:45 Questions and answers in relation to keynotes 3, 4 and 5.

10:45 – 11:15 BREAK (tea & coffee)

11:15 – 13:00 SESSION 5: MITIGRATION; OLIGOTROPHICATION AND RECOVERY (PART I)
Room: 20+21
Chair: **Jakob Walve**

11:15 – 11:20 Intro

11:20 – 11:40 **Managing Eutrophication in the Szczecin (Oder) Lagoon - development, present state and future perspectives**

Gerald Schernewski[1,2] & Rene Friedland[1]
[1] Leibniz-Institute for Baltic Sea Research (IOW), Rostock, Germany; [2] Marine Research Institute of Klaipėda University, Klaipeda, Lithuania

High riverine nutrient loads cause poor water quality, low transparency and an unsatisfactory ecological status in the Szczecin (Oder) Lagoon. Above 90 % of the riverine loads are entering with the Odra (Oder) river. Especially during summer, eutrophication effects like cyanobacteria blooms or fish kills due to hypoxia can cause serious economic problems for tourism. During the 1980's, total riverine N (P) loads into the lagoon were about 77,000 t (8,000 t) and declined to about 65,000 t (3,500 t) after 2010. While nutrient concentrations, water transparency (Secchi depth) and chlorophyll-a in the Polish eastern lagoon (Wielki Zalew) show a positive response, this is not the case in the German western lagoon (Kleines Haff). Here, the summer Secchi depth is 0.6 m and the summer chlorophyll-a concentration is about 80 µg/l. The latter exceeds the concentration for a good environmental status (15 µg/l) by four times. The lagoon obviously shows a hysteresis effect. According to the Baltic Sea Action Plan, the acceptable total riverine nutrient loads to the lagoon would be about 50,000 t TN (1,600 t TP). Measures in river basins that would allow meeting these target loads are very hard to implement and, in opposite, recent riverine loads show an increase again. Further, these loads would not be sufficient to transfer the lagoon into a non-eutrophic state. The presentation reviews the past 40 years of water quality management and focusses on recently assessed and tested internal measures to improve the lagoons' environmental status. The measures aim at removing nutrients and/or increasing water transparency. The latter to overcome the hysteresis effect and to initiate a recovery of macrophytes. One of the most promising approaches seems the cultivation of zebra mussels.

11:40 – 12:00 **Interannual variability of estuarine and coastal primary production in an agricultural catchment**

Joseph V. McGovern, Michael Hartnett & Stephen Nash
Department of Civil Engineering, Ryan Institute for environmental marine and energy research, National University of Ireland Galway, Ireland

More than 150,000 people are employed in the Agri-Food industry in Ireland. In recent times, the announcement of national programs such as Food Harvest 2020 and Food Wise 2025 have pointed to potential intensification of agricultural practices in Ireland going forward. The adjoining Argideen estuary and Courtmacsherry bay in the south west of Ireland drain a collection of predominantly agricultural sub-catchments totalling 150km2. The receiving waters were allocated poor ecological status under the Water Framework Directive at the most recent appraisal. In order to untangle the causative factors and identify potential measures to restore good trophic status, a bio-physical model of the receiving waters has been calibrated and validated subject to the prevailing climatic and nutrient loading regime. In this paper, we discuss the magnitude of seasonal nutrient load reduction necessary to restore good trophic status with respect to phytoplankton and macroalgae bloom magnitudes.

12:00 – 12:20 **Wadden Sea Eutrophication: Long-term trends and regional differences**

J.E.E. van Beusekom[1], J. Carstensen[2], K. Kolbe[3], H.-J. Lenhart[4], J. Pätsch[5] & J. Rick[6]
[1] Helmholtz-Zentrum Geesthacht, Institute for coastal research, Geesthacht, Germany; [2] University of Aarhus, Department of Bioscience, Roskilde, Denmark; [3] Niedersächsische Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz – Betriebsstelle Brake-Oldenburg, Norden, Germany; [4] University of Hamburg, research group scientific computing, Hamburg, Germany; [5] University of Hamburg, IfM, Hamburg, Germany; [6] Alfred-Wegener-Institut, Helmholtz-Zentrum für Polar-und Meeresforschung, List/Sylt, Germany

The Wadden Sea is a shallow intertidal coastal sea fringing the North Sea coast of the Netherlands, Germany and Denmark and largely protected by barrier islands. Riverine nutrient enrichment since the 1950's has exerted a major impact including a loss of seagrass, increased phytoplankton blooms and increased green macroalgae blooms. Available long-term data document an increase in eutrophication until the 1980s and a decrease since. Rivers are the major source of Wadden Sea eutrophication. The nutrient inputs of the major rivers impacting the Wadden Sea continue to decrease at an average pace of about 2.5 % per year for TN and about 5.4 % per year for TP causing increasing NP ratios. Phytoplankton biomass (measured as Chla) have clearly decreased since the 1980s and presently remain at a low level. In tidal inlet stations with a long-term monitoring, summer phytoplankton levels correlate with riverine TN loads but stations located within the Wadden Sea behave more complex. Regional differences are observed with highest levels in the southern Wadden Sea and in the mouth of the Elbe estuary and lowest levels in the northern Wadden Sea. Measures to reduce nutrient inputs in the past have led to a significant improvement of the eutrophication status. However, given that nutrient levels, N/P ratios, chlorophyll levels and macroalgal coverage still are clearly above background levels, we conclude that the trilateral goal of a eutrophication non-problem area has not been met yet.

