

Symposium on Decadal Variability
of the North Atlantic and its Marine
Ecosystems: 2010-2019



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International Council for
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Symposium on Decadal Variability of the North Atlantic and its Marine Ecosystems: 2010 – 2019

20-22 June 2022

Bergen, Norway

This symposium is endorsed by



2021 United Nations Decade
2030 of Ocean Science
for Sustainable Development

Welcome to the Symposium!

Building on the influential legacy of three earlier decadal symposia, ICES and NAFO welcome you to the “The Symposium on Decadal Variability of the North Atlantic and its Marine Ecosystems: 2010-2019”. The conference is hosted by the Institute of Marine Research 20-22 June 2022 in Bergen, Norway.

In a time where greater understanding of climate change and increased attention of the role the world’s oceans, this decadal symposium is especially timely and has also been endorsed as an activity under the UN Decade of Ocean Science for Sustainable Development. While initiated from the ICES Working Group on Oceanic Hydrography (WGOH), the particular focus here is to link changes in the ocean climate to changes in plankton, fish, and ecosystem response. We are thus glad to have a record high of 130 abstracts submitted to the symposium spanning broadly over these focal topics.

We especially welcome the selected honorees Alicia Levin, Bogi Hansen and Brian Petrie, whom all have contributed extraordinary to understanding long-term variability in Atlantic oceanic hydrography and its ecosystems. Finally, we look forward to three days of keynote talks, oral and poster presentations. We are excited for this opportunity to meet and discuss with colleagues and friends in person after the long isolation due the covid-19 pandemic.

Welcome to Bergen!



Øystein Skagseth
Chair Scientific Steering Committee

Symposium background

In October 1987, the ICES Council endorsed the conclusion of its Consultative Committee that annual publication of *Annales Biologiques* was no longer feasible. This publication gave an annual status of the physical and biological status in the different ICES areas. The Consultative Committee recommended that the essential purpose of *Annales Biologiques* might be met by promoting quite different activities within ICES, i.e. promote symposia or theme sessions on “Overviews of the Decade” following the approach of NAFO. It was suggested the first of these decadal overviews, which could be published by ICES in the Cooperative Research Report series, should be held in 1990 or 1991 to cover the decade of the 1980s. This recommendation was accepted by the Council, and at the 76th Statutory Meeting in Bergen the Council gave it substance by recommending that a Symposium on “Hydrobiological Variability in the ICES Area, 1980-1989” should be held in Mariehamn, Finland during June 1991.

The 1st Decadal Symposium tried to include all areas that traditionally used to be published in *Annales Biologiques*. The four main theme for the symposium were 1) Variations in the physical environment; 2) Variations in plankton in relation to environment; 3) Variations in fisheries in relation to environment; and 4) Variations in the Baltic and its approaches. The first symposium was designed to explore how changes in the ecosystem and the physical environment were linked in some understandable way.

The 2nd Decadal Symposium concluded that the decade of the 1990s, which was a most unusual one in the climatic history of the North Atlantic. During the early 1990s, the North Atlantic Oscillation (NAO) evolved to positive values unprecedented in the instrumental record. The latter part of the decade was hardly less spectacular; following a rapid drop to extreme low-index values in the winter of 1996. As varied examples of that response, we note that in the early 1990s, the storm index for the southern Norwegian Sea rose to a 100-year maximum, an extreme freshening visited the two dense overflows, the transport of the eastern overflow slackened by 25%, convection in the Labrador Sea reached unprecedented depths contributing to a full-depth change in the NW Atlantic that is thought to be the largest of the modern oceanographic record, the main Atlantic gyre circulation spun up to a century-long maximum as did the transport of Atlantic water passing through the Faroe-Shetland Channel, and the warmth recorded off the northern Norway rose to a 40-year peak. As might also be expected, the ecosystem of ocean and shelf responded to these changes, as one presentation after another revealed.

The 3rd Decadal Symposium in 2011 provided a comprehensive status report on the North Atlantic Ecosystem and served as a firm basis to proceed with advances in ecosystem approaches to ICES science and advice. The overwhelming observation across all regions of the North Atlantic was a general warming trend. Warming was associated with freshening of seawater in most regions. As the principal drivers of seawater density, changes in temperature and salinity produced distinct changes in ocean circulation patterns such as position of major currents, strength of gyres, and depth of mixed layers. Biological responses to oceanographic changes varied among regions, but common observations were changes in timing of plankton blooms or fish migrations, shifts in latitudinal or depth distributions of fish populations, and a variety of changes in system productivity. One common theme of the third symposium was that system changes were so pronounced in the last decade that some common metrics used to monitor atmospheric or oceanic patterns are no longer tracking the processes as originally intended.

Honours:

It is a design feature of these Decadal Symposia that the occasion is used to honour individuals who have worked to maintain the time series on which our knowledge and these discussions are based.

Scientists honored at the Symposia:

1991: Stig Henrik Johannes Fonselius (Sweden), Warren S. Wooster (USA), Lars Sudmann Midttun (Norway), Odd Henrik Sælen (Norway) and Arthur James Lee (UK)

2001: John Lazier (Canada), Svend-Aage Malmberg (Iceland), David Ellett (UK), Johan Blindheim (Norway) and Leo Otto (The Netherlands)

2011: R. Allyn Clarke (Canada), R.R. (Bob) Dickson (UK), Catherine Maillard (France), Jens Meincke (Germany), Tom Rossby (USA) and Manfred Stein (Germany)

2022: Bogi Hansen (Faroe Islands), Alicia Lavin (Spain) and Brian Petri (Canada)

Facts on Symposia:

The 1st ICES Decadal Symposium was held in Mariehamn, Finland on 5-7 June 1991. Conveners: Bob Dickson (UK), Pentti Mälkki (Finland), Günther Radach (Germany), Roald Sætre (Norway), and Michael Sissenwine (USA). There is no information on number of participants and number of talks and posters, but 48 papers were published ICES Marine Science Symposia, [vol 195, December 1992](#)

The 2nd ICES Decadal Symposium was held at the Royal College of Physicians, Edinburgh, Scotland on August 8-10, 2001. Conveners: Bob Dickson (UK) and Jens Meincke (Germany). The Symposium was highly successful, attracting a full programme of 155 participants, 42 selected talks and 55 posters describing the variability of the plankton, fish, ocean and atmosphere of the ICES area during the 1990s. Papers published in ICES Marine Science Symposia, [vol 219, 2003](#)

The 3rd ICES/NAFO Decadal Symposium on the Variability of the North Atlantic and its Marine Ecosystems during 2000–2009 was held in Santander, Spain, May 10-12, 2011. Conveners: Sarah Hughes (UK), Alicia Lavin (Spain), Stephen Dye (UK), Hedinn Valdimarsson (Iceland) and Glenn Nolan (Ireland). The 3rd Decadal Symposium was attended by 116 participants from 12 countries. Five keynote talks and 39 oral presentations, as well as 77 posters, made up the scientific program which was structured in six plenary theme sessions. Papers were published in ICES Journal of Marine Science ([2012](#)), [Vol 69](#)

The 4th ICES/NAFO Decal Symposium on Decadal Variability of the North Atlantic and its Marine Ecosystems: 2010-2019 will be held in Bergen, Norway on 20-22 June 2022.

Members of the Scientific Steering Committee were Øystein Skagseth (chair), Paula Fratantoni (USA), Agnieszka Beszczynska-Möller (Polen), Almudena Fontan (Spain), Barbara Berx (UK), Caroline Cusack (Ireland), Cesar Gonzalez-Pola (Spain), Eileen Bresnan (UK), Kjell Arne Mork (Norway), Frédéric Cyr (Canada), Julie Kellner (ICES), Ricardo F. Sánchez Leal (Spain) Stephen Dye (UK) Tycjan Wodzinowski (Poland) and Harald Loeng (Norway)

4 key notes and 57 oral presentations together approximately 60 posters will be on the program. 135 participants from 16 countries have registered for the Symposium. The symposium is endorsed by 2021-2030 United Nations Decade of Ocean Science for Sustainable Development

Keynotes

Theme Session 1: Ocean climate and physical environment in the North Atlantic and their linkages to changing marine ecosystem



Karin Margretha H. Larsen is a physical oceanographer and head of the environmental department at Havstovan (Faroe Marine Research Institute). She had her Master and PhD thesis in physical oceanography at the University in Bergen, Norway. In her PhD thesis Karin studied the Faroe Shelf and its surrounding front related to physical-biological couplings. For many years, Karin has been involved in monitoring of Greenland-Scotland Ridge exchanges and has participated in most of the major monitoring programs of the region since 1997. She is presently a WP leader in the EU-H2020 Blue-Action project and coordinator of smaller nationally funded projects. Since 2012 she has been a member of the ICES Working Group on Oceanic Hydrography (WGOH) and co-chaired the WGOH in the period 2015-2017 together with Sarah Hughes (Scotland, UK)

Abstract

NORTH ATLANTIC MARINE CLIMATE IN RECENT DECADES

Globally, the ocean has been warming over the last century, whereas some regions have become more saline and others fresher. The long-term warming is also apparent in several temperature time series from the North Atlantic Ocean, but during the last decade some areas have exhibited a cooling trend. Specifically, central parts of the subpolar North Atlantic stand out as a cold region not following the general warming trend – a phenomenon often referred to as the “cold blob”. Atlantic water temperature and salinity usually vary in phase, but during the last two decades certain locations have seen salinities switch from a record high to a record low. Consequently, in the subpolar North Atlantic the last decade is characterised by both an enhanced “cold blob” and extreme freshening. Despite the observed cooling in the subpolar region, and reported decline of the Atlantic Meridional Overturning Circulation, exchanges across the Greenland Scotland Ridge have remained stable. On the other hand, oceanic heat fluxes into the Nordic Seas have increased, influencing marine ecosystems downstream. In addition to these changes in physical properties, North Atlantic silicate concentrations have declined and together these changes are expected to impact marine ecosystems in the wider region. Based on the ICES Report on Ocean Climate and recent findings, an overview of the North Atlantic marine climate in recent decades is provided. Specific emphasis is placed on the main physical oceanographic events and potential implications for marine ecosystems are discussed.

Theme Session 2: Decadal change and trends in North Atlantic/sub-Arctic plankton and their ecosystems



Antonio Bode (PhD in Biology 1990, Universidad de Oviedo, Spain) is a Research Professor at the Instituto Español de Oceanografía (IEO, Spain), where he has been working since 1992. His research analyzes the dependence of the structure and functioning of the marine ecosystems from the environmental variability at different space and time scales, including the investigation of biodiversity patterns and food web structure using stable isotopes. He has collaborated in 165 articles in international journals and in monographies dealing with the composition and production of plankton, especially in relation to nitrogen fluxes, with the functioning of pelagic and benthic food webs, and with the long-term variability of plankton in relation to climatic and oceanographic changes. He has been member of the ICES Scientific Committee (SCICOM) and has been involved in several international actions fostering the sustainability and continued use of ship-based oceanic time series (IGMETS, POGO, EMODNET).

Abstract

PLANKTON IN THE NEW MILLENNIUM: SYNCHRONIC MULTIDECADAL TRENDS AND REGIME SHIFTS

Recent changes in oceanic plankton are being reported at unprecedented rates. Most changes are related to environmental factors and many were identified as driven by climate, either through natural cycles or by anthropogenic effects. However, the separation of both effects is difficult because of the small size of most observational series. Moreover, some changes are related to trends and cycles while others were perceived as system shifts, often synchronized over large spatial scales. Here, studies on observational series of plankton, with the focus in the N Atlantic, are reviewed. Two main quasi-synchronic shifts in species assemblages were identified: one in late 1980's and a most recent one in the first decade of the new millennium. While the origin and extent of most shifts vary locally, their synchronization seems to confirm the lagged response of plankton to changes in warming and in large-scale climatic factors. Changes in species abundance patterns are generally related to the strength of currents, but also to non-linear effects of warming, the latter particularly affecting species in regions near the limits of their thermal niche. Indeed, most of the changes are attributed to trade-offs between different biological strategies. Taken together, the reviewed case studies indicate a lagged biological response to variations in the local environment driven by large-scale climate forcing. The challenges for the interpretation of future changes include the consideration of local changes in a wider regional context, variations in species life-traits and possible top-down effects of plankton predators.

Theme Session 4: Expanding horizons: assessing decadal changes and incorporating Social-Ecological Systems in the North Atlantic



Anthony Charles is a professor at Saint Mary's University (Halifax, Canada). His research focuses on fishery, ocean and coastal systems, with emphasis on their human dimensions. His areas of study include climate change adaptation, integrated coastal management, ecosystem-based management, community-based management, and marine protected areas. He has authored such books as (1) Sustainable Fishery Systems; (2) Governance of Marine Fisheries and Biodiversity Conservation; (3) Governing the Coastal Commons; and (4) Communities, Conservation and Livelihoods. He works on practical and policy approaches, e.g., as lead author of a report by the UN Food and Agriculture Organization on how climate change responses can interact with poverty and food security, and as Director of the Community Conservation Research Network (www.CommunityConservation.Net), exploring local links of conservation and economy. He is a Pew Fellow in Marine Conservation, a member of IUCN's Fisheries Expert Group, and an advisor to various international, Indigenous and community organizations.

Abstract

UNDERSTANDING AND INCORPORATING HUMAN DIMENSIONS OF MARINE SOCIAL-ECOLOGICAL SYSTEMS

The uncertainties, complexities and dynamics of physical and biological processes in the ocean have direct counterparts on the human side of the system – coastal communities and human uses of the ocean. It is often said that natural scientists study the former while social scientists study the latter. There is some truth to that division, but increasingly, we see interdisciplinary, or ‘transdisciplinary’, approaches that link these together within a systems perspective. That is the implication behind the term ‘marine social-ecological system’, in which the ‘ecological’ side includes physical phenomena, and in parallel, the ‘social’ side includes economic, social, cultural, political, institutional, and technological aspects. Humans are relevant to marine social-ecological systems through their impacts on the ocean – resource use, land-based pollution, coastal development and so on – but also in positive ways, through their marine knowledge and their many marine stewardship activities. All of these aspects can be considered as ‘human dimensions’ of marine social-ecological systems. Within a modern social-ecological system framework, the human dimensions are included in analyses from the start, and are essential to our understanding, and management, of multiple uses of ocean space and conflicts across economic sectors. Key challenges in doing so lie in dealing with multiple scales, from local (a small bay, or a coastal community) to global, in setting spatial and jurisdictional boundaries, and in integration and decision-making within multi-sectoral, multi-use, multi-objective systems. Ways to understand and incorporate human dimensions of marine social-ecological systems, while also dealing with these challenges, will be discussed.

Theme Session 3: Trends and drivers of decadal variability in fish and invertebrates



Anne Hollowed has worked for the National Marine Fisheries Service for over 30 years and currently serves as a Senior Scientist with the Alaska Fisheries Science Center. She conducts research on the effects of climate and ecosystem change on fish and fisheries and leads the Status of Stocks and Multispecies Assessment program. Anne earned B.A. in biology and geology from Lawrence University, a M.S. in biological oceanography from the Department of Ocean, Earth, and Atmospheric Sciences from Old Dominion University, and a Ph.D. in fisheries from the School of Aquatic and Fishery Sciences (SAFS) at the University of Washington. She is an Affiliate Professor with the SAFS. Anne has served on the North Pacific Fishery Management Council's Scientific and Statistical Committee since 2003 and she is currently serving her fourth year as co-chair. She has been a lead investigator on several national and international multidisciplinary research projects and climate assessment teams. She served as a lead author on the Polar Chapter of Working Group II in the 5th Assessment of the Intergovernmental Panel on Climate Change (AR5 WGII Chapter 28) and the Polar Chapter of the IPCC Special Report on Oceans and Cryosphere in a Changing Climate (SROCC). She is a principal investigator for the Alaska Climate Integrated Modeling project (ACLIM) in the Bering Sea.

Abstract

SCIENTIFIC ADVANCEMENTS IN THE STUDY OF THE IMPACTS OF CLIMATE CHANGE AND DECADAL VARIABILITY ON MARINE ECOSYSTEMS AND OPTIONS FOR FUTURE MANAGEMENT OF LIVING MARINE RESOURCES

Hollowed, A. B., Holsman, K., Haynie, A., Hermann, A., Punt, A.

The impact of decadal variability in ocean conditions on the structure and function of marine ecosystems in the northern hemisphere have been recognized for over half a century. Although the global atmospheric drivers of decadal change remain elusive, studies of teleconnections linked to patterns of atmospheric variability hold nascent signs for advances in forecasting changing ocean conditions in northern latitudes. These patterns of non-linear change are now challenged by increasing evidence of climate change impacts on ocean systems creating an urgent need to assess decadal variability within the context of a changing climate. Considerable advancements in the knowledge of the complex relationships underlying species responses to ecosystem change has emerged in the last half century revealing multiple pathways for structural change and sustaining biodiversity. Similar scientific advancements have emerged in our understanding of fisher's choices when marine species exhibit shifts in distribution and abundance. Knowledge of fisher's responses to resource change lays the foundation for evaluations of adaptation options for managers and fishery dependent communities to changing fishing conditions. This talk will describe efforts in the United States to link these four elements of understanding (decadal shifts in atmospheric forcing, changing climate, biological response, fisher's choices, and adaptation strategy evaluation) in a coupled modeling system for use in fisheries and climate decision support. Products of these coupled modeling systems hold promise as tools for building climate resilient resource management systems in a changing climate.

Sponsors for the Decadal 2022

We would like to thank out sponsors for making this symposium possible



U.S. Department of State / National Oceanic
and Atmospheric Administration



Program

19 June, Sunday

1800 Icebreaker, *Institute of Marine Research, Nordnesgaten 50*

20 June, Monday

0900 Opening by the Director of IMR Nils Gunnar Kvamstø

Theme Session 1: Ocean climate and physical environment in the North Atlantic and their linkages to changing marine ecosystem

Chairs: Agnieszka Beszczynska-Möller and Kjell Arne Mork

- 0915 **Keynote:** *Larsen, Karin Margretha H:* North Atlantic Ocean climate in the recent decade
- 1000 *Galbraith, Peter S.* Gulf of St. Lawrence, Canada, undergoing warming conditions in the last decade
- 1015 *Dale, Alizée, Wallace, D. W. R., Gehlen, M.:* Contribution of physical nutrient supply to interannual nutrient variability in the Labrador Sea
- 1030 *Lavin, Alicia, Rodríguez, C., Villoria, A., Tel, E., Gonzalez-Pola, C., Somavilla, R.:* Data archaeology enlarge the Santander Standard Section.
- 1045 **Coffee/Tea**
- 1115 *Fontán, Almudena, Chifflet, M., Chust, G., Borja, Á., Esnaola, G., Ferrer, L., Franco, J., Larreta, J., Lejonaogitia, L., Revilla, M., Germán Rodríguez, J., Sáenz, J., Sagarmina, Y., Cotano, U., Boyra G., Santos, M., Álvarez, P., Muxika, I., Valencia, V.:* Variability in main physical processes controlling nutrient fluxes and its potential impact on phytoplankton biomass during the 2010-2019 decade: southeastern Bay of Biscay (Northeast Atlantic)
- 1130 *González-Pola, César, Somavilla, R., Ibañez, L., Graña, R., Vilorio, A., Álvarez, M., Rodríguez, C., Lavín, A.:* Recovery of conventional behavior of the eastern north Atlantic intergyre region in the 2010s after a transient flow reversal
- 1145 *Cyr, F., Galbraith, P. S., Bélanger, D.:* Seven decades of climate variability on the Newfoundland and Labrador shelf
- 1200 *Daly, Eoghan, Nolan, G., Berry, A., Büscher, J. V., Cave, R., Caesar, L., Cronin, M., Fennell, S., Lyons, K., McAleer, A., McCarthy, G., McGovern, E., McGrath, T., Uisce, A. F., O'Donnell, G., Thomas, R., Vaughan, M. L., White, M., Cusack, C.:* Decadal to seasonal scale water column variability in the Rockall Trough from model-enhanced transect timeseries
- 1215 *Hansen, Bogi, Erenbjerg, S. V., Eliassen, S.K., Larsen, K. M. H., Hátún, H.:* Competing effects of tidal mixing and air-sea heat flux on the primary production of the Faroe Shelf
- 1230 **Lunch**
- 1330 *Jónsson, Steingrímur, Ólafsdóttir, S. R., Macrander, A.:* Decadal variability in the ocean around Iceland in an era of anthropogenic climate change
- 1345 *Smedsrud, Lars H., Brakstad, A., Madonna, E., Muilwijk, M., Lauvset, S. K., Spensberger, C. Born, A., Eldevik, T., Drange, H., Jeansson, E., Li, C., Olsen, A., Skagseth, Ø., Slater, D. A., Straneo, F., Våge, K., Áρθun, M.:* Nordic Seas Heat Loss, Atlantic Inflow, and Arctic Sea Ice cover over the last century

- 1400** *Gjelstrup, Caroline V. B., Sejr, M. K., de Steur, L., Christiansen, J. S., Granskog M. A., Koch, B., Møller E. F., Winding, M. H. S., Stedmon C. A.*: Warm meets fresh: Thinning of Polar water layer and shoaling of Atlantic water on the Northeast Greenland shelf
- 1415** *Skagseth, Øystein, Broms, C., Gundersen, K., Hátún, H., Kristiansen, I., Kjell Arne Mork, K. A., Petursdottir, H., Søiland, H.*: Variability in Atlantic and Arctic waters in the Norwegian Basin and ecosystem implication
- 1430** *Ingvaldsen, Randi Brunvær, Assmann, K. M., Primicerio, R., Fossheim, M., Polyakov, I. V.*: Physical manifestations and ecological implications of Arctic Atlantification
- 1445** *Jones, Elizabeth, Chierici, M., Lødemel, H. H., Mourgues, C.*: Ocean acidification variability in the Atlantic and Arctic influenced Norwegian waters
- 1500** *Gimenez, Jose Luis, Boersma, M., Wiltshire, K. H.*: Marine Heatwaves: The new normal? A multiple baseline approach
- 1515** **Coffee/Tea**
- 1545** *Hátún, Hjálmar, da Silva, T., Skagseth, Ø., Grønkjær, P.*: Physical Drivers of Biogeographical Shifts in the Northeastern Atlantic – and Adjacent Shelves
- 1600** *Wiltshire, Karen Helen, Amorim, F., Lemke, P., Rick, J., Gimenez, L., Boersma, M., Guignard M., Kirstein, I. V.*: Ecologically relevant scales of temperature in the North Sea
- 1615** *Trifonova, NedaIvova, Scott, B., De Dominicis, M., Waggitt, J., Wolf, J.*: Indicators for whole ecosystem responses to separate climate from anthropogenic change in coastal seas

Theme Session 2: Decadal change and trends in North Atlantic/sub-Arctic plankton and their ecosystems

Chairs: Luis Valdés, Todd O'Brien

- 1630** **Keynote:** *Bode, Antonio*: Plankton in the new millennium: synchronic multidecadal trends and regime shifts
- 1715** *O'Brien, ToddD., Members of the ICES Working Group on Zooplankton Ecology (WGZE), members of the ICES Working Group on Phytoplankton and Microbial Ecology (WGPME)*: Changes and trends in North Atlantic plankton: A time-series-based overview from the ICES zooplankton and phytoplankton ecology working groups
- 1730** *Browman, Howard*: ICES publication special issue

1745 **Break**

1800 – 2000 Poster Session A

21 June, Tuesday

- 0830** *Guignard, Maité S., Maarten Boersma, M., Wiltshire, K. H.*: Shifting ecological niches of phytoplankton and zooplankton under environmental change
- 0845** *Balkoni, Areti, Wiltshire, K. H.*: What drives phytoplankton bloom dynamics at Helgoland Roads?
- 0900** *Clarke, Dave, Bresnan, E., Andersen, P., Anderson, D., Andree, K., Campás, M., Cembella, A., Davidson, K., De Rijke, M., Eikrem, W., Fernández, L., Fernández-Tejedor, M., Garces, E., Goncalves, A., Jacobsen, S., Karlson, B., Kobos, J., Kremp, A., Kulis, D., Lemoine, M. Lewis, A., Marnan, L., Mazur-Marzec, H., McKenzie, C., McKinney, A., Miller, P., Naustvoll, L. J., Pazos, Y., Poelman, M., Provoost, P., Siano, R., Sildever, S., Silva, A., Suikkanen, S., Swann, S., Vaiciute, D., Vila, M., Enevoldsen, H.*: Regional changes in harmful algal events in the North Atlantic area from 2010 – 2019

- 0915** *Leitao, Emma, Brennan, C. E., Gentleman, W. C., Maps, F., Johnson, C. L.*: Environmental variability shapes copepod life history: What we learn from optimizing a *C. finmarchicus* population model in the northwest Atlantic
- 0930** *Kristiansen, Inga, Hátún, H., Eliassen, S. K., Jacobsen, J. A., Eilif Gaard, F., Petursdóttir, H.*: Spatial variability of the feeding conditions for the Norwegian spring spawning herring in May
- 0945** *Broms, Cecilie, Børsheim, K. Y., Skagseth, Ø., Utne, K. R., Surma, S., Skogen, M. D., Lam, M. E., Pétursdóttir, H., Melle, W., Kristiansen, I., Gundersen, K., Pitcher, T. J., Libungan, L. A., Fiksen, Ø., Ólafsdóttir, A.*: Effects of bottom-up and top-down processes on lower trophic levels in the Norwegian and adjacent seas during the last decade
- 1000** *Karlson, Bengt, Johansen, M., Karlberg, M., Skjevik, A. T.*: Long term changes in the diversity and biogeography of phytoplankton communities in the Skagerrak-Kattegat, NE Atlantic
- 1015** **Coffee/Tea**
- 1045** *Szeligowska, Marlena, Trudnowska, E., Boehnke, R., Blachowiak-Samołyk, K.*: Inter-annual variability in particles and zooplankton in the warming Arctic fjord (Isfjorden, West Spitsbergen)
- 1100** *Holland, Matthew M., McQuatters-Gollop, A.*: Decadal variability in the response of plankton lifeforms and taxa to environmental drivers
- 1115** *da Silva, Edson F. F., Counillon, F., Brajard, J., Korosov, A., Pettersson, L., Samuelson, A., Keenlyside, N.*: Twenty-one years of phytoplankton bloom phenology in the Barents, Norwegian and North seas
- 1130** *Skjoldal, Hein Rune*: Size-fractionated zooplankton biomass in the Barents Sea ecosystem: changes during four decades of warming and four capelin collapses (1980-2020)
- 1145** *Vad, Johanne, Puerta P., Head E., Kenchington T., Kenchington E.*: Temporal trends in zooplankton community composition and life stage abundances on the Scotian Slope during 1999-2019
- 1200** *Deschamps, Margot, Boersma M., Meunier C., Di Pane J.*: Evidence of major shift in the copepod functional community of the southern North Sea in the late 80s: environmental factors and potential repercussions on the food web
- 1215** *Di Pane, Julien, Wiltshire, K. H., McLean, M. J., Boersma, M., Meunier, C. L.*: Environmentally induced functional shift in phytoplankton communities and its consequences for ecosystem functioning
- 1230** *Marques, Raquel, Otto, S. A., Di Pane, J., Boersma, M., Kröncke, I., Meunier, C., Möllmann, C., Neumann, H., Wiltshire, K. H., Renz, J.*: Long-term shifts in taxonomic and functional biodiversity of the meso-/macrozooplankton community in the Southern North Sea, mediated by environmental and anthropogenic changes
- 1245** **Lunch**

Theme Session 4: Expanding horizons: assessing decadal changes and incorporating Social-Ecological Systems in the North Atlantic

Chairs: Caroline Cusack and Silvana Birchenough

- 1345** **Keynote:** *Charles, Anthony*: Understanding and incorporating human dimensions of marine social-ecological systems
- 1430** *Townhill, Bryony L., Reppas-Chrysovitsinos, E., Sühling, R., J. Halsall, C. J., Mengo, E., Sanders, T., Dähnke, K., Crabeck, O., Kaiser J., Birchenough, S. N. R.*: Pollution in the Arctic Ocean: An overview of multiple pressures and implications for ecosystem services

- 1445** *Beckensteiner, Jennifer, Charles A., Villasante, S., Le Grand, C., Thébaud, O.*: Resilience for whom and according to what criteria? An examination of adaptation to changes in the Bay of Biscay anchovy fishery
- 1500** *Liu, Xiaozhi, Costello, C., Heino, M., Ojea, E.*: Shifting stocks and the consequences of non-adaptive transboundary fisheries agreements
- 1515** **Coffee/Tea + Poster session B**
- 1615** *Quillet, Etienne, Plante, S., Pigeon, L. E.*: Influence of the social representations on actors' adaptation strategies of the redfish (*Sebastes* spp.) fishery in the face of social ecological changes in the Gulf of St. Lawrence (Canada)
- 1630** *Lam, Mimi E, Perryman, H. P., Surma, S., Pitcher, T. J.*: Inserting Values in Ecosystem-based Fisheries Management
- 1645** *Buttay, Lucie, Solvang, H., Planque, B.*: Combining social and ecological time series to describe long-term dynamics of the Norwegian Sea ecoregion.
- 1705** **Early career networking activities**
- 1900** **Symposium Dinner at the Aquarium of Bergen, Nordnesbakken 4**

22 June, Wednesday

Theme Session 3: Trends and drivers of decadal variability in fish and invertebrates

Chairs: Kathy Mills, Sigrid Lehuta and Tara Marshall

- 0830** **Keynote:** *Hollowed, Anne B*: Scientific advancements in the study of the impacts of climate change and decadal variability on marine ecosystems and options for future management of living marine resources
- 0915** *Planque, Benjamin, Favreau, A., Husson, B., Mousing, E. A., Hansen, C., Broms, C., Lindström, U., Sivel, E.*: Reconstructing trophic interactions in the Norwegian Sea pelagic food-web over multiple decades.
- 0930** *Merillet, Laurene, Skogen, M. D., Vikebø, F., Jørgensen, L. L.*: Fish communities of subarctic fjords show early signals facing climate change compared to benthic communities: the example of the Porsangerfjord, Norway.
- 0945** *Silvar-Viladomiu Minto, C., Lordan, C., Brophy, D., Bell, R., Collie, J., David G. Reid, D. G.*: Stochastic modelling of fish recruitment productivity in the Celtic Seas Ecoregion
- 1000** *Mills, Kathy E., Kerr, L. A., Nye, J. A.*: Emergence of climate change effects on Northeast U.S. fish populations and communities
- 1015** *Le Bris, Arnault*: Decadal variability in the American lobster fishery across the Northwest Atlantic
- 1030** **Coffee/Tea**
- 1100** *Jónsdóttir Ingibjörg G., Björnsson, B., Ragnarsson, S. A., Elvarsson, B. Þ., Sólmundsson, J.*: Distribution and condition of haddock following population expansion
- 1115** *Vad, Johanne, Puerta P., Kenchington T., Head E., Kenchington E.*: Temporal trends in demersal fish and invertebrate abundances on the Scotian Slope during 1999-2019
- 1130** *Polo, Julia, Pecuchet, L., Hidalgo, M., Primicerio, R., Sainz-Bariain, M., Punzón, A., López-López, L.*: Disentangling the effects of fishing and climate in benthic-demersal communities by assessing their vulnerability