12:20 – 12:40 **Assessing the effects of climate change on coastal ecosystems, based on surveillance monitoring following the Water Framework Directive (WFD)**

Helene Frigstad[1], Andre Staalstrøm[1], Marit Norli[1], Guttorm Christensen[2], Roger Kvalsund[3], Andrew King[1], Øyvind Kaste[1] & Kai Sørensen[1]
[1] Norwegian Institute for Water Research (NIVA), Grimstad and Oslo, Norway
[2] Akvaplan-NIVA AS, Tromsø, Norway; [3] Runde Environmental Centre, Runde, Norway

There has been an overall decline in inorganic nutrient concentrations over the past 20 years in the Norwegian Skagerrak. This is related to a decrease in advected nutrients, owing to management efforts to reduce eutrophication. However, analyses of long-term monitoring data from the Arendal station, showed a sharp increase in suspended material around 1998-2000, especially in the calculated fraction of non-autrotrophic particulate organic matter. This was hypothesized to be related to increased river run-off and could be connected to the reported darkening of coastal waters. Norwegian national ecosystem monitoring of coastal waters (ØKOKYST) is designed to monitor the environmental status, following the requirements in the Water Framework Directive (WFD). Surveillance monitoring should in principle detect long-term changes, both in natural conditions and due to human perturbations. However, climate change can impact eutrophication status, through changes in the riverine loads of suspended particles and nutrients, and thereby have an indirect

(and often unquantifiable) impact on biological quality elements. NIVA has, through its strategic institute initiative on land-ocean interactions, extended the monitoring on three ØKOKYST-stations spanning the Norwegian coastline since July 2017. The standard WFD-monitoring has been extended to include parameters relevant for detecting changes in riverine inputs (DOC, cDOM, light) and effects of coastal ocean acidification (DIC and alkalinity). The aim is to detect effects of climate change in coastal waters, and give advice to future monitoring efforts. This presentation will provide the first analysis of the extended ecosystem monitoring, coupled with historic data and results from other relevant national monitoring programs.

12:40 – 13:00 **The synergies of human pressures driving coastal acidification**

Jacob Carstensen[1] & Carlos M. Duarte[2,3]

[1] Aarhus University, Department of Bioscience, Frederiksborgvej 399, DK-4000 Roskilde, Denmark; [2] King Abdullah University of Science and Technology (KAUST), Red Sea Research Center (RSRC), Thuwal, 23955-6900, Saudi Arabia; [3] Arctic Research Centre, Department of Bioscience, Aarhus University, C.F. Møllers Allé 8, DK-8000 Aarhus C, Denmark

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. 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 to maintain coastal ecosystem services.

11:15 – 13:00 SESSION 6: MONITORING, REMOTE SENSING AND MODELLING (PART I)

Room 22+23

Chair: **Günther Nausch**

11:15 – 11:20 Intro

11:20 – 11:40 **Do environmental drivers shape phytoplankton biomass off Western Iberia?**

Ana C. Brito[1,2], Paloma Garrido-Amador[3] & Afonso M. Ferreira[1]
1 MARE – Marine and Environmental Sciences Centre, Faculdade de Ciências da Universidade de Lisboa, Lisboa, Portugal
2 Departamento de Biologia Vegetal, Faculdade de Ciências da Universidade de Lisboa, Campo Grande, 1749-016, Lisboa, Portugal
3 Max Planck Institute for Marine Microbiology, Celsiusstrasse 1, D-28359, Bremen, Germany

Phytoplankton is recognized as an important bioindicator of environmental changes in oceanic and coastal ecosystems. Ocean colour remote sensing has been extensively used to study phytoplankton throughout the world, yet there is still much to understand in terms of what influences phytoplankton variability at regional scales. This study aims at investigating the drivers of phytoplankton anomalies in the Western Iberian Coast (36ºN-45ºN), using satellite and modelling data. Spatio-temporal series (2002-2014) of chlorophyll a, sea surface temperature, nutrient data (dissolved inorganic nitrogen, phosphate and silicates), mixed layer depth and euphotic depth were acquired from the Copernicus Marine Environment Monitoring Service (CMEMS) and Centre for Environmental Data Analysis (CEDA). Along-shore wind stress was also calculated for the period of 1997-2014 from wind data derived from NOAA's NCEP Climate Forecast System Reanalysis. Correlations were used as preliminary analyses to evaluate the relationship between phytoplankton biomass anomalies and environmental variables. Positive chlorophyll a anomalies were observed, from 2007 to 2011, which seem associated with nitrogen concentrations. Additional statistical analyses will also be used to investigate the seasonal and interannual patterns of phytoplankton and to distinguish which are the most influential environmental agents that shape these patterns. Potential use of these results towards environmental management in the context of the European Marine Strategy Framework Directive (MSFD) will be considered.

11:40 – 12:00 **The JMP_EUNOSAT project: developing a eutrophication assessment of the North Sea using satellite data**

Lisette Enserink[1], Anouk Blauw[2], Dimitry van der Zande[3], Stiig Markager[4] & Theo Prins[2]
[1] Rijkswaterstaat, Lelystad, the Netherlands; [2] Deltares, Delft, the Netherlands; [3] RBINS, Brussels, Belgium; [4] Aarhus University, Roskilde, Denmark

The European Marine Strategy Framework Directive (MSFD) aims to achieve good ecological status of marine areas. For eutrophication, countries around the North Sea strive for nutrient and chlorophyll concentrations that deviate less than 50% from "natural background concentrations". Countries have used different definitions of "natural background conditions" and applied different methods to estimate them. For the assessment of ecological status countries use monitoring data with different sampling strategies and analytical methods. The incoherence in assessment levels and monitoring data leads to incoherence of assessment results between countries. The launch of the COPERNICUS programme provides satellite data for the whole North Sea that can be used as a source of coherent monitoring data. In the project JMP-EUNOSAT all countries bordering the North Sea work together towards coherent MSFD assessments for eutrophication in the North Sea, using satellite data. The project addresses both 1) the definition of coherent assessment levels and

assessment areas and 2) the use of satellite data as coherent monitoring data and 3) how countries can collaborate on coherent assessments and monitoring. Natural background concentrations are estimated with a suite of modelling tools, with the same method for the whole North Sea. The models simulate nutrient loads from rivers and corresponding concentrations of nutrients and chlorophyll in the North Sea. For monitoring of chlorophyll, a coherent satellite product is developed that combines available satellite products. The assessment results using the newly developed assessment levels and satellite data are compared with traditional assessment results.