- 1145** *Ottersen, Geir Holt, R. H.:* Barents Sea cod recruitment less affected by temperature variability when spawning stock includes old, large fish
- 1200** *Vollset, Knut Wiik, Urdal, K., Kjell Utne, K., Thorstad, E. B., Sægrov, H., Raunsgard, A., Skagseth, Ø., Lennox, R. J., Østborg, G. M., Ugedal, O., Jensen, A. J., Bolstad, G. H., Fiske, P.:* Evidence of an ecological regime shift in the North-east Atlantic revealed from the unprecedented reduction in marine growth of Atlantic salmon
- 1215** *Ólafsdóttir, Anna H., Guðnason, K., da Silva, T., Pétursdóttir, H., Ólafsdóttir, S.:* Location of the arctic front east of Iceland during summer impacts mackerel migration into Icelandic waters.
- 1230** **Lunch**
- 1330** *Frank, Kenneth T, Petrie, B., Leggett, W. C.:* Temporal evolution of critical traits, trophic interactions and their relationship to cod stock collapse and recovery
- 1345** *dos Santos Schmidt, Thassya C., Slotte, A., Ólafsdóttir, A. H., Nøttestad, L., Jansen, T., Jacobsen, J. A., Homrum, E. Í., Eliassen, S. K., Smith, L., Bjarnason, S., Lusseau, S. M., Ono, K., Hølleland, S., Thorsen, A., Kjesbu, O. S.:* Atlantic mackerel (*Scomber scombrus*) migrates farther north to spawn under the current warm climate scenario
- 1400** *Utne, Kjell Rong, Skagseth, Ø., Thorstad, E., Wennevik, V.:* Northeast-Atlantic salmon post-smolt – geographic variation in marine feeding and the effect a changing ecosystem
- 1415** *Peñas-Torramilans, Raquel, Castelle, B., Outeiral, R., Santiago, T., Seoane, P., Vázquez, E., Weidberg, N.:* Study of wave trends along the Galician coast and evaluation of their potential impact on the quality of the stalked barnacle, *Pollicipes pollicipes*
- 1430** *Henriksen, Ole, Rindorf, A., Mosegaard, H., Payne, M. R., van Deurs, M.:* Get up early: Revealing behavioural responses of sandeel to ocean warming using commercial catch data
- 1445** **Summary of sessions and closing remarks**
- 1515** **Adjourn**

Posters

Theme Session 1: Ocean climate and physical environment in the North Atlantic and their linkages to changing marine ecosystem

1. Ólafsdóttir, A., Arneberg, P., Planque, B., Anker-Nilsen, T., Bjarnason, S., Broms, C., Børsheim, K. Y., Eliassen, S., Frie, A. K., Hallfreðsson, E., Hansen, C., Homrum, E. Í., Høines, Å., Libungan, L., Liu, X., Lorentsen, S. H., van der Meeren, G., Mell: A summary of ecosystem status and trends for the Norwegian Sea
2. Sandøy, A. B., Mousing, E. A., Budgell, W. P., Hjøllo, S. S., Skogen, M. D., Ådlandsvik, B.: Barents Sea plankton production and controlling factors in a fluctuating climate
3. Sammartino, S., García-Lafuente, J., Nadal-Arizo, I., Sánchez-Leal, R.: How biomass diel migration affects the reliability of currents measurements in the Strait of Gibraltar?
4. García-Lafuente, J., Sammartino, S., Sánchez-Leal, R., Nadal-Arizo, I., Naranjo, C.: Increased warming trend of the Mediterranean outflow into the North Atlantic Ocean
5. Sánchez-Leal, R., Bellanco, M. J., González-Pola, C., Sammartino, S., García-Lafuente, J., Naranjo, C., Vargas-Yañez, M., Roque, D., Bruno, M.: Thermohaline and transport variability in the Gulf of Cadiz in the 2010s
6. Cyr, F., Galbraith, P. S., Bélanger, D.: Seven decades of climate variability on the Newfoundland and Labrador shelf
7. Skjelvan, I., Lauvset, S., Johannessen, T., Gundersen, K., Skagseth, Ø.: Decadal trends in Ocean Acidification from the Ocean Weather Station M in the Norwegian Sea
8. Assmann, K. M., Husson, B., Ingvaldsen, R. B., Fossheim, M., Primicerio, P.: Asymmetric Atlantification in the Barents Sea and its effect on the ecosystem
9. Wakamatsu, T., Raj, R.: On the prolonged summer spring bloom period in the Norwegian Sea during 2010-2019.
10. Saes, M., Gjelstrup, C. V. B., Stedmon, C. A.: Separating annual, decadal and regional change in sea surface temperature in the Northeastern Atlantic and Nordic Seas
11. del la Barra, P., van Leeuwen, S., Bijleveld, A., Bom, R., Camphuysen, K., Dekinga, A., Dekker, R., Ens, B., Jan van Gils, J., Holthuijsen, S., ten Horn, J., van Leeuwen, A., van der Molen, J., Peck, M., Piersma, T., Philippart, K., van der Veer, H: Long-term shifts in main drivers of coastal food webs
12. Mork, K. A., Skagseth, Ø., Søiland, H.: Water mass properties and distribution in the Nordic Seas during the 2010s, and in relation to the changes during the last 50 years
13. Walczowski, W., Merchel, M., Wieczorek, P.: Ocean climate changes in the north-eastern Greenland Sea from synoptic and Lagrangian measurements
14. Büscher, J. V., McGrath, T., McAleer, A., Fennell, S., McGovern, E., Cusack, C., Rachel R. Cave, R. R.: Decadal trend and seasonal variability of the aragonite saturation in the Rockall Trough, Northeast Atlantic
15. Beszczynska-Möller, A., Walczowski, W., Grynczel, A.: Modifications of Atlantic inflow along the Fram Strait Branch to the Arctic Ocean from ship-borne and moored observations in the last two decades
16. Koul, V., Brune, S., Baehr, J., Schrum, C.: Decadal trends in the North Atlantic Subpolar Gyre and their impact on marine environment of the Barents Sea

Theme Session 2: Decadal change and trends in North Atlantic/sub-Arctic plankton and their ecosystems

17. *Gundersen, K., Lien, V. S.*: Declining silicate and nitrate concentrations in the Nordic Seas
18. *Gluchowska, G., Ormańczyk, M.R., Patuła, W., Strzelewicz, A., Kwaśniewski, S.*: A boreal breeze in the functional structure of arctic zooplankton
19. *Jacobsen, S., Gaard, E., Hátún, H.*: Decline in pre-bloom *Calanus finmarchicus* egg production on the Faroe shelf since the 1990s
20. *Aarflot, J. M., Hjøllø, S. S., Strand, E., Skogen, M. D.*: Transportation and predation control structures the distribution of a key calanoid in the Nordic Seas
21. *Uriarte, I., Iriarte, A., Villate F., Barroeta, Z., Bidegain, G.*: Patterns of variations in the neritic copepod community of the Basque coast (Bay of Biscay) during the last two decades (1998-2020) in relation to climate teleconnection and local environmental variables
22. *Ndah. A. B., Kirstein, I. V., Meunier, C., Wiltshire, K. H., Boersma, M.*: Helgoland Roads – A stepwise approach to unravel potential zooplankton indicators
23. *González Cabrera, C., Romero P., Moya F., García-Martínez M.C., Baldo P., Llopes M., Vilas C., González-Ortegon E, Jiménez M.P., Sánchez-Leal R.*: The evolution of the zooplankton community in the Gulf of Cádiz, SW Iberian Peninsula
24. *Børsheim, K. Y., Skagseth, Ø., Mork, K. A.*: Primary production in the Norwegian Sea
25. *Petursdottir, H., Gislason, A., Silva, T.*: Zooplankton variability in the waters around Iceland
26. *van Bortel, L., van den Oever, A.*: Phytoplankton trends in the Noordwijk transect
27. *Kwasniewski, S., Gluchowska, M., Olszewska, A., Walczowski, W., Carstensen, J.*: Vertical distribution of zooplankton and climate variability – A decadal glimpse from the West Spitsbergen Current
28. *Dutz, J., Huwer, B., Dierking, J.*: Phenological variations of zooplankton in the central Baltic Sea during a decade of warming
29. *Chen, E. Y.S., Blachowiak-Samołyk, K., Trudnowska, E.*: Planktonic ostracods at the gateway to a changing Arctic: Decadal variability of abundance, biodiversity, and vertical distribution in Kongsfjorden
30. *Bélanger, D., Cyr, F.*: Seasonal and decadal variation in zooplankton community composition in coastal Newfoundland waters
31. *Falkenhaug, T., Johannessen, T.*: Decadal trends in gelatinous zooplankton along the Norwegian Skagerrak coast
32. *Hubert, Z., Epinoux, A., Gallot, C., Cornille, V., Louchart, A., Bonato, S., Crouvoisier, M., Bruaut, M., Lebourg, E., Delarbre, J., Dédécker, C., Caillault, E. P., Hébert, P. A., Wacquet, G., Artigas, L. F.*: Decennial phytoplankton dynamics in the Strait of Dover by applying an automated in vivo approach
33. *Vilas, C., Baldo F., Gonzalez-Ortegon E., van Bergeijk S., Cabrera S., Ramirez A., Cardenas P., Cañavate P.*: Decadal variability 2010-2021 of zooplankton community at the Guadalquivir estuary (Southern Spain)
34. *Clarke, D., Yamanaka, T., Cusack, C., Kelly, J.*: Review of changes in phytoplankton species occurrence, abundance and distribution in Irish Coastal Waters 2010-2019.
35. *Balazy, K., Trudnowska, E., Boehnke, R., Dąbrowska, A. M., Jakubas, D., Wojczulanis-Jakubas, K., Darecki, M., Szeligowska, M., Blachowiak-Samołyk, K.*: How does the dynamics of primary production affect the availability of food for seabirds in the fluctuating high-Arctic environment?

Theme Session 3: Trends and drivers of decadal variability in fish and invertebrates

36. *González-Ortegon, E., Cuesta, J. A., Baldó, F., Vilas, C.:* Trends in the species composition at the southernmost estuary of the Atlantic coast of Europe
37. *Ottersen, G., Holt, R. H.:* Barents Sea cod recruitment less affected by temperature variability when spawning stock includes old, large fish
38. *Vaughan, L., Minto, C., Reid, D., Cusack, C., Poole, R., Stokes, D., Lynam, C., Brophy, D.:* Impacts of climate change on commercial fish stocks in Irish waters
39. *Vilas, C., Simon, F.W., Baldo, F., Ramos, F., Gonzalez-Ortegon, E., Drake, P., Vasseur, D.:* Multidecadal (1997-2020) telecoupling of water management for terrestrial agriculture and a marine fishery at Southern Spain
40. *Eliassen, S. K., Eydna í Homrum, E. Í., Jacobsen, J. A., Kristiansen, I., Óskarsson, G. J., Are Salthaug, A., Erling Kåre Stenevik, E. K., I:* Spatial distribution of different age groups of herring in Norwegian Sea, May 1996-2020
41. *Brown-Vuillemin, S., Chabot, D., Nozères, C. Tremblay, R., Robert, D. Sirois, P.:* Diet composition of redfish (*Sebastes* sp.) during periods of collapse and massive resurgence of the Gulf of St. Lawrence stock
42. *Surma, S., Skaret, G., Pitcher, T. J., Lam, M. E.:* Decadal trends in the Norwegian and Barents Sea ecosystem, 2010-2018
43. *Sowa, A. M., Balazy, P., Chelchowski, M., Kukliński, P.:* Settlement variability of Arctic cryptic benthic communities (between 2010 and 2020) as a result of natural environmental fluctuations
44. *Højgaard, D. P., Danielsen, J., Steingrund, P.:* Nest-site attendance of Northern Fulmar (*Fulmarus glacialis*) reflects marine ecosystem productivity based on monthly counts over a 26 year period
45. *Steingrund, P., Matras, U., Kristiansen, I., Broms, C. T., Pétursdóttir, H., Jansen, T.:* Long term dynamics of the Faroe Shelf ecosystem and potential effects of zooplankton advected from the Norwegian Sea
46. *Burns, C. M., Plourde, S., Lehoux, C., Pepin, P., Sirois, P., Robert, D.:* Drivers of the shifting recruitment dynamics of redfish (*Sebastes mentella*) in the Gulf of St. Lawrence, Canada
47. *Coussau, L., Robert, D., Sirois, P.:* Spatiotemporal variability in otolith elemental fingerprint and the potential to determine redfish (*Sebastes mentella*) origins in the Gulf of St. Lawrence, Canada
48. *Kajiya Endo, C. A., Skogen, M. D., Hjøllo, S. S., Stige, L. C., Vikebø, F. B.:* Effects of climate and demographic structure of spawners on growth and survival of offspring
49. *Tøsdal, T. G. H., Folkvord, A., Iversen, S. A., Skagseth, Ø., Nøttestad, L.:* Long-term spatial and temporal patterns in the Norwegian mackerel fishery from 1900 to 2020
50. *Gauthier, C., Robert, D., LeBris, A., Fisher, J. A. D., Sirois, P.:* Quantifying spatial dynamics and stock structure of Atlantic halibut within the Gulf of St. Lawrence to improve sustainable exploitation and management
51. *Nascimento, M. C., Husson, B., Guillet, L., Torstein Pedersen, T.:* Modeled species distributions and changes in water temperature and ice coverage in the Barents Sea in the last decade
52. *Stiansen, J. E., Sandø, A. B., Ohansen, G. O., Aglen, A., Renner, A.:* Climate change and new potential spawning sites for North East Arctic cod

Theme Session 4: Expanding horizons: assessing decadal changes and incorporating Social-Ecological Systems in the North Atlantic

53. *Gómez-Ballesteros, M., Cervera-Núñez, C., Campillos-Llanos, M., Quintela, A., Sousa, L., Márcia Marques, M., Lopes Alves, F., Virto C. M., Neil Alloncle, N., Sala, P., Capote, A. L., Simao, A. P., Costa, A., Carval, D., Bailly, D., Nys, C., Henry, S.*: Transboundary cooperation and mechanisms for Maritime Spatial Planning
54. *Gómez-Ballesteros, M., Cervera-Núñez, C., Campillos-Llanos, M., Algarra, S. A., Capote, A. L., Virto C. M.*: Maritime Spatial Planning transboundary pilot projects and their implication in the national process in Spain
55. *Verísimo, P., Fernández-Arcaya, U., Rodríguez-Basalo, A., Polo, J., Rodríguez, J., Ceballos, E., Ruiz, M., Sánchez, F., Punzón, A.*: Effects of “El Cachucho” MPA Implementation on fishing exploitation patterns
56. *Mikkelsen, N., Planque, B., Arneberg, P., Skern-Mauritzen, M., Hansen, C., Fauchald, P., Holsman, K. K., Haynie, A., Ottersen, G.*: Building conceptual models of marine socio-ecological systems with stakeholders

THE GULF OF ST. LAWRENCE, CANADA, UNDERGOING WARMING CONDITIONS IN THE LAST DECADE

Galbraith, P.S.

The Gulf of St. Lawrence is a semi-enclosed Canadian sea, covering an area of about 235000 square km, subject to rising temperatures. Concerning sea surface temperatures, 5 of the 12 warmest May-November SST averages on record (since 1982) have occurred in that 12-year period. Changes deeper in the water column have been even more startling. In winter, the Gulf can become completely covered by sea ice and nearly half of its volume of water usually gets cooled to temperatures below 0C within the winter mixed layer. But winter air temperatures have been warming at more than twice the rate of other seasons. In the same 12-year period, 8 of the 12 weakest recorded sea ice seasons have occurred, and 3 of them nearly without ice of the 5 on historical records. The winter mixed layer gets capped in spring, creating a cold intermediate layer that persists until late fall that determines the bottom temperature habitat over a large area. This layer has been warming and decreasing in volume since 1990 with large inter-annual variability. Waters deeper than roughly 150 to 200 m are entrained inwards from the continental slope by estuarine circulation, taking several years to reach the heads of the Gulf deep channels while mixing and diffusion occurs. This layer has been warming since 2009, with temperature increasing almost linearly at 300 m depth from 5.3C to 6.8C in 2021, with some waters currently >8C, and with the 100+ year record broken every year since 2015.

Oral presentation

CONTRIBUTION OF PHYSICAL NUTRIENT SUPPLY TO INTERANNUAL NUTRIENT VARIABILITY IN THE LABRADOR SEA

Dale, A., Wallace, D. W. R., Gehlen, M.