12:00 – 12:20 **Use of FerryBox ships of opportunity for monitoring and assessment of eutrophication related to the Water Framework Directive**

Kai Sørensen, Andrew King, Marit Norli, Dag Hjermann, Trond Kristiansen, Sabine Marty, Pierre Jaccard, Wenche Eikrem & Jesper H. Andersen
Norwegian Institute for Water Research (NIVA), Oslo, Norway

The Norwegian FerryBox network has been in operation since 2001 and covers a large part of the Norwegian coast, the Barents Sea opening, and part of the northern North Sea. The network will be extended and upgraded to a national infrastructure in the new program NorSOOP (Norwegian Ships Of Opportunity Program for marine and atmospheric research). The FerryBox network has already showed great success for several years being part of national and EU monitoring and research programs related to sensor development, Water Framework Directives, harmful algal blooms, ocean acidification, and satellite products validation, and ocean literacy. The FerryBox system is based on technical design developed at NIVA using different physical and biogeochemical sensors for temperature, salinity, oxygen, chlorophyll-a fluorescence, phycocyanin- and cDOM-fluorescence, and turbidity. The network now also includes new advanced sensor technology for carbonate system variables and ocean colour validation sensors. The achievements after 15 years of operation, comparisons with traditional monitoring programs, development of the network towards a new infrastructure and application for water monitoring programs addressing anthropogenic impacts on coastal waters, including eutrophication, as well as the experience from satellite product validation will be presented.

12:20 – 12:40 **Artificial deep water ventilation induces inflows from adjacent areas and oxi-dizes near-bottom water in a stratified coastal basins**

Jouni Lehtoranta[1], Jørgen Bendsen[2], Christer Lännergren[3], Erkki Saarijärvi[4] & Heikki Pitkänen[1]
[1] Finnish Environment Institute SYKE, Helsinki, Finland; [2] ClimateLab, Copenhagen, Denmark; [3] Stockholm Vatten, Sweden; [4] WaterEco Ltd, Kuopio, Finland

To study possibilities to improve the status of anoxic coastal basins, experi-mental three years artificial oxygenation was conducted in two basins: Län-nerstasundet off Stockholm suffering from semi-permanent anoxia, and Sandöfjärden, Southwestern Finnish archipelago suffering from summertime anoxia. The experiments in 2009-2011 were based on pumping of oxygen-rich surface water through pycnocline into near-bottom anoxic waters. In Län-nerstasundet, the pumping rate about 1 m3 s-1 could oxidize the hydrogen sulphide containing near-bottom water to concentrations of 0.2 to 2.0 mg O2 l-1 without breaking the pycnocline. The pumping decreased water density below the pycnocline and enabled inflows of oxic water from the

neighboring basin into the anoxic basin under oxygenation. The inflows maintained the basin oxic up to months after the pumping was ended, whereas in the reference basin anoxia prevailed comparable to conditions before the experiment. In a larger basin in Finland the pumping rate about 6 m3 s-1 could not prevent the development of anoxia in late summer, probably because the pumping could not create inflow into the anoxic basin, and also due to considerable warming of deep water and enhanced consumption of oxygen. The main conclusion is that in a semi-enclosed basin with halocline and suitable bottom topography, it is possible to generate oxic conditions with a relatively low need of energy and without breaking of pycnocline.

13:00 – 14:00 LUNCH

13:45 – 15:40 SESSION 5 continued: MITIGATION, OLIGOTROPHICATION AND RECOVERY (PART II)
Room 20+21
Chair: **Lumi Haraguchi**

13:45 – 13:50 Intro

13:50 – 14:10 **The vicious circle of Baltic Sea eutrophication supported by observations**
Oleg P. Savchuk[1], Ragnar Elmgren[2] & Mati Kahru[3]
[1] Baltic Nest Institute, Stockholm University, Sweden; [2] Department of Ecology, Environment and Plant Sciences, Stockholm University, Sweden; [3] Scripps Institution of Oceanography, University of California San Diego, La Jolla, California

In the brackish Baltic Sea, large-scale offshore hypoxia and extensive cyanobacterial blooms, documented for millennia, are interlocked in a “vicious circle”: inorganic nitrogen removal due to denitrification and phosphate release from anoxic bottoms result in a Redfield excess of phosphate that forces dinitrogen into biotic cycling via nitrogen-fixing cyanobacteria, thus increasing primary production, sedimentation and decomposition of organic matter, in turn leading to further expansion of the hypoxic zone and increased denitrification and phosphate release. The individual processes composing this positive feedback loop are well documented and have been successfully parameterized in ecosystem models. However, attempts to empirically demonstrate the functioning of this loop with field measurements at individual stations have been largely inconclusive. Here we present correlations between variations of hypoxia, nutrients, and cyanobacterial blooms based on long-term (1979-2016) observations in the Baltic Proper. The variables used are real large-scale, aggregated ecosystem properties: total areas of the hypoxic zone and cyanobacterial accumulations as well as annual averages of basin-wide integrated inorganic nitrogen and phosphorus pools. The cyanobacterial bloom area correlates most strongly with the basin-wide inorganic phosphate pool and surface water temperature. Although these interactions occur chiefly in the Baltic Proper, they also strongly affect neighbouring basins and must be accounted for in ecosystem-based management. The managerial implications of such interactions between global warming and regional anthropogenic eutrophication include prioritization between reductions of external N and P loads, and evaluation of possible geoengineering measures intended to weaken the “vicious circle”.

14:10 – 14:30 **Past, present and future eutrophication status of the Baltic Sea**

Ciarán Murray[1], Bärbel Müller-Karulis[2,3], Jacob Carstensen[4,5], Daniel Conley[6], Bo Gustafson[2,3] & Jesper H. Andersen[1]

[1] NIVA Denmark Water Research, Copenhagen, Denmark; [2] Stockholm University, Stockholm, Sweden; [3] Baltic Nest Institute, Stockholm, Sweden; [4] Aarhus University, Roskilde, Denmark; [5] Baltic Nest Institute Denmark, Roskilde, Denmark; [6] Lund University, Sweden

We model and assess the past, present and future eutrophication status of the Baltic Sea. The assessment covers the period 1850-2200 and is based on: (1) different scenarios for input of nitrogen (TN) and phosphorus (TP), (2) modelling of concentrations of DIN, DIP, chlorophyll-a, as well as Secchi depth, and oxygen, and (3) the application of a multi-metric indicator-based tool for assessment of eutrophication status, i.e. HEAT 3.0. Our results show significant changes in eutrophication status in all Baltic Sea sub-basins over the assessment period. In the open parts of the Baltic Sea the shift from a healthy state without eutrophication problems took place in the 1950s and early 1960s. We began to see recovery in some basins in the late 1990s, whilst in others it begins just after the turn of the century. Based on the modelled results, we expect a status without eutrophication in some parts of the Baltic from around 2050. However, not all basins are likely to meet the targets agreed upon and to attain a status unaffected by eutrophication, e.g. the Gulf of Riga. These results can be used in support of continuous development and implementation of the regional ecosystem-based nutrient management strategy, the HELCOM Baltic Sea Action Plan.

14:30 – 14:50 **Nutrient Credits in Governmental and Voluntary Eutrophication Management**

Antti Iho

Bioeconomy and environment unit, Natural Resources Institute Finland (Luke), Helsinki, Finland

Verified and potentially transferrable nutrient credits have been utilized in eutrophication management in various voluntary and regulatory programs in the U.S., Australia and New Zealand. There has been a growing interest in assessing the potential and applicability of such flexible mechanisms in the Baltic Sea protection. In a three-year NutriTrade-project we have analyzed the potential of transferrable nutrient offsets in both governmental and voluntary protection. We found the prerequisites for a Baltic-wide cap and trade nutrient trading weak. The efficiency gains would be lost in overlapping and complex regulatory and legal frameworks. However, we believe nutrient offsets might play a role in enabling fulfilling the tightening requirements of marine protection as put forward by, for instance, the recent Weser ruling. Its strict interpretation of Water Framework Directive helps achieving and securing good ecological status of the Baltic – but only if the requirements are achievable in economically sustainable way. We argue that the combination of strict WFD interpretation and utilization of nutrient credits in permitting processes may increase the environmental effectiveness and economic efficiency of Baltic Sea protection, particularly its coastal areas. We also analyze the potential for voluntary offsetting of nutrient footprints. The project launched a platform (Nutribute) to match verifiable abatement actions and donations to finance them. Overall, our work sheds light to alternatives to improve the management

structures and institutions for the eutrophication management in general and Baltic Sea protection in particular.

14:50 – 15:10 **Agriculture and nutrient management – or why are farmers always so angry?**
Marie van Maarschalkerweerd
Danish Agriculture & Food Council

Politicians, researchers, environmentalists and farmers all agree on a common goal: We need to obtain the best possible ecological status of our surface waters. However, conflict lures and often appears high above the surface. Because, what is the best possible? How do we get there? Who should pay? And why are farmers always so upset? Farmers work in conditions that are much different from what is found in other industries. Weather conditions have crucial influence on yields, but also on the level of environmental stress caused by farming. Even when applying best farming practices, loss of nutrients to the aquatic environment cannot be avoided. Therefore, when regulation is applied, it inevitably leads to dilemmas concerning the balance of producing an essential good, the food we all eat, versus protecting the environment. How can strict regulation be implemented in a sector that works in such variable and unforeseeable conditions? The "polluter pays – principle" should be applied, we hear from environmentalists. But should it? And can it? This talk will give an insight into the reality and the dilemmas farmers meet, when environmental regulation is applied and cast light on why new regulation is rarely met with consent and joy. It will encourage thinking in broader perspectives and flexible regulation to support achievement of environmental goals. The talk will open for a discussion on how we approach the good environmental status without, ultimately, compromising food safety.

13:45 – 15:40 SESSION 6 continued: MONITORING, REMOTE SENSING AND MODELLING (PART II)
Room 22+23
Chair: **Hege Gundersen (to be confirmed)**

13:45 – 13:50 Intro

13:50 – 14:10 **Species richness of green tides increase persistence and stability: field and experimental evidences**
Ricardo Bermejo[1], Maria Galindo-Ponce[1], Svenja Heesch[2], Moya O'Donnell[1], Micheal McMonagle[1], Eve Daly[1] & Liam Morrison[1]
[1] *Earth and Ocean Sciences, School of Natural Sciences and Ryan Institute, National University of Ireland, Galway*
[2] *Algal Genetics, Station Biologique de Roscoff, France*

Molecular identification tools allow now a better understanding of the species composition and genetic diversity of Ulva blooms. Green tides have been traditionally considered monospecific, but increasing evidences indicated that multispecific green tides are more common than previously thought. The seasonal monitoring of three Ulva blooms across Ireland, and the performanced of different laboratory experiments indicated that multispecific blooms of Ulva were more persistent and stable when subjected to a wide range of environmental conditons (i.e. salinity, temperature, grazing) than monospecific. These findings should be considered when

green tides are modelled in order to improve our ability to predict these events in a global change context.

14:10 – 14:30 **Eutrophication and global change: temporal and spatial responses of coastal communities**

E. Bonsdorff[1], M.C. Nordström[1], M. Järnström[1], A. Törnroos[1,2] & B. Weigel[1,3]
[1] Environmental and Marine Biology, Åbo Akademi University, Turku, Finland; [2] Centre for Ocean Life, DTU Aqua, Kgs. Lyngby, Denmark; [3] Organismal and Evolutionary Biology, University of Helsinki, Helsinki, Finland

The structure and function of zoobenthos and fish assemblages in Baltic Sea coastal and archipelago ecosystems have been significantly impacted by secondary effects of eutrophication (increased organic enrichment, accumulations of drifting filamentous algal mats, as well as increased occurrence of hypoxia). These changes were dramatic from the 1970's onwards, and during the past decade, drivers relating to global climate change (temperature, salinity, oxygen) have gained in importance, amplifying the effects of eutrophication. The large-scale changes of the environment have also facilitated changes in species distributions, and the establishment of invasive non-native species affecting functional properties at community- and food web level. Today, the ecosystem is governed by a complex mix of climate, nutrient loads, and alterations in the structural and functional properties of zoobenthos and fish. We illustrate these processes on scales ranging from long-term (40 y) structural/functional changes in coastal zoobenhtos and fish along the Baltic gradient (Kattegat, Baltic Proper, Bothnian Sea), regional changes in relation to eutrophication and climate-driven change (Åland Islands; 30-40 y), gradual break-down of food-web structure and linkages following local organic enrichment and hypoxia/anoxia, to small-scale functional adaptations of zoobenthos coupling sediment type and benthic/pelagic fluxes. These changes are related to climate-change scenarios, indicating continued stress for the ecosystem for decades to come.