The North Atlantic exhibits intense biological productivity for which nutrients such as nitrate, phosphate and dissolved silica (DSi) are essential. Between 1994 and 2007, these three macro-nutrients declined in the subpolar North Atlantic, to increase again from 2007 until 2019. Previous studies have suggested a link between these changes and physical supply of nutrients, but none have directly assessed the key drivers of variability in the North Atlantic physical-biogeochemical system. Here we directly quantify the contributions of two known sources (i.e. Arctic transport and deep convection) and we focus on the specific 1994-2007 short-term change relative to the longer historical 1965-2019 period. We use a global configuration of a coupled ocean-biogeochemistry model, to assess relative contributions of deep convection variability and transport from Arctic. First results show that winter deep convection variability is the main contributor of the variability of pre-bloom surface nutrient concentrations in the Labrador Sea. We highlight the negligible contribution of Arctic transport of DSi (1.9% of the mean DSi inventory), nitrate (0.4%) and phosphate (1.1%) to their respective Labrador Sea pre-bloom inventories. Furthermore, we find a correlation between both the temporal and spatial variabilities of deep convection and the variability of pre-bloom surface nutrient concentrations. Our results support the hypothesis that the observed nutrient decline in the subpolar North Atlantic is caused by a weakening of deep convection, and also argues against hypothesis of a direct Arctic origin. Implications for the broader subpolar gyre beyond the Labrador Sea will also be discussed

Oral presentation

DATA ARCHAEOLOGY ENLARGE THE SANTANDER STANDARD SECTION.

Lavin, A., Rodríguez, C., Villoria, A., Tel, E., Gonzalez-Pola, C., Somavilla, R.

Long time series is a necessity for studying variability and climate change. Shelf contained CTD systems were developed in the early 80's, but previously, inverted bottles with thermometers, as well as batitermograph and XBT were used and data were hand-recorded.

Santander Standard Section, in Southern Bay of Biscay, has been sampled from 1990 covering the shelf, shelf break and deep water, but some information was previously collected in the area.

In 1928 Spain was integrated in the ICES and the Spanish Institute of Oceanography (IEO) accepted a mandate for weekly hydrographic sampling and cruises with hydrographic sections in Western Iberia and Bay of Biscay. Spanish navy boats were used for the sampling and data was sent to the ICES Committees. Knowing that, we have proposed to located those data and all the oceanographic information close to Santander available to enhance the time series.

Data from thermometers, batitermograph plates (200 m scale) and XBT (200 and 460m) plots have been quality checked, as much as possible, to be included in the time series. Some Salinity determinations will be presented.

The Book of the Santander Laboratory contains 213 temperature profiles of 25, 40 and 100m depth stations from 1928-32, 1950-59 and 1964 and a total of 1585 temperature records. Information increases late due to technical improvement.

As a preliminary result, we have detected mix layer temperatures in the older times colder than in the last 30 years. New information will permit describe the last decade 2010-2019 in a wider temporal contest.

Oral presentation

VARIABILITY IN MAIN PHYSICAL PROCESSES CONTROLLING NUTRIENT FLUXES AND ITS POTENTIAL IMPACT ON PHYTOPLANKTON BIOMASS DURING THE 2010-2019 DECADE: SOUTHEASTERN BAY OF BISCAY (NORTHEAST ATLANTIC)

Fontán, A., Chifflet, M., Chust, G., Borja, Á., Esnaola, G., Ferrer, L., Franco, J., Larreta, J., Lejonagoitia, L., Revilla, M., Germán Rodríguez, J., Sáenz, J., Sagarmina, Y., Cotano, U., Boyra G., Santos, M., Álvarez, P., Muxika, I., Valencia, V.

This study is focused on the southeastern (SE) Bay of Biscay, located in the intergyre region of the Northeast Atlantic, where subpolar and subtropical origin Eastern North Atlantic Central Waters (ENACW) converge. In 2010-2019 decade, an increase of the phytoplankton biomass (chlorophyll-a) was detected. We hypothesise that this increase was mediated by enrichment of water in nutrients due to physical processes such as winter mixing, coastal upwelling, advection of nutrient-rich subpolar origin ENACW and river discharges.

Trends, anomaly patterns and regime shifts in the above physical processes have been analysed during the 2010-2019 decade in relation to longer-term variability (1986-2019). To this end, monthly and quarterly repeat hydrographic and biogeochemical measurements were complemented with high-frequency hydrographic measurements from an adjacent deep-sea buoy and with hydrographic measurements from opportunity research surveys. Atmospheric reanalysis products, ocean colour remote sensing observations and river gauge data have also been analysed.

The 2010-2019 decade was characterised by enhanced mixing in winters of 2010, 2016 and 2018. Since the mid-2010s, increase in precipitation, river discharges and advection of nutrient-rich subpolar origin ENACW was also observed. In contrast, a weakening of coastal upwelling was detected. The complex interaction between these physical processes could have influenced water column nutrients and chlorophyll-a in the SE Bay of Biscay during the 2010-2019 decade.

Oral presentation

RECOVERY OF CONVENTIONAL BEHAVIOR OF THE EASTERN NORTH ATLANTIC INTERGYRE REGION IN THE 2010S AFTER A TRANSIENT FLOW REVERSAL

González-Pola, C., Somavilla, R., Ibañez, L., Graña, R., Vitoria, A., Álvarez, M., Rodríguez, C., Lavín, A.

Monitoring programs by the Spanish Institute of Oceanography has been providing hydrographical and biogeochemical series around Spanish waters since early 1990s. The oceanic Santander Atlantic Time-Series Station (SATS) in southern Biscay provides long-term regional tracking of intermediate and deep waters on a monthly basis. Conditions at the Western Iberian Margin deep basin covered by a full-depth section visited at least annually complete a broader view of North and NW Iberia. Subsurface and intermediate waters showed unabated warming and salt-increase for more than 2 decades since the start of the sampling until mid 2010s, adding up to 0.3°C and 0.08 in salinity at East North Atlantic Central Waters core levels. The warming period was first characterized by heave (TS diagram preserving isopycnal sinking) until regional very strong winter mixing in 2005 shifted abruptly water mass properties. In 2014, upper central waters showed freshening and cooling for the first time, a process which enhanced in the following years and follows the large salinity drop observed in the subpolar gyre around 2012. The regime shifts observed within the last two decades reveals a contrasting behavior of the weakly circulating reservoir so-called intergyre region. Such region, classically described as flowing southward and feeding the subtropical gyre, experienced a lasting flow reversal after the enhanced mixing of 2005 that brought the region into milder and saltier southern-like conditions. The enhanced inflow of northern cold and fresh waters starting by mid 2010s restored the typical subsurface hydrographic and flow conditions of the 1990s.

Oral presentation

SEVEN DECADES OF CLIMATE VARIABILITY ON THE NEWFOUNDLAND AND LABRADOR SHELF

Cyr, F., Galbraith, P. S., Bélanger, D.,

Located on the western edge of the north Atlantic subpolar gyre, the Newfoundland and Labrador (NL) shelf is especially affected by large-scale ocean circulation changes. Such circulation changes impact not only the regional climate, but also the overall water masses composition, with consequences on physical conditions, nutrient availability, oxygen content, pH, etc. Systematic hydrographic observations on NL shelf have been carried out by Canada and other countries since the late 1940's. The observational program was reinforced in 1999 with the creation of the Atlantic Zone Monitoring Program (AZMP), ensuring enhanced seasonal coverage and new biogeochemical observations. In 2014, this monitoring was extended to ocean acidification parameters. Here we review historical physical-biogeochemical interactions on the NL shelf, with an emphasis on low frequency variability and cycles. Results suggest, for example, that winter conditions above the North Atlantic largely set the stage for the ocean physical and biogeochemical conditions on the NL shelf during the rest of the year. It is also shown that decadal changes of the sea-level pressure above the North Atlantic influences the subpolar gyre, and thus the interactions between the Labrador and the North Atlantic currents, two major contributors to the NL shelf climate variability. This variability has in turn important consequences on the biogeochemistry and the overall productivity of the NL shelf ecosystem.

Oral and poster presentation

DECADAL TO SEASONAL SCALE WATER COLUMN VARIABILITY IN THE ROCKALL TROUGH FROM MODEL-ENHANCED TRANSECT TIMESERIES

Daly, E., Nolan, G., Berry, A., Büscher, J. V., Cave, R., Caesar, L., Cronin, M., Fennell, S., Lyons, K., McAleer, A., McCarthy, G., McGovern, E., McGrath, T., Uisce, A. F., O'Donnell, G., Thomas, R., Vaughan, M. L., White, M., Cusack, C.

The southern entrance to the Rockall Trough is subject to a complex set of dynamic processes, influenced by warm North Atlantic inflow and slope boundary currents, gyre fronts, variable wind stress forcing, mesoscale activity, and a changing supply of water masses formed elsewhere in the Atlantic. These processes drive large temporal and spatial variations, and mixing of surface and intermediate water mass properties that advect through the Trough and drive variations in the deeper waters circulating around it. Here, we investigate variability across the southern and central Rockall Trough over the lifetime of two standard hydrographic sections (2006 – 2021), to better understand recent freshening events, changes in water column characteristics (e.g. Labrador Seawater) and water mass modification during advection into the northern Rockall Trough.

This emerging timeseries is bolstered by model analysis, where choice of model was pre-assessed and validated, before intercomparison with in-situ observations on standard-station and climatological reference scales. Ship-based biogeochemistry measurements extracted from standard transect observations were examined in conjunction with associated physical properties and processes to assess any biophysical interactions with key fish species. Constraining physical environmental factors that influence the abundance and distribution of fish stocks is of high importance to resource management and conservation efforts.

Oral presentation

COMPETING EFFECTS OF TIDAL MIXING AND AIR-SEA HEAT FLUX ON THE PRIMARY PRODUCTION OF THE FAROE SHELF

Hansen, B., Erenbjerg, S. V., Eliassen, S.K., Larsen, K. M. H., Hátún, H.

Observations over three decades have documented a high inter-annual variability of the primary production on the Faroe Shelf which affects the productivity of higher trophic levels such as sandeel, sea-birds and demersal fish including cod and haddock. A number of studies have linked variations of the primary production to air-sea heat flux, while mixing induced by tidal currents also has been claimed to be important. A holistic picture, explaining both the timing and magnitude of the Faroe Shelf spring bloom in individual years, has not, however, been achieved. The main effect of air-sea heat flux is to generate vertical and/or horizontal density gradients between adjacent water masses, whereas tidal mixing tends to break down these gradients. On the Faroe Shelf, the tidal currents are strong, but they generally decrease with increasing bottom depth. On the central shallow shelf, this leads to a domain, which is permanently well-mixed by the strong tidal currents. Outside of this domain, there is a region with variable stratification during spring/summer, depending on both heat flux and tidal mixing. Using observations of physical parameters and sea-surface chlorophyll, as well as results from a numerical model, we discuss how the variation in temporal overlap of air-sea heating and tidal mixing has affected stratification and primary production in this region and the shelf as a whole. Based on this, we estimate the extent to which this competition can explain inter-annual variations in the spring bloom on the Faroe Shelf since the early 1990s.

Oral presentation

DECADAL VARIABILITY IN THE OCEAN AROUND ICELAND IN AN ERA OF ANTHROPOGENIC CLIMATE CHANGE

Jónsson, S., Ólafsdóttir, S. R., Macrander, A.

The ocean around Iceland is much warmer than the average for its latitude. The reason for this is the currents south of Iceland, that carry warm and saline Atlantic water, that extends to the shelf north of Iceland. The area is characterized by high variability due to the presence of water masses with particularly different properties and varying distributions. As well there are variations in properties within the different water masses. This variability influences the ocean ecosystems in the area in various ways. Regular seasonal measurements of temperature and salinity in the ocean around Iceland started in 1971 at standard stations that show clearly multi-decadal as well as shorter term variability. Prior to that, data were obtained irregularly from some stations but without seasonal resolution. Current meter measurements have been made since 1994 that make it possible to calculate the volume and heat transport of Atlantic water to the continental shelf north of Iceland. This data has been used in combination with other data to make a budget of volume and heat fluxes to the Arctic Mediterranean. The heat transport to the north Icelandic shelf increased from a low in 1995 and rose to a maximum in 2003 and since then it has remained high but stable. This is reflected in the temperature and salinity in the area north of Iceland. The variable conditions in the ocean around Iceland during the last 50 years will be discussed as well as the most important drivers and their influences on the ecosystem.

Oral presentation

NORDIC SEAS HEAT LOSS, ATLANTIC INFLOW, AND ARCTIC SEA ICE COVER OVER THE LAST CENTURY

Smedsrud, L. H., Brakstad, A., Madonna, E., Muilwijk, M., Lauvset, S. K., Spensberger, C., Born, A., Eldevik, T., Drange, H., Jeansson, E., Li, C., Olsen, A., Skagseth, Ø., Slater, D. A., Straneo, F., Våge, K., Årthun, M.

Poleward ocean heat transport is a key process in the earth system. We detail and review the northward Atlantic Water (AW) flow, Arctic Ocean heat transport, and heat loss to the atmosphere since 1900 in relation to sea ice cover. Our synthesis is largely based on a sea ice-ocean model forced by a reanalysis atmosphere (1900-2018) corroborated by a comprehensive hydrographic database (1950-), AW inflow observations (1996-), and other long-term time series of sea ice extent (1900-), glacier retreat (1984-) and Barents Sea hydrography (1900-). The Arctic Ocean, including the Nordic and Barents Seas, has warmed since the 1970s. This warming is congruent with increased ocean heat transport and sea ice loss and has contributed to the retreat of marine-terminating glaciers on Greenland. Heat loss to the atmosphere is largest in the Nordic Seas (60% of total) with large variability linked to the frequency of Cold Air Outbreaks and cyclones in the region, but there is no long-term statistically significant trend. Heat loss from the Barents Sea (~30%) and Arctic seas farther north (~10%) is overall smaller, but exhibit large positive trends. The AW inflow, total heat loss to the atmosphere, and dense outflow have all increased since 1900. These are consistently related through theoretical scaling, but the AW inflow increase is also wind-driven. The Arctic Ocean CO₂ uptake has increased by ~30% over the last century - consistent with Arctic sea ice loss allowing stronger air-sea interaction and is ~8% of the global uptake.

Oral presentation

WARM MEETS FRESH: THINNING OF POLAR WATER LAYER AND SHOALING OF ATLANTIC WATER ON THE NORTHEAST GREENLAND SHELF

Gjelstrup, C.V. B., Sejr, M. K., de Steur, L., Christiansen, J. S., Granskog M. A., Koch, B., Møller E. F., Winding, M. H. S., Stedmon C. A.

The Northeast Greenland shelf (NEGS) is a central node as recipient of Polar Water (PW) from the central Arctic Ocean, Greenland Ice Sheet melt, and Atlantic Water (AW). Here, we compile available observational data to quantify long-term hydrographic changes on the NEGS. We find profound change in the vertical distribution of water masses, with AW shoaling > 60 m and thinning of the PW layer at a rate of 20 m per decade since 2000. The properties of these waters have also changed, with AW now 1 °C warmer, and summer surface and PW core respectively 2 and 0.68 less saline than in the early 2000's. The combined effect on upper water column stratification reveals a prominent latitudinal division at ~74 °N. In the northern area, surface and PW freshening dominate, partially offsetting the effect of AW changes. Conversely, warming and shoaling of AW have substantially weakened stratification in the southern area, indicating increased accessibility of heat and nutrients associated with AW. The increased presence and shoaling of AW, including inflow into shallow sill fjords previously void of warm AW, is an important driver for ecosystem change through expansion of water masses with higher heat and nutrient content and organisms that are biogeographically different.

Oral presentation

VARIABILITY IN ATLANTIC AND ARCTIC WATERS IN THE NORWEGIAN BASIN AND ECOSYSTEM IMPLICATION

Skagseth, Ø., Broms, C., Gundersen, K., Hatun, H., Kristiansen, I., Kjell Arne Mork, K. A., Petursdottir, H., Søyland, H.