14:30 – 14:50 **The Sea-MAT Project: Understanding large macroalgal blooms in Irish estuaries**

Liam Morrison[1,2], Ricardo Bermejo[1,2], Nessa Golden[1,2], Maeve Edwards[1], Edna Curley[1], Owen Fenton[3], Svenja Heesch[4] & Eve Daly[2]
[1] Irish Seaweed Research Group, Ryan Institute, National University of Ireland Galway, Galway, Ireland; [2] Earth and Ocean Sciences, School of Natural Sciences, National University of Ireland Galway, Galway, Ireland; [3] Teagasc, Johnstown Castle, Co. Wexford, Ireland; [4] Station Biologique Roscoff, Place Georges Teissier, 29680 Roscoff, France

Macroalgal blooms occur readily in many coastal waters, particularly estuarine areas, as a result of nutrient enrichment, changes in environmental conditions (e.g. climate change, hydrodynamic reduction), the arrival of non-native species or a combination of all these factors. The significant macroalgal biomass that develops and decomposes is an environmental risk to protected habitats, a risk to human health and a financial burden on local communities. The scientific knowledge about these macroalgal blooms is key for proper and effective management. In Ireland, four locations that consistently support significant green, brown or red blooms (Courtmacsherry Bay, Clonakilty Bay, Tolka Estuary and Killybegs Harbour) have been studied in the Sea-MAT project (2016-2018). The obtained results will help to improve our understanding of these opportunistic blooms, to develop new

monitoring strategies based on unmanned aerial vehicles (UAVs), and consider other important aspects for bloom management such as metal contents in bloom forming seaweeds. The use of molecular tools allowed us to identify eight different species in Irish green tides, and to describe a temporal succession along the bloom season. Furthermore, different laboratory experiments were performed in order to understand the effects of biodiversity on bloom persistence and stability, and assess the effects of climate change in the composition and development of Irish blooms.

14:50 – 15:10 **Two for the price of one: The study of two green tides in Ireland reveals a temporal succession between at least two Ulva spp.**

Moya O'Donnell[1], Ricardo Bermejo[1], Svenja Heesch[2], Micheal McMonagle[1], Eve Daly[1], & Liam Morrison[1]

[1] Earth and Ocean Sciences, School of Natural Sciences and Ryan Institute, National University of Ireland, Galway; [2] Algal Genetics, Station Biologique de Roscoff, France

Anthropogenic nutrient enrichment of estuarine and coastal waters seems to be a key factor to explain the development of heavy and persistent green tides. However, the extent, distribution, and species composition of blooms vary strongly among systems of similar nutrient loading, which compromises our ability to predict these events based on information about nutrient status alone. Additional factors may play a role in the control and development of macroalgal blooms. The identification of relevant scales of variation is a necessary prerequisite before explanatory models can be proposed and tested. In this study spatial (perpendicular and parallel to the coast) patterns of biomass distribution were assessed for two Ulva morphologies in two Irish estuaries at seven sampling occasions. The obtained results revealed considerable perpendicular and horizontal spatial variation in biomass distribution. Temporal changes in biomass can also be observed, with an increase in the biomass of laminar morphologies along the bloom, while the opposite trend was observed for tubular morphologies. These results suggest the existence of a spatial and temporal succession betweenUlva morphotypes. Furthermore, preliminary genetic analyses revealed the existence of at least 8 different species of Ulva, with U. prolifera, U. compressa and U. rigida the most abundant.

15:15 – 15:45 BREAK (tea & coffee)

16:00 – 18:00 WORKSHOP 1: FROM MONITORING DATA TO INTEGRATED ASSESSMENTS

Room 20+21

Convened by: Jacob Carstensen, Mats Lindegarth, Ciaran Murray & Jonas Svensson

We will present a web-based tool for assessing the ecological status of water bodies according to the EU Water Framework Directive. The tool accesses data from monitoring databases and uses an extendable R-library for calculating indicators and their uncertainty for the various biological quality elements. Indicator values and their associated standard errors are integrated through a hierarchical aggregation scheme to provide an overall ecological status assessment. The tool is transparent such that the aggregation scheme is displayed at all levels of the hierarchy. The system is based on aggregating distributions for indicators rather than values and provides a complete confidence assessment of the ecological status classification.

16:00 – 18:00 **WORKSHOP 2: STEPS TOWARD A HARMONIZED ASSESSMENT OF EUTROPHICATION IN EUROPE'S SEAS**

Room 22+23

Convened by: Jesper Andersen, Vivi Fleming-Lehtinen, Wera Leujak & Johnny Reker

We will present the process leading to the first ever harmonized assessment of marine eutrophication in Europe's seas. Special focus will be put on: 1) the European Environment Agency's 'Marine Road Map' for thematic assessments 2016-2021, 2) an overview of the development and application of multi-metric indicator-based eutrophication assessment tools in coastal and marine waters in Europe, 3) the recent application of the OSPAR Comprehensive Procedure in relevant water bodies of the Northeast Atlantic Ocean, 4) the recent application of the HELCOM Eutrophication Assessment Tool (HEAT) in the Baltic Sea as well as 5) the results and interim conclusions from the thematic assessment of eutrophication in Europe's seas. Strength and weaknesses will be discussed in relation to data availability and eutrophication status assessment tools together with selected key results of the pan-European eutrophication assessment.