Over the last 25 years the relative influence of Arctic Water in the Norwegian Basin has shown large changes. Through the 1990s and into the early 2000s Arctic Intermediate Water was a pronounced feature as a wedge separating the upper Atlantic layer from the Norwegian Sea Deep Water. However, through the first decade of the 2000s the salinity of the Atlantic Inflow increased largely, and the layer of Arctic Intermediate water basically vanished. Again, after about 2015 the Atlantic Inflow have freshened, leaving us now at a stage of a lighter Arctic type water at least partly with origin from the Greenland and Iceland Seas. Having identified these major changes in the ocean climate of the Norwegian Basin we proceed to discuss potential ecosystem implication. From winter observations we find macronutrient concentrations, and silicate in particular, are generally higher in Arctic surface waters. Lower initial silicate concentrations at the onset of the spring bloom season may lead to minor diatom blooms and hence, less successful growth and survival of zooplankton and fish larvae from commercial stocks in these oceans. However, zooplankton diets are diverse and hence, not solely dependent on diatom growth and development. Therefore, we propose that the magnitude and longevity of the spring bloom, determined by the total amount of available nitrate in surface waters at the onset of the spring bloom, may play an equally important role in determining the seasonal magnitude of new production available for zooplankton growth and development in these waters.

Oral presentation

PHYSICAL MANIFESTATIONS AND ECOLOGICAL IMPLICATIONS OF ARCTIC ATLANTIFICATION

Ingvaldsen, R. B., Assmann, K. M., Primicerio, R., Fossheim, M., Polyakov, I. V.

The Atlantic gateway to the Arctic Ocean is influenced by vigorous inflows of warm Atlantic Water. The high latitude impacts of these inflows have strengthened owing to climate change, particularly since 2000, driving so-called ‘Atlantification’—a transition of Arctic waters to a state more closely resembling that of the Atlantic. In this presentation, we discuss manifestations of this “Atlantification” in a hotspot region of climate change spanning from the southern Barents Sea to the Eurasian Basin. Atlantification is driven by anomalous AW inflows and is modulated by local processes, inducing warming, sea ice loss and weaker stratification in ice-covered regions. Key mechanisms include reduced atmospheric cooling amplifying warming in the southern Barents Sea, reduced freshwater input and stronger influence of ice import in the northern Barents Sea, and enhanced upper ocean mixing and air-ice-ocean coupling in the Eurasian Basin. The ecosystem responses to Atlantification are numerous and include increased production, northward expansion of boreal species (borealization) and increased importance of the pelagic compartment populated by new species, while the ice-associated ecosystem compartment gradually vanishes. The food web becomes increasingly connected and the emerging ecosystem develops an increased capacity to adjust to Atlantification.

Oral presentation

OCEAN ACIDIFICATION VARIABILITY IN THE ATLANTIC AND ARCTIC INFLUENCED NORWEGIAN WATERS

Jones, E., Chierici, M., Lødemel, H. H., Mourgues, C.

A decade of ocean acidification monitoring has revealed large variability attributed to oceanographic and anthropogenic processes that influence oceanic pH and calcium carbonate saturation (Ω) state. Variability in the carbonate system in the Skagerrak was driven by mixing of Atlantic waters, fresher water of Baltic origin and riverine inputs. Since 2010, general increases in temperatures and salinity indicated greater incursions of warm and saline water at 600 m depth. Concurrent lower pH and Ω resulted from remineralisation of organic matter and presence of older carbon-rich Atlantic waters, where a trend in Ω of $\approx 0.02 \text{ yr}^{-1}$ (2010-2020) was evident. Nearshore waters are strongly influenced by the Norwegian coastal current where variability in pH and Ω was driven by freshwater inputs, biological production and mixing with sub-surface Atlantic water. In the Norwegian Sea, the saturation horizon for aragonite ($\Omega = 1$) occurred between 2000-2500 m depth and showed depth variability related to the presence Atlantic and Arctic waters. Further north, the Barents Sea opening is also affected by coastal water, Atlantic water and Arctic water. Lowest pH and Ω were found in the cold and fresh Arctic water layer overlying the seafloor, where cooling and freshening in the last 5 years has lowered Ω . Future integrated monitoring, including measurements or proxies for biological productivity, ocean physics, and land-ocean exchanges, is essential to resolve the spatio-temporal variability of drivers of ocean acidification. This work is part of 'Monitoring ocean acidification in Norwegian Seas' funded by the Norwegian Environment Agency.

Oral presentation

MARINE HEATWAVES: THE NEW NORMAL? A MULTIPLE BASELINE APPROACH

Gimenez, J.L., Boersma, M., Wiltshire, K. H.

Marine heatwaves (MHW) and other extreme temperature events are sources of mass mortality, but their effects depend on how they are experienced by biological systems (species and societies). We applied two different baselines (fixed and mobile) to a time series of North Sea water temperature to explore how slowly vs. fast adapting systems would experience extreme temperatures. A fixed baseline produced an increase in the frequency and duration of MHWs, which must be experienced as the new normal by slowly adapting systems. The shifting baseline produced a concentration of MHWs in the 1990's which must have been experienced as a bottle neck by fast adapting systems. For both baselines, temperature variability was characterised by low frequency, large amplitude fluctuations (i.e. as red noise), known to drive extinction events, which are being experienced irrespective of adaptability. MHW were strongly associated to atmospheric heatwaves, suggesting a way for prediction and mitigation irrespective of the baseline.

Oral presentation

PHYSICAL DRIVERS OF BIOGEOGRAPHICAL SHIFTS IN THE NORTHEASTERN ATLANTIC – AND ADJACENT SHELVES

Hátún, H., da Silva, T., Skagseth, Ø., Grønkjær, P.

The subpolar North Atlantic Ocean is characterized by its rich ecosystems – rapid spring blooms, vast energy-rich zooplankton stocks, huge migratory pelagic fish stocks, large seabird colonies and highly productive demersal fish stocks on the shelves surrounding the oceanic basins. A multidisciplinary Research Topic in *Frontiers in Marine Science* has brought together 20 research articles under themes related to physical drivers of biogeographical shifts in the northeastern Atlantic and adjacent shelves. The main results from this Research Topic will be summarized in an editorial (in progress), which shall bind this collection of papers into an eBook. In this talk, I will present highlights from the editorial.

Oral presentation

ECOLOGICALLY RELEVANT SCALES OF TEMPERATURE IN THE NORTH SEA

Wiltshire, K.H., Amorim, F., Lemke, P., Rick, J., Gimenez, L., Boersma, M., Guignard M., Kirstein, I. V.

Global warming of coastal and shelf seas is fact. Long-term temperature and climate time series, as well as models, provide the evidence. The pressure is on to provide concurrent data-driven knowledge of ecosystem reactions and stability. It is imperative to translate this warming into evinced and graspable ecosystem effects and consequences; otherwise, management strategies and scenario discussions are difficult/impossible to realise.

Ecosystems and organisms react to shifts in environments on different time scales. The potential death, fitness, resilience and adaptation of species is dependent on the intensity, duration and frequencies of environmental shifts/ events. Frequently the exact changes in environmental drivers are statistically difficult to grasp in time and spatial scales. Thus, the understanding of and foundation for long-term management of ecosystem and biodiversity shifts in terms of temperature can be scientifically deviant and sometimes tenuous.

We analysed the temperature data from detailed long-term marine ecological time series Helgoland Roads, Sylt Roads and the North Sea with global, continental, regional and local temperature time series. Long-term trends, warming and cooling events, seasonal shifts are identified, and anomalies and frequency distributions of temperature over time evaluated. Plankton, life cycle, and food web interaction information are placed in the ecological context of time and spatial scale.

We define a hierarchy of necessary analyses in order to be able to relate marine ecosystem change to temperature in terms of relevant time and spatial scales.

Oral presentation

INDICATORS FOR WHOLE ECOSYSTEM RESPONSES TO SEPARATE CLIMATE FROM ANTHROPOGENIC CHANGE IN COASTAL SEAS

Trifonova, N.I., Scott, B., De Dominicis, M., Waggitt, J., Wolf, J.

Understanding ecosystem dynamics within coastal seas is of great importance to support marine spatial management of natural populations and activities such as fishing and offshore renewable energy production to combat climate change. Given the possibility of future changes, a baseline is needed to predict ecosystems responses to such changes. This study uses Bayesian techniques to find the data-driven estimates of interactions among a set of physical and biological variables and a human pressure within the last 30 years in the North Sea with four contrasting regions and their associated ecosystems. Data-driven estimates of interactions were identified, highlighting physical (e.g. bottom temperature) and biological variables (e.g. net primary production) to be strong indicators of ecosystem change. Another important finding was the dramatic changes in the strength of many interactions over time, as these led to the identification of two potentially significant periods of ecosystem change (2005 and 2010), linked to changes in temperature, salinity and primary production changes. The indicators were used to build dynamic Bayesian network models to examine species response to change in the context of climate and offshore renewable developments. We were able to predict trends of increase vs decline, with the patterns of these effects varying by species and habitat type, highlighting some species as much better indicators compared to others. Such information will be useful to guide what habitats and species are more resilient/at-risk to what type of disturbances and therefore what management decisions are required to steer towards more ecologically sustainable conditions.

Oral presentation

CHANGES AND TRENDS IN NORTH ATLANTIC PLANKTON: A TIME-SERIES-BASED OVERVIEW FROM THE ICES ZOOPLANKTON AND PHYTOPLANKTON ECOLOGY WORKING GROUPS

O'Brien, T. D., Members of the ICES Working Group on Zooplankton Ecology (WGZE), members of the ICES Working Group on Phytoplankton and Microbial Ecology (WGPME)

More than two decades after its very first 10-site overview (a zooplankton-only annex produced in 2001), the time-series work of the ICES Working Group on Zooplankton Ecology (WGZE) and the ICES Working Group on Phytoplankton and Microbial Ecology (WGPME) has expanded to include over 100 in situ plankton time series. The collaborative work of these two groups now examines trends and patterns in the zooplankton, phytoplankton, microplankton, and a variety of co-sampled environmental parameters (e.g., pigments, nutrients, temperature, salinity, oxygen). Their collection of survey and monitoring data comes from both coastlines of the North Atlantic, the open ocean, and the Baltic and Mediterranean Seas. This spatio-temporal coverage allows for a true trans-Atlantic examination of plankton interannual and decadal states, trends, and patterns within and across multiple regions.

In the North Atlantic, the last decade has seen considerable changes in water temperatures and productivity. This presentation gives an overview of how these changes impact and manifest themselves in the regional and trans-Atlantic plankton communities, integrating both satellite and in situ data into its analyses.

This presentation is given on behalf the ICES zooplankton and phytoplankton working groups (WGZE/WGPME), and highlights results from their next installment in the ICES Plankton Status Report publication series.

Oral presentation

SHIFTING ECOLOGICAL NICHEs OF PHYTOPLANKTON AND ZOOPLANKTON UNDER ENVIRONMENTAL CHANGE

Guignard, M. S., Maarten Boersma, M., Wiltshire, K. H.

Environmental change, including change in sea temperature and nutrient availability, is altering ecological niches. The breadth of a species' niche comprises the range and variety of environments tolerated. A wider niche breadth may be an important ecological trait under climate change and extreme events, enabling a taxon to be resilient and to adapt to environmental change. Environmental conditions are shifting, leading to niche expansion for some, and constraining the niches of other species/taxonomic groups. The subsequent shifting of environmental niche impacts on the role a species plays in the ecological community, in predator-prey interactions, and in the community structure.

We use long-term phytoplankton and zooplankton abundance data spanning five decades to construct species ecological niches and track realized species niches through time. We investigate the resilience of species and of plankton communities to environmental drivers and to extreme events such as climate anomalies within a long-term context, and within the 2010s decade. We compare species realised niches and peak bloom phenology between years and seasons, and how these comprise the phytoplankton and zooplankton communities in terms of species presences and in terms of key functional traits.

Oral presentation

WHAT DRIVES PHYTOPLANKTON BLOOM DYNAMICS AT HELGOLAND ROADS?

Balkoni, A., Wiltshire, K. H.

Phytoplankton blooms present as ecological hotspots and changes in phytoplankton bloom dynamics can have important implications in trophic interactions and in turn, in food-web structures. The German Bight, a highly dynamic coastal system of the southern North Sea, is particularly vulnerable to these changes due to important alternations in two major drivers of phytoplankton blooms: dissolved inorganic nitrogen to dissolved inorganic phosphorus ratios (DIN:DIP) and sea surface temperature (SST) increase. We investigated changes in the timing of phytoplankton bloom onset and its relationships with both biotic and abiotic factors from 1975 to 2019 using the in-situ, work-daily Helgoland Roads LTER data. The phytoplankton bloom onset was defined as the maximum acceleration of diatoms growth and was estimated for winter (1st bloom of the year) and spring seasons. We demonstrate that warmer conditions in Helgoland Roads were associated with substantially earlier bloom initiation for both 1st and spring blooms. Furthermore, DIN:DIP before the bloom initiation showed a moderate positive relationship with the 1st bloom onset, implying that under P-limited conditions the 1st bloom of the year tended to be delayed. The results of this study extend our knowledge on how the combination of SST rise and altered nutrient ratios influence phytoplankton dynamics in temperate coastal ecosystems.

Oral presentation

REGIONAL CHANGES IN HARMFUL ALGAL EVENTS IN THE NORTH ATLANTIC AREA FROM 2010 - 2019

Clarke, D., Bresnan, E., Andersen, P., Anderson, D., Andree, K., Campás, M., Cembella, A., Davidson, K., De Rijke, M., Eikrem, W., Fernández, L., Fernández-Tejedor, M., Garces, E., Goncalves, A., Jacobsen, S., Karlson, B., Kobos, J., Kremp, A., Kulis, D., Lemoine, M.

The International Council for the Exploration of the Sea (ICES) - Intergovernmental Oceanographic Commission of UNESCO (IOC) Working Group on Harmful Algal Bloom Dynamics (WGHABD) has entered data into the Harmful Algal Event (HAEDAT) database for the last 20 years. These entries report information about harmful algal events that result in management actions such as closures of shellfish harvesting areas or negative environmental impacts e.g. mortalities of marine mammals and formed a significant component of the recent IOC Global HAB Status report. These HAEDAT data reveal a regional distribution in harmful algal events in the North Atlantic area and a number of changes have been observed since 2010. Closures of shellfish harvesting areas due to Diarrhetic Shellfish Toxins (DSTs) and Amnesic Shellfish Toxins (ASTs) above regulatory thresholds have become more frequently enforced along the east coast of the USA since 2012 and 2014 respectively. In Europe, Ciguatera Poisoning (CP) associated with consumption of contaminated fish has been recorded almost every year in the Canary Islands since 2010 requiring the development of new monitoring and management actions. A number of extreme events in the North Atlantic area have also been recorded during the decade resulting in mortalities of farmed fish and biota and closures of recreational beaches. Additional studies have also recorded the presence of harmful algal species in Arctic waters.

During the last decade, the observed changes in phytoplankton abundance and distribution associated with harmful algal events have resulted in additional challenges to the management of aquaculture operations.

Oral presentation

ENVIRONMENTAL VARIABILITY SHAPES COPEPOD LIFE HISTORY: WHAT WE LEARN FROM OPTIMIZING A *C. FINMARCHICUS* POPULATION MODEL IN THE NORTHWEST ATLANTIC

Leitao, E., Brennan, C. E., Gentleman, W. C., Maps, F., Johnson, C. L.

Calanus finmarchicus dominates the biomass of mesozooplankton in the northwest Atlantic and has significant importance as the main prey of the endangered North Atlantic right whale. In recent decades, abundance declines and distribution changes in these copepods have been observed, possibly having negative impacts on North Atlantic right whales. This modeling study examines regional differences of *C. finmarchicus* characteristics and investigates the role of environmental variability in regulating their populations. Population models require specification of a suite of parameters related to mortality, egg production, and development rates, some of which are well defined, whereas others are not and need to be tuned. Here, we used a genetic algorithm to find parameter values that best fit model outputs to observations from the Anticosti Gyre station in the Gulf of St. Lawrence and the Halifax-2 station on the Scotian Shelf. Using historically warm and cool years, we then investigated the robustness of these populations to environmental variability. Model optimization highlighted trade-offs of different, but equally viable, parameter sets at each station, as well as diversity of strategies available between regions. When forced with historical environmental variability, the model reproduced observations and highlighted that warming and a delayed spring bloom are associated with population declines. This investigation emphasizes how regional environmental differences shape *C. finmarchicus* subpopulation characteristics and underscores the need for temporal resolution of parameterization. Interannual environmental variability directly impacts *C. finmarchicus* phenology and abundance and predicting these sub-decadal shifts is critical for North Atlantic right whale management and conservation.

Oral presentation

SPATIAL VARIABILITY OF THE FEEDING CONDITIONS FOR THE NORWEGIAN SPRING SPAWNING HERRING IN MAY

Kristiansen, I., Hátún, H., Eliassen, S. K., Jacobsen, J. A., Eilif Gaard, F., Petursdóttir, H.

The abundance and ecologically important copepods *Calanus finmarchicus* and *C. hyperboreus* within the Norwegian and Iceland Seas are key prey species of Norwegian spring spawning herring. The volume flux of East Icelandic Water, carrying the *Calanus* spp. into the southern Norwegian Sea, is highly variable. The years 1996 to 2002 have previously been characterized as high influx years, 2003-2015 as low influx years and since 2016 a reversal to higher influx has been apparent. Hydrographic and zooplankton data, as well as fish size and diet content, from the International Ecosystem Surveys in the Nordic Seas (IESNS) in May have been used in this study. Focus is on the south-western Norwegian Sea, where herring has regularly been observed in May since 2005 and where changes in plankton availability and hydrographic conditions have also been observed. Diet biomass from 2017-2020 (higher influx period) showed higher stomach fullness compared to 2007-2011 (lower influx years), with tendencies of highest stomach fullness furthest westwards. A notably higher biomass of *C. hyperboreus* was ingested in 2020 compared to 2007-2011, indicating a preference for the larger and more nutritious copepod. Zooplankton analysis from 2020 revealed the area with highest zooplankton biomass, was located within the subarctic waters immediately north/west of the junction between the IFF and the Jan Mayen Front. This area was mainly represented by overwintering stages and the derived adult stages of *C. finmarchicus* and *C. hyperboreus*. The interplay between food availability and accessibility, in terms of temperature, to the western feeding area, is discussed.

Oral presentation

EFFECTS OF BOTTOM-UP AND TOP-DOWN PROCESSES ON LOWER TROPHIC LEVELS IN THE NORWEGIAN AND ADJACENT SEAS DURING THE LAST DECADE

Broms, C., Børsheim, K. Y., Skagseth, Ø., Utne, K. R., Surma, S., Skogen, M. D., Lam, M. E., Pétursdóttir, H., Melle, W., Kristiansen, I., Gundersen, K., Pitcher, T. J., Libungan, L. A., Fiksen, Ø., Ólafsdóttir, A.

Production at lower trophic levels is a measure of the total productive capacity of the ecosystem, and variability in production levels of plankton may propagate up the food chain and affect living marine resources. The present study is anchored in the ICES WGINOR (Working Group on Integrated Ecosystem Assessments for the Norwegian Sea) and in a broad collaboration spanning several research fields and trophic levels. The aim of the study is to identify key bottom-up and top-down processes influencing lower trophic levels in the Norwegian Sea and adjacent areas. The focus of the study is inter-annual variability in zooplankton abundance from 2008 to 2018, including spatial differences between Atlantic and Arctic water masses and temporal differences during the growth season. Firstly, this variability is linked to environmental variables representing the level and timing of primary production and phytoplankton (net primary production, spring bloom initiation day, the day and maximum concentration of chlorophyll) obtained from satellite data. Secondly, two ecosystem models, Norwecom.E2E and Ecopath with Ecosim (NorBar) are used to quantify i) predation pressure on zooplankton from the three large planktivorous fish stocks in the Norwegian Sea (northeast Atlantic mackerel, *Scomber scombrus*; Norwegian spring-spawning herring, *Clupea harengus*; and northeast Atlantic blue whiting, *Micromesistius poutassou*), and ii) how changes in these stock abundances influence zooplankton biomass and production, overall zooplankton consumption by pelagic fish, and total pelagic fish biomass. Using multiple models in ecosystem assessments allows for robust evaluation of the modelling results and their uncertainties.

Oral presentation

LONG TERM CHANGES IN THE DIVERSITY AND BIOGEOGRAPHY OF PHYTOPLANKTON COMMUNITIES IN THE SKAGERRAK-KATTEGAT, NE ATLANTIC

Karlson, B., Johansen, M., Karlberg, M., Skjevik, A. T.

The Kattegat and the Skagerrak are transition areas between the Baltic Sea and the North Sea. Long term monitoring of phytoplankton started in the 1980:s and has seen an increase in geographical coverage since then. DNA-metabarcoding is being introduced in monitoring. An overview of long-term changes in the length of the growing season and in biodiversity and biogeography will be presented and discussed in the context of changes in environmental factors and zooplankton abundance. The advantages and drawbacks with genomic methods vs. morphology-based methods will also be examined. Diatoms contribute the largest part of phytoplankton biomass in the area. Changes at the species level include that *Pseudosolenia*, absent from the area for a long time, re-occurred in the area in years 2009-2010 and has been a permanent member of the phytoplankton community since then. Dinoflagellates is the second most important group regarding biomass. *Alexandrium pseudogonyaulax*, producer of the phycotoxin goniiodomin, was not observed in the 1990:s, very rare in the first decade of 2000:s and common from 2010 to 2020. *Dinophysis* spp., producers of diarrhetic shellfish toxins, are common in the area. *D. tripos* has increased in abundance since 2013. *D. acuta* has decreased in abundance since c. 2010. This co-occurs with a decrease in concentrations of diarrhetic shellfish toxins in blue mussels, *Mytilus edulis*. *Pseudochattonella*, a fish killing genus in the Dictyochophyceae, started blooming in the area in 1998 with recurrent blooms since then. Fish mortalities have been observed mainly in the Danish part of the Kattegat.

Oral presentation

INTER-ANNUAL VARIABILITY IN PARTICLES AND ZOOPLANKTON IN THE WARMING ARCTIC FJORD (ISFJORDEN, WEST SPITSBERGEN)

Szeligowska, M., Trudnowska, E., Boehnke, R., Błachowiak-Samołyk, K.

The most rapid and substantial climate-related changes in functioning of marine ecosystems are observed in the Arctic. In this polar region, the retreat of glaciers resulting in intensified freshwater discharge with suspended sediments is one of the most visible consequences of climate fluctuations. Plumes of turbid glacial meltwater are visible at the surface and have far-reaching consequences for downstream ecosystem that can extend beyond the coastal zone into the open ocean. Thus, it is of great importance to track small-scale spatial patterns and inter-annual variability of particles discharge and their interplay with mesoplankton. In this study, the sampling was performed in nine following summers (2013–2021) along a hydrographical gradient in Isfjorden – the largest Spitsbergen fjord system – from the main basin, which is under the influence of Atlantic Water, up to Billefjorden – the innermost glacial bay that is strongly affected by meltwater from Nordenskiöldbreen. Combining satellite images, laser-based measurements (LOPC) with standard plankton sampling allowed us to conclude that along with hydrographical stratification and meltwater discharge, also eddy activity was forcing patchy distribution of plankton and particles. Moreover, plankton responded not only to the local processes, but also to the inter-annual fluctuations, e.g. in colder years we observed lower fluorescence of chlorophyll a, which had influence on plankton community. In the end, such studies will form a basis to predict how plankton community will shift over the coming decades in an era of rapid glacial melt.

Oral presentation

DECADAL VARIABILITY IN THE RESPONSE OF PLANKTON LIFEFORMS AND TAXA TO ENVIRONMENTAL DRIVERS

Holland, M. M., McQuatters-Gollop, A.

Plankton time-series data are complex and often require a high level of integration before they can be useful for revealing meaningful patterns or trends. One approach to deal with the large number of taxa is to group them into lifeforms sharing similar functional traits since taxa within lifeforms are likely to contribute to the same ecosystem function. However, taxa within lifeforms can have different responses to environmental conditions and much of this important taxonomic detail is lost in the process of integration. We analysed 60 years of Continuous Plankton Recorder (CPR) data with pelagic indicators developed for OSPAR MSFD assessment and compared the past decade of monitoring data with the previous 50 years. We observed large-scale changes in lifeform abundance across the northeast Atlantic and the North Sea over this period. We then investigated the relative contributions of environmental drivers, including sea surface temperature, nutrient concentration, and the North Atlantic Oscillation, on lifeforms and on individual taxa within these regions. We found evidence of large-scale shifts in phytoplankton and zooplankton abundance, with variable responses to environmental drivers within and among lifeforms. Both lifeforms and individual taxa also exhibited regional variability in their response to these drivers, suggesting spatially variable changes in ecosystem functioning that may require implementation of spatially-explicit management measures to achieve Good Environmental Status. This finding suggests that it is critical to retain taxonomic detail when examining the functional role of plankton lifeforms, as both provide important evidence required for decision-making around the implementation of management measures.

Oral presentation

TWENTY-ONE YEARS OF PHYTOPLANKTON BLOOM PHENOLOGY IN THE BARENTS, NORWEGIAN AND NORTH SEAS

da Silva, E. F. F., Counillon, F., Brajard, J., Korosov, A., Pettersson, L., Samuelson, A., Keenlyside, N.

We use satellite chlorophyll-a from 2000 to 2020 to assess the climatological and interannual trends of spring and summer blooms onset, peak day, duration and intensity. We also correlate the interannual variability of the blooms with mixed layer (ML), sea surface temperature (SST), winds and suspended particulate matter (SPM) retrieved from models and satellite. The climatological spring blooms start on March 10th and end on June 19th. The climatological summer blooms begin on July 13th and end on September 17th. In the Barents Sea, years of shallower mixed layer driven by calm waters and higher freshwaters input keeps the phytoplankton in the euphotic zone, causing the spring bloom to start earlier and reach higher biomass but end sooner due to the lack of nutrients upwelling from the deep. In the Norwegian Sea, a correlation between SST and the spring blooms is found. Warmer waters are correlated to earlier and stronger blooms in most regions but with later and weaker blooms in the eastern Norwegian Sea. In the North Sea, years of shallower ML reduces the phytoplankton sinking below the euphotic zone and limits the SPM increase from the bed shear stress, creating an ideal environment of stratified and clear waters to develop stronger spring blooms. Last, the summer blooms onset, peak day and duration have been rapidly delaying at a rate of 1.25-day year⁻¹, but with inconclusive causes based on the parameters assessed in this study. More details can be found in [doi:10.3389/fmars.2021.746327](https://doi.org/10.3389/fmars.2021.746327).

Oral presentation

SIZE-FRACTIONED ZOOPLANKTON BIOMASS IN THE BARENTS SEA ECOSYSTEM: CHANGES DURING FOUR DECADES OF WARMING AND FOUR CAPELIN COLLAPSES (1980-2020)

Skjoldal, H. R.,

Zooplankton biomass in the Barents Sea has been monitored by IMR in collaboration with PINRO since 1986. Along with data for the early 1980s (presented at the first ICES decadal symposium) we have now witnessed dynamics and changes of zooplankton over four decades. There is a general spatial pattern of lower biomass in the central part and higher biomass in the southwestern and northern parts of the Barents Sea. The biomass has fluctuated inversely with collapses and recoveries of the Barents Sea capelin stock, which is a major predator on zooplankton. The biomass of the central Barents Sea has shown a declining trend over the recent decades, interpreted as a combined effect of warming and increased predation. The data show a general pattern of higher proportion of the small size fraction (<1 mm) when the total zooplankton biomass decreases, i.e. a shift toward smaller species. A feature of the last decade has been lower biomass of the large fraction (>2 mm) compared to earlier. The boreal copepod species *Calanus finmarchicus* and the Arctic species *Calanus glacialis* are dominant components of zooplankton biomass in the Barents Sea. The changes in zooplankton biomass is discussed in relation to number of generations and expatriation of *C. finmarchicus*, and retreat and decline of *C. glacialis* under warming climate.

Oral presentation

TEMPORAL TRENDS IN ZOOPLANKTON COMMUNITY COMPOSITION AND LIFE STAGE ABUNDANCES ON THE SCOTIAN SLOPE DURING 1999-2019

Vad, J., Puerta P., Head E., Kenchington T., Kenchington E.

Understanding how plankton communities respond to environmental variation is key to predicting the consequences of climate change for marine food webs. We analysed time series of both zooplankton community composition (55 taxa) and the life stages of the principal copepod species (*Calanus finmarchicus*, *C. glacialis* and *C. hyperboreus*), in both spring and fall on the eastern Scotian Slope during 1999–2019. The study area, off Nova Scotia, Canada, is influenced by complex oceanographic interactions between warmer, north-eastward flowing waters derived from the Gulf Stream and colder south-westward flowing waters from the Labrador Current and Gulf of St. Lawrence. Trajectory analysis, multivariate regression trees and dynamic factor analysis revealed a single, significant linear trend common to both seasonal datasets, in which the abundances of 18 taxa decreased after 2008. The copepod life stage dataset was highly variable but a potential breakpoint around 2008 was indicated. Further investigation of environmental drivers of zooplankton change is underway, through analysis of both oceanographic model outputs and field data. However, surface and subsurface temperatures along the Scotian Slope have increased in recent decades, as the influence of warm slope water has increased. This may have contributed to the observed biological shifts. This work is part of the Horizon 2020 iAtlantic project, which aims to assess the status of deep-sea and open-ocean ecosystems across the Atlantic Ocean.

Oral presentation

EVIDENCE OF MAJOR SHIFT IN THE COPEPOD FUNCTIONAL COMMUNITY OF THE SOUTHERN NORTH SEA IN THE LATE 80S: ENVIRONMENTAL FACTORS AND POTENTIAL REPERCUSSIONS ON THE FOOD WEB

Deschamps, M., Boersma M., Meunier C., Di Pane J.

In marine ecosystems, mesozooplankton represents the base of the consumer food web and is therefore a major component of ecosystem health. Within it, copepod form the bulk of the secondary production and are a food resource for many organisms. Due to their short life span and the high metabolic cost of undergoing developmental transition they are extremely sensitive to climate and environmental changes. In turn, changes in their functional structure can have profound impacts on ecosystem functioning. Using a trait-based approach, we examined changes in the functional structure of the copepod community in the southern North Sea over the past five decades in relation to the environment. From 1975 to 1990, the copepod community was characterised by large herbivores, with a long development time, able to diapause and displaying peak of abundance in summer. After 1990, the functional structure shifted abruptly and permanently to a dominance of small detritivores or carnivores' taxa, with a shorter development time, lesser able to make diapause and displaying an abundance peak in autumn. Sea warming, change in water chemistry and decreasing dinoflagellate abundances appeared to be linked to this rapid reorganization of the functional structure. These changes could have had major repercussions on higher trophic levels such as fish and could explain the decrease in recruitment success observed for some species in the North Sea. These results emphasize the profound potential impact that global and regional changes could have on coastal ecosystems through the lever represented by copepod.

Oral presentation

ENVIRONMENTALLY INDUCED FUNCTIONAL SHIFT IN PHYTOPLANKTON COMMUNITIES AND ITS CONSEQUENCES FOR ECOSYSTEM FUNCTIONING

Di Pane, J., Wiltshire, K. H., McLean M. J., Boersma, M., Meunier C. L.