19:00 – ... SYMPOSIUM DINNER

WEDNESDAY 20 JUNE 2018

09:00 – 10:00 **KEY NOTE 6 AND KEY NOTE 7**

Plenary Session in Sal J

Chair: **Marianne Holmer**

09:00 – 09:30 KN6: EUTROPHICATION SCIENCE IN A CHANGING WORLD: WHAT HAVE WE LEARNED AND WHERE TO GO FROM HERE?

Jeremy M. Testa

Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, Solomons, Maryland, USA

Eutrophication continues to be a compelling topic of study at a time of significant change. While some regions of the world are actively degrading or appear to be locked in a eutrophic state, others are positively responding to managed eutrophication abatement. Temperature has increased in a variety of systems within the timeframe of nutrient and phytoplankton monitoring programs, allowing for assessments of climatic change impacts within the period of record. The generation of scientists who documented eutrophication across the globe is in the process of retiring and in many cases, their academic offspring have been given the opportunity to investigate the dynamics of eutrophication abatement. Given this backdrop, the community has been challenged to apply our conceptual models of eutrophication to the study of eutrophication reversal within the dynamics of global change. As the literature begins to swell with papers investigating eutrophication abatement using several decades of accumulated monitoring data and a variety of new computational tools and resources, there is an opportunity to synthesize our understanding of eutrophication, but also to ask questions related to the current and future state of the science. For example, to what extent are ecosystem responses to mitigation consistent across systems? Have there been unexpected consequences of eutrophication mitigation? How can science help inform adaptive strategies as we assess progress in mitigation and consider the impacts of uncertain future climates? This presentation aims to address these questions across a range of estuaries and consider the implications of these messages for future research.

09:30 – 10:00 **KN7: FROM BLOOM TO DOOM - 30 YEARS OF MANAGING EUTROPHICATION IN THE NORTH AND BALTIC SEAS**

Ulrich Claussen

German Environment Agency, Section for the Protection of the Marine Environment, Dessau, Germany

Since the 1950s, excessive nutrient inputs have led to anthropogenic eutrophication effects in the North and the Baltic Seas. Algal blooms, oxygen depletion and fish kills were among the effects that triggered political commitments to ambitious nutrient reduction targets. An important step was the 2nd International North Sea Conference in London, 1987, where the Environment Ministers of the North Sea States agreed to reduce nutrient inputs in the order of 50 % within 10 years. OSPAR and HELCOM adopted this agreement and substantial actions to reduce nutrient inputs in particular from point sources. While effects of eutrophication have started to wane in large parts of the North Sea, the Baltic Sea remains impacted by eutrophication. Nutrient reduction measures have still not achieved to eliminate anthropogenic eutro-

phication in coastal and marine parts of both seas. It remains a challenge in OSPAR and HELCOM to agree and implement country wise nutrient reduction targets. While it is clear that ambitious measures in agriculture are required to further mitigate eutrophication these are difficult to achieve. This is also due to contradicting EU policies, e.g. the Common Agricultural Policy continuing to subsidise agriculture to the disadvantage of the environment or the EU Blue Growth Initiative promoting mariculture. Currently, a paradigm shift seems to take place in HELCOM eutrophication management, moving from measures tackling nutrient losses and discharges at source to measures inter alia trialling sea-based techniques to mitigate eutrophication.

10:00 – 10:15 Questions and answers in relation to keynotes 6 and 7.

10:15 – 10:30 BREAK (tea & coffee)

10:30 – 12:00 **SELECTED CONTRIBUTED ORAL PRESENTATIONS IN RELATION TO THE THEMES COVERED BY KEYNOTE 6 AND KEYNOTE 7**
Plenary Session in Sal J
Chair: **Ciaran Murray**

10:30 – 10:35 Into

10::35 – 10:55 Mitigation of eutrophication and indicator responses to resulting oligotrophication in Danish coastal ecosystems

Jens W. Hansen[1*] & Jacob Carstensen[2]
[1]Department of Bioscience, Aarhus University, Silkeborg, Denmark; [2]Department of Bioscience, Aarhus University, Roskilde, Denmark

Danish coastal waters suffer from eutrophication. In the 1980s extensive hypoxia and associated fish kills called for political response to remediate the negative consequences of nutrient over-enrichment. Since the mid-1980s several mitigation measures have been adopted to reduce nutrient input from land – a process continued with the European Water Framework Directive and Marine Strategy Framework Directive, both aiming at establishing good environmental status. Based on data from more than 25 years of monitoring this presentation will describe responses of coastal ecosystems to oligotrophication. Nutrient inputs from land were reduced by almost 50% for nitrogen and just over 50% for phosphorus since 1990 – nitrogen mostly due to regulation of agricultural practice, phosphorus mostly due to improved waste water treatment. These reductions resulted in significant declines in nutrient concentrations, and initiated a shift in the dominance of primary producers towards less phytoplankton and more macroalgae. Within the last decade eelgrass has also expanded with improved water clarity. The reduction in phytoplankton was also associated with a general decrease in the biomass of benthic macrofauna, composed of a drastic decline of filter feeders and a comparable increase of deposit feeders. This community shift was most likely related to increased stratification, reducing the accessibility of plankton to benthic filter feeders. Reduced benthic filtration probably kept more particles in suspension, which together with increased resuspension due to reduced sediment stability can explain why improvements in water clarity were modest. Further, bottom water oxygen conditions have not improved, presumably because more frequent stratification and higher water temperatures have counteracted the expected positive effects of reduced nutrient inputs. Overall, several ecosystem components

demonstrated clear signs of improvement, suggesting that at least partial recovery is attainable with different time lag of the indicators. On this basis we propose a conceptual scheme for recovery of shallow coastal ecosystems following oligotrophication.