Phytoplanktonic organisms represent a direct link between abiotic and biotic compartments within the marine food web. The strong relation they have with the environment makes them particularly sensitive to global and regional changes. In turn, changes in their functional structure can have profound impacts on ecosystem functioning. Using a trait-based approach, we examined changes in the functional structure of the southern North Sea phytoplankton community over the past five decades in relation to the environment. We highlighted a sudden shift in functional structure between 1998 and 2004. The phytoplankton community was initially dominated by slow growing, autumnal blooming, mixotrophic organisms, and changed after the early 2000's, towards a dominance of earlier blooming and fast-growing microalgae. Sea warming and decreasing dissolved phosphorus concentrations were linked to this rapid reorganization of the functional structure. The inherent traits of the current functional structure make them more competitive in response to warming and de-eutrophication contexts. Early blooming lead to an earlier senescence and energy sinking, depleting nutrients for late bloomers, while organisms displaying high growth rate are more competitive due to higher plasticity and better nutrient uptake, which is advantageous in the current de-eutrophication context of the southern North Sea. We then identified the potential top-down and bottom-up consequences of this functional change, through the depletion of dissolved nutrient and through a food quality-driven negative influence on copepod abundances. Overall, our study highlights that, by altering phytoplankton functional composition, global and regional changes have profound long-term impacts on coastal ecosystems.

Oral presentation

LONG-TERM SHIFTS IN TAXONOMIC AND FUNCTIONAL BIODIVERSITY OF THE MESO-/MACROZOOPLANKTON COMMUNITY IN THE SOUTHERN NORTH SEA, MEDIATED BY ENVIRONMENTAL AND ANTHROPOGENIC CHANGES

Marques, R., Otto, S. A., Di Pane, J., Boersma, M., Kröncke, I., Meunier, C., Möllmann, C., Neumann, H., Wiltshire, K. H., Renz, J.

The North Sea is changing rapidly, driven by modifications in human activities and impacts of climate change. Decreasing fishing intensity (top-down control), reduction of nutrient loads from local river discharges (bottom-up control) and rising water temperatures act in synergy, directly or indirectly, resulting in modifications to the structure of marine communities. Zooplankton plays a critical role in the function of marine food webs, but their response to these changes has only been partially assessed, ignoring the importance of large zooplankton taxa. Here we used a 43-year time series of meso- and macrozooplankton community ($> 500 \mu\text{m}$, including decapod larvae, gelatinous zooplankton, among others), monitored at Helgoland Roads, to describe their long-term changes in taxonomic and functional biodiversity. We used taxonomic and functional diversity indices combined with taxa- and trait-based multivariate analysis to describe the temporal variability in biodiversity and community structure, identify biological shifts and uncover the main drivers of such variability. These complementary analyses not only allow to simplify the complex changes in community composition but also to understand the potential consequences for ecosystem processes. The results highlight a community shift in the early 2000s, the importance of decapod larvae in driving the observed changes in community structure and the influence of top-down pressures. This might have important implications in the function of pelagic food webs due to decapods top-down control, but it can also affect the benthic-pelagic coupling of meroplankton taxa, regulating the recruitment and composition of adult benthic communities, with possible significant ecological and socioeconomic effects.

Oral presentation

POLLUTION IN THE ARCTIC OCEAN: AN OVERVIEW OF MULTIPLE PRESSURES AND IMPLICATIONS FOR ECOSYSTEM SERVICES

Townhill, B. L., Reppas-Chrysovitsinos, E., Sühling, R., J. Halsall, C. J., Mengo, E., Sanders, T., Dähnke, K., Crabeck, O., Kaiser J., Birchenough, S. N. R.

The Arctic is undergoing unprecedented change. Observations and models demonstrate significant perturbations to the physical and biological systems. Arctic species and ecosystems, particularly in the marine environment, are subject to a wide range of pressures from human activities, including exposure to a complex mixture of pollutants, climate change and fishing activity. These pressures affect the ecosystem services that the Arctic provides. Current international policies are attempting to support sustainable exploitation of Arctic resources with a view to balancing human wellbeing and environmental protection. However, assessments of the potential combined impacts of human activities are limited by data, particularly related to pollutants, a limited understanding of physical and biological processes, and single policies that are limited to ecosystem-level actions. This manuscript considers how, when combined, a suite of existing tools can be used to assess the impacts of pollutants in combination with other anthropogenic pressures on Arctic ecosystems, and on the services that these ecosystems provide. Recommendations are made for the advancement of targeted Arctic research to inform environmental practices and regulatory decisions.

Oral presentation

RESILIENCE FOR WHOM AND ACCORDING TO WHAT CRITERIA? AN EXAMINATION OF ADAPTATION TO CHANGES IN THE BAY OF BISCAY ANCHOVY FISHERY

Beckensteiner, J., Charles A., Villasante, S., Le Grand, C., Thébaud, O.

This research investigates how fishing communities, on the one hand, and fishery management institutions, on the other, have responded and adapted to large-scale changes. It is assumed that adaptation processes of fishers and governance occur at different temporal scales. Specifically, it is expected that these temporal divergences in responses could limit fishers' adaptation to changes or generate "maladaptation" from an ecosystem-based perspective. The case study presented here is the socio-ecological system of the anchovy fishery from the Bay of Biscay, which has undergone important transformations in the last two decades. The closure of the fishery from 2005 to 2010 might have led to negative repercussions on the system: displacement of fishing effort increasing pressure on other species and loss of market for the French professionals. While the anchovy stock has recovered, the fishery socio-ecological system has not returned to its pre-collapse status.

Through a multidisciplinary approach combining quantitative methods (time series analyses of fisheries data) and qualitative methods (interviews with key stakeholders), we are 1) comparing adaptive responses between fishing communities and fisheries management, 2) examining potential opportunities or barriers to adaptation in France and in Spain, and 3) identifying governance mechanisms that support adaptation towards more resilient and sustainable fishery systems. This retrospective analysis can serve as a framework basis for a more comprehensive assessment and understanding of the long-term responses at the sectoral, coastal community and institutional levels of other fisheries systems that have faced shocks (e.g., cod fishery in Nova Scotia).

Oral presentation

SHIFTING STOCKS AND THE CONSEQUENCES OF NON-ADAPTIVE TRANSBOUNDARY FISHERIES AGREEMENTS

Liu, X., Costello, C., Heino, M., Ojea, E.

We ask whether transboundary agreements, designed without climate change in mind, will likely be sustained in the face of climate-induced range shifts. The answer hinges on the incentives of the participating countries. We develop a dynamic game model in which a non-adaptive, cooperative agreement is formed under the assumption of no climate-induced shifts. We then use that model to evaluate countries' incentives to sustain that agreement as climate-induced shifts start to materialize. When range shifts are very slow, there is little change to the status quo, and we find that transboundary agreements are likely to be sustained. But as the pace of range shifts quickens, we find that the country whose waters are being exited by the stock has strong incentives to break the transboundary agreement; this "defection" can cause significant overfishing and loss of aggregate value of the fishery. When range shifts are very rapid, the stock-losing country may defect, but it is of little consequence because the stock-gaining country can efficiently manage the resource. We applied the game theoretical model to 126 transboundary marine species that are projected to shift under the RCP 8.5 emissions scenario. We find that most species (60%) have anticipated range shifts that are sufficiently slow such that agreements are likely to persist, so bio-economic losses are limited to less than 10%. These results suggest that current transboundary agreements may actually hold up to climate-induced shifts in species ranges.

Oral presentation

INFLUENCE OF THE SOCIAL REPRESENTATIONS ON ACTORS' ADAPTATION STRATEGIES OF THE REDFISH (SEBASTES SPP.) FISHERY IN THE FACE OF SOCIAL ECOLOGICAL CHANGES IN THE GULF OF ST. LAWRENCE (CANADA)

Quillet, E., Plante, S., Pigeon, L. E.

For the last decade, the fishing sector in Quebec (Canada) has undergone many transformations, and the case of redfish is certainly the most striking example. In 1995, following a resource depletion, the redfish fishery was closed in the Gulf of St. Lawrence. Between 2011 and 2013, three years of unprecedented recruitment allowed the stock to be rebuilt. In 2019, redfish represented 90% of the biomass of all groundfish in the Gulf. As these changes in the ecosystem occurred, management principles and fishing practices had been transformed, integrating notions of sustainable development (ecosystem, precaution, and responsibility approaches). Presently, the reopening of this fishery is being considered by the actors, but they must develop adaptation strategies to integrate these changes into their practices, and not reproduce past mistakes. In this context, our research focuses on the social representations of fishing, redfish and its ecosystem, as built by the stakeholders, in order to understand how it influences their adaptation practices. A social representation is a collective construction of an object, based on shared knowledge, experiences, and beliefs, which determines a social group's behavior. To do this, we conducted 34 semi-structured interviews, with managers, fishermen and fish factories owners of Gaspésie and Magdalen Islands, between January 2018 to February 2020. Our research highlights the issues of social and environmental justice linked to the distribution of fishery resources, the lack of intrinsic value assigned to the redfish, and the difficulties for actors to get in a transformative process of the social ecological system.

Oral presentation

INSERTING VALUES IN ECOSYSTEM-BASED FISHERIES MANAGEMENT

Lam, M. E., Perryman, H. P., Surma, S., Pitcher, T. J.

To overcome the societal challenges of implementing ecosystem-based fisheries management, we explored diverse value-based scenarios for the Norwegian spring-spawning herring fishery. We conducted dynamic ecosystem simulations with management strategy evaluation (MSE) to evaluate the trade-offs in performance amongst candidate fisheries management strategies, while considering the impacts of uncertainties and errors. We ran MSE simulations with two updated ecosystem models for the Norwegian and Barents Seas: Atlantis 'NoBa' and Ecopath with Ecosim (EwE) 'NorBar'. Atlantis is a biogeochemical-based, end-to-end model that simulates physical, chemical, and biological oceanography, as well as ecology while EwE is a whole-ecosystem, mass-balanced model that tracks energy flows among functional groups that can span all trophic levels. We simulated six alternative value- and ecosystem-based management scenarios for Norwegian spring-spawning (NSS) herring that prioritized different stakeholders' and citizens' values (in parentheses): 1. no herring fishing (conservation); 2. fishing herring for human consumption only (food security); 3. Lenfest Forage Fish Task Force recommendations (ecosystem services); 4. adopted ICES harvest-control rule (HCR) (political compromise); 5. industry-proposed HCR (socio-economic stability); and 6. fishing herring to collapse (short-term profit maximization). We explored the societal implications of these scenarios alongside the fate of commercially important fish species, such as herring and cod, and the ecosystem trophodynamics. Using multi-model inference, we compared the MSE-scenario model outputs to give a robust value- and ecosystem-based integrated assessment of the societal and ecological impacts and risks, and consequent policy trade-offs, of conflicting uses and potential regime shifts of marine resources in the Norwegian and Barents Seas.

Oral presentation

COMBINING SOCIAL AND ECOLOGICAL TIME SERIES TO DESCRIBE LONG-TERM DYNAMICS OF THE NORWEGIAN SEA ECOREGION.

Buttay, L., Solvang, H., Planque, B.

One challenge for Integrated ecosystem assessments (IEAs) is to synthesise historical changes that have occurred in multiple components of the social-ecological system, from climate to ecosystem and humans. Statistical methods, able to cope with the nature of the data IEAs are based on (e.g. many time-series, few observations, non-stationarity) are therefore required. In the present work, we employ the TRend Estimation and Classification (TREC) method to reveal common trends among time-series in order to describe the main changes that have occurred in the Norwegian Sea ecoregion during the last decades. Up until now, the IEA for the Norwegian Sea has primarily focused on the physical and ecological dimensions of the ecosystem. In the present work, we combine these with time-series that describe the most important sectors and activities in the ecoregion (fishing, oil and gas production, shipping, aquaculture and research) and some related pressures (species extractions, bycatch, contaminants, noise, etc). In addition to trends determination and classification we used an extension of the TREC method to identify individual time-series that display extreme values in the most recent years and should warrant special attention. Our results provide the first integrated description of changes in the Norwegian Sea from physics to humans and highlight the potential of the TREC method to be used in IEAs to properly synthesize the information in many different time series and provide warning for recent extremes events.

Oral presentation

RECONSTRUCTING TROPHIC INTERACTIONS IN THE NORWEGIAN SEA PELAGIC FOOD-WEB OVER MULTIPLE DECADES.

Planque, B., Favreau, A., Husson, B., Mousing, E. A., Hansen, C., Broms, C., Lindstrøm, U., Sivel, E.

Animal biomass in the Norwegian Sea pelagic ecosystem have greatly varied over the past decades. These variations are associated with important changes in trophic interactions. It is generally difficult to quantify changes in trophic interactions through the entire food-web because trophic flows are difficult to observe in nature and usually available for few species only. Inverse food-web modelling offers a way to combine information on biomass and flows to reconstruct the multidecadal dynamics of the pelagic food-web. In addition, model outputs can be used to investigate trophic controls, such as top-down and bottom-up regulations. In this study, we use a minimalistic food-web model to reconstruct the Norwegian Sea food-web dynamics over the last 3.5 decades and to explore possible drivers of changes in pelagic fish and invertebrate biomasses. The model is based on the principles of Chance and Necessity (CaN). It is primarily data-driven and relies on a minimal set of assumptions. We show that it is possible to quantify past variations in trophic flows in a way that is fully compliant with existing observational time-series. Our results support the hypothesis of bottom-up control of small pelagic fish but show no clear indication of top-down control on copepods and krill. The case of amphipods is more complex, with population growth being alternatively limited by high predation or low resource availability.

Oral presentation

FISH COMMUNITIES OF SUBARCTIC FJORDS SHOW EARLY SIGNALS FACING CLIMATE CHANGE COMPARED TO BENTHIC COMMUNITIES: THE EXAMPLE OF THE PORSANGERFJORD, NORWAY.

Merillet, L., Skogen, M. D., Vikebø, F., Jørgensen, L. L

Arctic benthic ecosystems appear very vulnerable to climate change due to the high speed of environmental changes they undergo (decreased sea ice coverage, increased temperature and precipitations). Subarctic fjords are located at a latitude where warm-water boreal taxa dominate offshore. Their inner-most parts are often forming basins in which water remains very cold and may thus offer a refuge for cold-water arctic species. In addition to climate change, those fjords also faced king crabs *Paralithodes camtschaticus* invasion since the end of the 1990s. The Porsangerfjord in Northern Norway offers a case study of the dynamics of biodiversity of subarctic fjords facing multiple stressors, i.e. climate change and invasive species. Based on a time series of megabenthic invertebrates and benthic-demersal fishes over 2007-2019, a complex multivariate analysis (STATICO) was used to identify the trends in the relationship between taxa and the environment. A strong along-fjord gradient was visible for both benthic and fish communities. Species richness and Shannon diversity of fishes significantly increased, due to the arrival of warm-water species. Conversely to what can be expected, no significant decrease in the biomass of the cold-water benthic species was visible, which could indicate an efficient refuge effect of the fjord. In the inner fjord, there was a change in species dominance as king crabs become a dominant species. These changes had social repercussions on the local fisheries, from targeting cold-water fish (halibut, plaice, capelin and herring) to king crabs and shrimps.

Oral presentation

STOCHASTIC MODELLING OF FISH RECRUITMENT PRODUCTIVITY IN THE CELTIC SEAS ECOREGION

Silvar-Viladomiu, P., Minto, C., Lordan, C., Brophy, D., Bell, R., Collie, J., David G. Reid, D. G.

The Northwest European continental shelf is a large ecosystem undergoing major changes, which influence fish productivity. Productivity of many stocks have shown evidence of change over decadal timescales. Varying factors might drive these dynamics in the Celtic Seas, but for many stocks these have not been fully understood nor identified. We study dynamic productivity for 29 stocks in the Celtic Seas by tracking integrated stochastic signals in the relationship between stock size and recruitment using state-space modelling. Our research objectives comprise: (i) comparing survey-derived versus assessment-derived signals; (ii) determining how the structural form of the modelled relationship influences inference; (iii) identifying common trends and factors explaining stochastic variability; and (iv) evaluating how well can we predict future change over varying time horizons. Preliminary results suggest the trends are consistent across structural forms. Our results on non-stationary productivity relationships can contribute to improved management advice for Celtic Seas stocks.

Oral presentation

EMERGENCE OF CLIMATE CHANGE EFFECTS ON NORTHEAST U.S. FISH POPULATIONS AND COMMUNITIES

Mills, K. E., Kerr, L. A., Nye, J. A.