10:55 – 11:15 **Reducing nitrogen leaching from fertilizers to surface waters: catchment specific indications of economic benefits**

Mikael Skou Andersen[1], Gregor Levin[1] & Mette Vestergaard Odgaard[2]
[1] Department of Environmental Science, Aarhus University, Denmark; [2] Department of Agroecology, Aarhus University, Denmark

We explore with impact pathway methodology the economic benefits of reducing nitrogen leaching to transitional surface waters, as expected for a proportionality test under the EU's Water Framework Directive article 4. Ten different catchments are analysed for a policy scenario where downstream discharges to estuaries are reduced by 35%, which is predicted to curb leaching with 5,200 ton N and provide Secchi-depth improvements of up to 2.5 meter. The integrated assessment method suggests aggregate economic benefits for beachgoers and waterfront house-owners of €17 million annually. External costs are catchment-specific and range for the downstream discharges from €0.5 to €14 per kg N, while for upstream rootzone losses up to €4.5 per kg N. When considered per hectare of farmland the policy scenario involves economic benefits of €3-80/ha. The variations call into question non-regionalized intervention policies based on a uniform ceiling to abatement costs per unit of nitrogen reduction.

11:15 – 11:35 **Social, economic and cultural options to recover from eutrophication**

Desmit X.[1], Thieu V.[2], Lassaletta L.[2], Dulière V.[1], Campuzano F.[3], Ménesguen A.[4], Silvestre M.[5], Garnier J.[2], Sobrinho J.[3], Pinto L.[3], Gypens N.[6], Ramiro N.[3], Billen G.[2] & Lacroix G.[1]
[1] *DO Natural Environment, RBINS, Brussels, Belgium; [2] UMR 7619 METIS, Univ. Paris 06, Paris, France ; [3] MARETEC, Universidade de Lisboa, Lisbon, Portugal ; [4] Dynamiques de l'Environnement Côtier, IFREMER, Plouzané, France ; [5] FIRE FR-3020, Univ. Paris 06, Paris, France ; [6] Ecology of Aquatic Systems, Univ. Libre de Bruxelles, Brussels, Belgium*

Anthropogenic eutrophication remains a considerable stressor to marine ecosystems worldwide. In the North East Atlantic waters (NEA), most countries sustain coastal eutrophication with toxic algal blooms and ecological nuisances. Marine eutrophication in the NEA directly relies on nutrient enrichment at the river outlets, which is linked to human activities and land use in the watersheds. The question rises of whether the human society can reduce its nutrient emissions by changing its land use without compromising its food security. A new generic river model (PyNuts-Riverstrahler) was designed to estimate the point and diffuse nutrient emissions (N,P) to the rivers depending on land use in the watersheds across Western Europe (agro-food systems, waste-water treatment plants). The resulting loads from the river model have been used as inputs to three marine ecological models (PCOMS, ECO-MARS-3D, MIRO&CO) covering together a large part of the NEA from the Iberian shelf to the Southern North Sea. The modelling of the land-ocean continuum allowed quantifying the impact of changes in land use on marine eutrophication in the NEA. A "pristine-like" scenario was tested to scale the current level of eutrophication with

respect to an absolute “natural” level. “Future” scenarios were also tested to appraise the impact of the actual EU recommendations (WFD, Nitrate Dir., UWWT Dir.), and to propose a more radical but still realistic scenario. It is shown that a paradigmatic change in agricultural practices combined with the relocalization of economic exchanges and a large-scale demitarian diet might sensibly reduce both riverine and marine eutrophication.

11:35 – 11:55 **Eutrophication management for the Great Barrier Reef – current failure but solutions for the future**

Brodie, J.[1], M. Devlin[2], Eberhard[1] & J. Waterhouse[1]
[1] ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Queensland, Australia; [2] Centre for Environment, Fisheries and Aquaculture Science. Lowestoft. UK

Australia’s Great Barrier Reef (GBR) is in severe ecological decline with, for example, large reductions in coral cover and periodic losses in seagrass biomass. The principal causes of the decline are associated with climate change effects and poor water quality. Poor water quality is principally due to increased loads of nutrients, both dissolved inorganic nitrogen and phosphorus, and particulate nutrients in association with fine sediment from land-based runoff. The risks of excess nutrient discharge from the land include increased populations of crown of thorns starfish, increased macroalgal growth at the expense of coral, increased bioerosion of coral by both burrowing algae and filter feeding organisms, increased incidence of coral disease, and enhanced coral bleaching sensitivity. The principle source of these anthropogenic nutrient increases are from agricultural activities on the catchment of the GBR, with fine sediment and particulate nutrients associated with erosion in beef grazing lands and dissolved inorganic nutrients primarily from fertilizer losses. Financial support for the management of agricultural practices, primarily in the two principal industries, sugarcane cultivation and rangeland beef grazing, has been in place for over 10 years and more than one billion dollars of government and farmer funding has been spent. Progress has been slow and completely inadequate to meet official government end of system pollutant load reduction targets based on ecological thresholds in the GBR. The continuation of the current approach of water quality management plans and actions, and the present levels of financing are highly unlikely to meet the load reduction targets by 2025. This dire situation is largely due to reluctance on the part of the national and state governments to increase funding of incentives programs to the required level to achieve the targets in the relatively short timeframes required, and the failure to use existing laws to regulate farming to an adequate extent. While the current state government is showing renewed impetus for targeted actions including regulation and the piloting of tailored incentive programs at smaller scales, long-term progress is hampered by short term political cycles and uncoordinated policy positions within and between the two levels of government. We present a number of recommendations that would allow faster progress towards reaching the targets in the required timelines.

11:55-12:15 **Oligotrophication under a changing baseline: interactive effects of nutrient loading and climate change**

Mark J. Brush & Samuel J. Lake
Virginia Institute of Marine Science, Gloucester Point, VA, USA

After decades of nutrient enrichment, many estuaries worldwide are undergoing large-scale reductions in anthropogenic nutrient loading. These systems are expected to respond by undergoing oligotrophication, with a reduction in organic matter supply and resulting improvements in water quality. However, responses to load reductions will be modulated by both site-specific attributes and a changing baseline due to global climate change, which will in turn affect ecosystem recovery trajectories. We present results from a cross-system, comparative ecosystem modeling analysis in which we ran nutrient and climate change scenarios through a reduced complexity, widely applicable estuarine ecosystem model applied to systems along the US East and Gulf Coasts. Systems in which most nutrient inputs arrive at the head of the estuary responded strongly to reductions in these "near field" loads, while tributary estuaries connected to larger, eutrophic systems may respond more strongly to "far field" inputs entering via estuarine circulation. Increasing temperature also reduced chlorophyll-a, but resulted in increased hypoxia particularly in systems with large organic loads, indicating that greater load reductions will be required in a warmer climate to obtain the same improvement achievable under current conditions. Finally, results highlight that managing to reduce eutrophication via load reductions may need to be balanced against other outcomes such as managing to increase carbon storage. Reduced productivity resulting from load reductions drove net metabolism to increasing heterotrophy, especially in a warmer climate, resulting in reduced carbon storage and greater efflux of CO2 to the atmosphere.

12:15 – 13:15 LUNCH

13:15 – 14:15 SYMPOSIUM SUMMARY

Plenary Session in Sal J
Chair: **Jacob Carstensen**

UNDERSTANDING EUTROPHICATION: HOW FAR HAVE WE COME AND WHERE DO WE GO FROM HERE?

Robinson W. Fulweiler[1], Dorte Krause-Jensen[2] & Katherine Richardson[3]
[1] Departments of Earth & Environment and BiologyBoston University, Boston, USA
[2] Department of Bioscience, Århus University, Silkeborg, Denmark; [3] University of Copenhagen, Copenhagen, Denmark

An outsider would be forgiven for assuming that we are again listening to talks describing detailed understanding of the mechanisms driving eutrophication. Instead, if we compare the research reported here to that reported a decade ago, we find we are examining a more holistic picture of eutrophication impacts on ecosystem function. After all – eutrophication causes more than low oxygen conditions, unclear waters, and loss of biota. Today eutrophication research is directed towards understanding the collective impacts of increased organic matter in the waters of the Earth System as a whole. For example, much focus is directed toward the possible positive feedbacks in the climate system caused by the release of reactive nitrogen to the environment. In this era of climate change, a major challenge at hand is also to

understand how increasing temperatures along with changes in wind speed and precipitation – will alter the impact of eutrophication. To this end, emerging examples of recovery pathways from eutrophication following management actions provide a new knowledge base ripe for exploration. Moreover, research is showing us that imbalanced nutrient reductions can alter a range of ecosystem properties including plankton community composition, the vertical distribution of photosynthesis, and energy flows to higher trophic levels. It is now well established that marine systems provide a wealth of ecosystem services including marine forests acting as buffers against eutrophication and climate change. Our emerging challenge is in understanding combined and interactive effects of eutrophication in concert with other aspects of global change. Moving forward, our understanding will be greatly enabled by harnessing the power of new technologies including breakthroughs in environmental molecular techniques, automated sensors, remote sensing, and "big data." Ultimately, our primary goal remains – we must facilitate management towards sustainable marine ecosystems.

Followed by questions and dicussion ...

14:15 – 14:30 **CLOSING CEREMONY**

Jesper H. Andersen

NIVA Denmark (EUTRO 2018 Organizing Committee chair)

4 Symposium Proceedings

Based on presentation at EUTRO 2018, we aim to publish Symposium Proceedings as a Research Topic in Frontiers in Marine Science.

The motivation for this Research Topic reads:

> *Coastal eutrophication has been and remains an important issue for the scientific community and ecosystem management. Despite many efforts to mitigate coastal eutrophication, the problems associated with eutrophication are still far from being solved. Under the Research Topic "Research and Management of Eutrophication in Coastal Ecosystems" we are aiming to discuss:*
>
> 1. *Presentation and discussion of existing knowledge and recent scientific results in relation to specific eutrophication issues, e.g.: i) Causative factors and direct and indirect effects of eutrophication, ii) climate and physical control on the biogeochemical dynamics and eutrophication status of the coastal zone, and iii) effects of eutrophication of biodiversity, food webs and ecosystem services.*
> 2. *Monitoring, modelling and assessment of eutrophication.*
> 3. *Presentation and discussion of evidence-based or ecosystem-based nutrient management strategies and polices.*
> 4. *Next steps: From eutrophication to oligotrophication in a changing climate.*
>
> *We encourage interdisciplinary contributions and those tackling the following crosscutting topics: (a) Direct and indirect effects of nutrient enrichment in relation to changes in nutrient load and climate, (b) Recent developments in relation to modelling and multi-metric indicator-based assessment tools and (c) Nutrient management strategies and actions – what works and what does not?*

Topic Editors are Jesper H. Andersen, NIVA Denmark; Jacob Carstensen, Aarhus University; Marianne Holmer, University of Southern Denmark; Dorte Krause-Jensen, Aarhus University; and Katherine Richardson, University of Copenhagen.

The editorial team encourages participants in EUTRO 2018 to submit to this Research Topic.

Deadline for submission of abstracts: **1 July 2018**.

Deadline for submission of manuscripts: **1 September 2018**.

More information, including author guidelines, can be found here:
https://www.frontiersin.org/research-topics/7364/research-and-management-of-eutrophication-in-coastal-ecosystems

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NIVA Denmark is the name, water is our game

NIVA Denmark Water Research is a regional office of the Norwegian Institute for Water Research (NIVA) and has just recently been established to resolve environmental issues concerning the freshwater and marine systems that relate to Denmark.

NIVA Denmark has primary focus on research-based implementation of a number of EU's directives inter alia the Water Framework Directive and the Marine Strategy Framework Directive together with international conventions (HELCOM, OSPAR, BDC). We occasionally provide consultancy to authorities and small and medium-sized companies.

NIVA Denmark is a a place for practice, observation, testing and synthesis. Key research and test areas include eutrophication, hazardous substances, biodiversity, and ecosystem health as well as the implications of multiple human activities in marine waters and in streams, rivers and lakes. We develop indicators, monitoring methods and tools to assess the state of an ecosystem in order to carry out analyses and contribute to evidence based and sustainable solutions to the challenges we and the environment face.

NIVA Denmark, as a regional office to NIVA has thus the backing of more than 200 dedicated researchers and experts.

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