Ocean waters of the Northeast U.S. continental shelf have warmed rapidly in recent years, and the region is also experiencing an increase in the frequency of marine heatwaves and shifts in the seasonal cycle of warming and cooling. The substantial changes in temperature trends, events, and cycles have directly and indirectly affected fish populations, fish community characteristics, and fisheries in the region. As the effects of ocean temperature changes have emerged in the past decade, they have been associated with changes in spatial distribution, population productivity, growth rates, body size, and phenology of life history events across marine and diadromous fish species. These population-level changes subsequently affect community characteristics such as composition, size spectrum, and predator-prey interactions. Moreover, they have implications for fisheries in the region, including for harvesters, supply chain actors, and management processes. This presentation will focus on describing the nature of warming impacts on Northeast U.S. fish populations, with syntheses and examples based on observations to date, and it will briefly summarize changes at the scales of fish communities and fisheries. Past observations provide an understanding of relationships between climate-driven physical changes and fish population and community responses, which can be coupled with climate model outputs to project changes in fish and fisheries in the future.

Oral presentation

DECADAL VARIABILITY IN THE AMERICAN LOBSTER FISHERY ACROSS THE NORTHWEST ATLANTIC

Le Bris, A.

Disentangling the effects of climate change, climate variability, and fishing on marine fish and shellfish populations requires long-term time series across wide spatial range. Thanks to a population boom in the last 20 years, the American lobster (*Homarus americanus*) has become the most economically valuable fishery in the Northwest Atlantic, and many coastal communities now rely on this unique species for their livelihood. Climate induced changes in regional physical and biological oceanography, local management measures and the removal of predator fishes have been proposed as explanations for the boom in lobster abundance. However, the overall increase in lobster abundance belies different trajectories across the species range, highlighting the need for broad spatial and temporal scales study to better understand mechanisms driving contrasting trends. In this study, I provide a new overview of trends in the American lobster fishery across the Northwest Atlantic over the last 70 years and explore potential large scales effects and regional drivers of the trends in the fishery. Despite significant differences in regional oceanography and management across the species range, similar ~20-year cycles were observed pre-2000's suggesting that large-scale climate effects were driving past population trends. However, in the last 20 years a decoupling has been observed between climate cycles in the North Atlantic and lobster fishery trends suggesting that other mechanisms are now driving abundance and fishery trends.

Oral presentation

DISTRIBUTION AND CONDITION OF HADDOCK FOLLOWING POPULATION EXPANSION

Jónsdóttir, I. G., Björnsson, B., Ragnarsson, S. A., Elvarsson, B. Þ., Sólmundsson, J.

Haddock (*Melanogrammus aeglefinus*), a demersal gadoid fish species, is a commercially important groundfish species that has long supported important fisheries throughout the North Atlantic. For decades, haddock has been found in greatest abundance along the south and southwest coast of Iceland, but its distribution ranges all around Iceland. Here we describe changes in geographical distribution of Icelandic haddock based on annual fish stock survey data for 36-year period 1985 – 2020. A substantial shift in the distribution of haddock occurred during this period. In 1985 – 2005, higher abundance of haddock was found south of Iceland. Several large year classes appeared during favourable conditions around 2000, including the exceptionally large 2003-year class, which was transported as juveniles from the main spawning grounds in the southwest, to north of Iceland via strong inflow of Atlantic water. After 2005, the distribution of biomass shifted towards the north. Even though haddock biomass remained higher in the north compared with before, these distributional changes were temporary as bulk of the haddock population has been found off south Iceland since 2018. Sea water temperature and food availability seem to be quite important shaping the distribution of haddock.

Oral presentation

TEMPORAL TRENDS IN DEMERSAL FISH AND INVERTEBRATE ABUNDANCES ON THE SCOTIAN SLOPE DURING 1999-2019

Vad, J., Puerta P., Kenchington T., Head E., Kenchington E.

Understanding the impacts of environmental change on demersal fish populations is key to predicting the effects of climate change on commercial fish stocks. We assessed temporal trends in demersal fish and invertebrate (32 taxa) abundance data from annual science-directed surveys conducted on the eastern Scotian Slope (off Nova Scotia, Canada) during 1982–2019 at depths of 100–730 m. Trajectory analysis, multivariate regression trees and dynamic factor analysis revealed two periods of significant change in taxon abundances. First, a sharp increase in one third of the taxa was identified between 1996 and 2000. Second, there was a decrease in the abundances of eight fish species after 2012, while a few taxa, including the squid *Illex illecebrosus*, displayed strong increases in biomass towards the end of the time series. The study area currently sees only limited fishing but did experience intense trawling before 1993. It is also subject, at continental-slope depths, to complex and temporally variable interactions between warmer water masses, of southern origin, and colder Labrador Sea Water. To further investigate their possible effects on the observed trends in the fish, outputs from oceanographic models and field data are currently being analysed. This work is part of the Horizon 2020 project iAtlantic, which aims at assessing the status of deep-sea and open-ocean ecosystems across the Atlantic Ocean.

Oral presentation

DISENTANGLING THE EFFECTS OF FISHING AND CLIMATE IN BENTHO-DEMERSAL COMMUNITIES BY ASSESSING THEIR VULNERABILITY

Polo, J., Pecuchet, L., Hidalgo, M., Primicerio, R., Sainz-Bariain, M., Punzón, A., López-López, L.

Many studies have focused on vulnerability of marine communities to either fishing or climate change, but few studied how the spatial heterogeneity of both impacts combined affects the ecosystem's global vulnerability. We aimed to comparatively determine the main patterns of variation of vulnerability across geographic gradients, accounting for the combined impacts of decadal sea warming with fishing pressure on the Atlantic and Mediterranean benthic-demersal communities, complex systems known to be prone to abrupt reorganizations.

Building on trait-based climate change vulnerability assessments and indexes of sensitivity to trawling, we studied the spatio-temporal variation of species sensitivity to both stressors in two impacted marine ecosystems in the North and South-East Iberian Peninsula, for the time periods 1983-2020 and 1994-2020, respectively. Based on literature, we identified species life-history traits and ecological properties expected to condition species responses to climate change and fishing. We classified the species according to their sensitivity to combined anthropogenic impacts and by extrapolating this classification to community level, we approached the benthic-demersal community's vulnerability.

The variation in the vulnerability indicators showed two contrasting pathways of community performance between Atlantic and Mediterranean ecosystems. Atlantic community recovered from a long history of overfishing while the Mediterranean shows spatial diversity in its response. Both areas appear to respond discontinuously to the combined effects of warming and fishing. This kind of integrative analyses of vulnerability indicators may provide a solid characterization of the mechanisms of recovery against perturbations under different ecological contexts.

Oral presentation

EVIDENCE OF AN ECOLOGICAL REGIME SHIFT IN THE NORTH-EAST ATLANTIC REVEALED FROM THE UNPRECEDENTED REDUCTION IN MARINE GROWTH OF ATLANTIC SALMON

Vollset, K.W., Urdal, K., Kjell Utne, K., Thorstad, E. B., Sægrov, H., Raunsgard, A., Skagseth, Ø., Lennox, R. J., Østborg, G. M., Ugedal, O., Jensen, A. J., Bolstad, G. H., Fiske, P.

Ecological regime shifts are abrupt changes in the structure and function of ecosystems that persist over time. We present growth data from >68 000 individual wild Atlantic salmon across 188 populations showing that growth of salmon across the North-east Atlantic abruptly decreased around 2005 in populations from rivers draining into the Norwegian Sea and has not rebounded.. This occurred at the same time as a decrease in the proportion of early maturing salmon returning after only one year at sea. This sudden growth decline occurred after a marked decrease in the extent of Arctic Water in the Norwegian Sea, a subsequent warming in temperature prior to salmon entering the sea, and a approximately 50% reduction in zooplankton across large geographic areas of the Northeast Atlantic Ocean. In support of the ecosystem-scale regime shift hypothesis, a sudden decrease in growth was also observed among mackerel inhabiting these marine areas. We suggest that this is driven by a climate-driven ecological regime shift in the Northeast Atlantic Ocean, which may explain other ecological phenomena occurring simultaneously during this time period.

Oral presentation

LOCATION OF THE ARCTIC FRONT EAST OF ICELAND DURING SUMMER IMPACTS MACKEREL MIGRATION INTO ICELANDIC WATERS.

Olafsdottir, A. H., Guðnason, K., da Silva, T., Pétursdóttir, H., Ólafsdóttir, S.

In summer 2020, Northeast-Atlantic mackerel abundance and distribution range in Icelandic waters declined greatly compared to previous decade. Results from the International ecosystem summer survey in Nordic Seas indicates that during the decade 2010-2019 approximately 17-37% of stock biomass fed in Icelandic waters compared to 4% in 2020. Declining biomass coincided with retraction of geographical distribution. Distribution was limited to southeast coast of Iceland in 2020 compared to earlier years when mackerel occupied warm Atlantic waters along the east, south and west coast. Mackerel migrate into Icelandic waters in June either from the Norwegian Sea towards the east coast or from the British Isles towards the southeast coast. The migration route towards the east coast is a frontal area between cold Arctic waters and warm Atlantic waters. Mackerel usually occupies temperatures $> 8^{\circ}\text{C}$. Preliminary results of daily temperature in the surface mixed layer, from May 1 to September 30st, for period 2010-2020 indicate 2020 was unusually cold as temperature became $> 8^{\circ}\text{C}$ in middle of August compared to middle of June during other years. Temperature south and west of Iceland were similar in 2020 compared to previous decade. Prey abundance in 2020 was similar to other years. Our results suggest waters too cold for mackerel presence ($< 8^{\circ}\text{C}$) dominated the area east of Iceland from May to middle of August 2020 disrupting mackerel from migrating westward to the south and west coast where waters were warmer ($> 8^{\circ}\text{C}$) and prey abundant.

Oral presentation

TEMPORAL EVOLUTION OF CRITICAL TRAITS, TROPHIC INTERACTIONS AND THEIR RELATIONSHIP TO COD STOCK COLLAPSE AND RECOVERY

Frank, K.T., Petrie, B., Leggett, W. C.

We examine the evolution of the Flemish Cap (NAFO Division 3M) cod (*Gadus morhua*) stock from a spawning biomass of ~30,000 t in the late 1980s, to ~2,000 t during the late 1990s – early 2000s, and recovering to recent (2016-2020) levels of ~50,000 t. Over these stages of pre-collapse, collapse and recovery, the stock decomposed into two distinct states whose temporal progression was defined by four traits: spawning biomass, maturity- and weight-at-age, and recruitment; all were significantly different between the two states. The time scale of transition between states was distinct, occurring over 2-3 years. The evolution of these demographic traits was consistent with a density dependent model suggesting phenotypic plasticity during the rebuilding of the stock. Ocean climate, characterized by bottom temperature, was a key component accounting for age-at-maturity. The broader fish community characterized by 11 species/groups on Flemish Cap can also be decomposed into 2 states; within them, cod is the leading species with a negative (positive) relationship with 8 (2) species/groups. The temporal progression of the community parallels that of the states defined by cod traits. The same demographic variables emerge for the adjacent Northern Cod (NAFO Division 2J3KL) stock which underwent a similar pattern of decline, collapse, but only partial recovery. This partial recovery deviated from expectations based on a density dependent model. Management action in the form of moratoria on directed cod fishing were enacted in both regions We briefly comment on the dichotomous responses of the two stocks from an ecosystem-based management perspective.

Oral presentation

ATLANTIC MACKEREL (SCOMBER SCOMBRUS) MIGRATES FARTHER NORTH TO SPAWN UNDER THE CURRENT WARM CLIMATE SCENARIO

dos Santos Schmidt, T.C., Slotte, A., Olafsdottir, A. H., Nøttestad, L., Jansen, T., Jacobsen, J. A., Homrum, E. Í., Eliassen, S. K., Smith, L., Bjarnason, S., Lusseau, S. M., Ono, K., Hølleland, S., Thorsen, A., Kjesbu, O. S.

Following a warmer ocean and a succession of large year classes after 2000, the stock size of Northeast Atlantic mackerel reached historically high levels after 2010. Simultaneously, the spawning area expanded northwards to a yet unknown degree. Hence, we scrutinized whether mackerel had de facto extended the spawning activity into the main feeding area in the Nordic Seas north of 60°N. We consulted an extensive amount of biological data on individual mackerel (N=16400) that for other purposes were collected from various surveys in the area during the late part of the spawning season; May-July 2004-2021. Spawning mackerel were regularly observed in the southern part of the Norwegian Sea in May-June from 2009 onwards. We noticed a general increase in the proportion of mature and spawning/partly spent fish in May-July along the time-series. Additionally, a clear shift happened in July from 2012 onwards, with low proportions of spawning/partly spent fish over large areas north to 75°N. The mean age was found to not vary across the maturity stages, although it has increased from 4 to ~7 years old over the study period in all months. Our macroscopic-based results were complemented with an in-depth histological examination demonstrating that over 90% of the females in May-2018 were spawning capable, compared to ~10% in June and July-2018. Approximately 38% of the mackerel analyzed by histology in July-2018 terminated their spawning by absorbing oocytes through atresia. We conclude that the spawning area of this stock has significantly expanded northwards in the last two decades.

Oral presentation

NORTHEAST-ATLANTIC SALMON POST-SMOLT – GEOGRAPHIC VARIATION IN MARINE FEEDING AND THE EFFECT A CHANGING ECOSYSTEM

Utne, K. R., Skagseth, Ø., Thorstad, E., Wennevik, V.

During the last decades, many wild Atlantic salmon populations have declined dramatically. One hypothesis for an observed reduction in salmon marine growth and survival is reduced abundance of prey at sea. However, how temporal and spatial variation in marine prey abundance affects post-smolt feeding conditions has not previously been identified. Here we use stomach content data from 2571 salmon post-smolts sampled during 25 years in the Northeast Atlantic to examine spatial and temporal changes in diet and stomach fullness. There was a reduction of fish larvae in the post-smolt stomachs over a large geographic area when comparing the period 1995-2004 to 2008-2019. This is probably a bottom up driven process, as reduced inflow of arctic water masses and an observed drop in zooplankton abundance in the Norwegian Sea are correlated to post-smolt stomach fullness in the area. Furthermore, the interspecific competition for fish larvae between post-smolts and mackerel may have increased with a larger mackerel stock expanding the feeding migrations northwards since 2007.

Oral presentation

STUDY OF WAVE TRENDS ALONG THE GALICIAN COAST AND EVALUATION OF THEIR POTENTIAL IMPACT ON THE QUALITY OF THE STALKED BARNACLE, *POLLICIPES POLLICIPES*

Peñas-Torramilans, R., Castelle, B., Outeiral, R., Santiago, T., Seoane, P., Vázquez, E., Weidberg, N.

Due to climate change, several studies show increased maximum wave height and period over the last decades along the Atlantic coast of Europe, which is linked to large-scale climate patterns of atmospheric variability in the north Atlantic. Changes in wave height, wave period and surf zone orbital currents are hypothesized to drive marked shifts in the shape of intertidal organisms such as the stalked barnacle *Pollicipes pollicipes*, whose quality and market price is known to decrease with the relative length of its peduncle. This study evaluates wave activity trends in Galicia, NW Iberian Peninsula, using the Spanish Port System 1958-2020 SIMAR wave hindcast, and trends in stalked barnacle morphology and quality is estimated from the management regions of A Coruña, Baiona and A Guarda between 2011 and 2020. Results show positive trends in all wave variables, as well as in both NAO and WEPA indices which explain part of the variability in the maximum wave height and wave period. For stalked barnacles, 28 significant morphological trends towards more elongated and low quality individuals were observed at different sites and intertidal levels. In addition, the coupling between shifts in wave-driven orbital currents and stalked barnacle morphology was also studied, finding very significant reductions in quality with decreasing eastward orbital currents that explain up to 90% of the variability in the relative length of the peduncle. In conclusion, changes in stalked barnacle morphology depend on shifts in wave climate modulated by topographic variables, such as the intertidal level and shore orientation.

Oral presentation

GET UP EARLY: REVEALING BEHAVIOURAL RESPONSES OF SANDEEL TO OCEAN WARMING USING COMMERCIAL CATCH DATA

Henriksen, O., Rindorf, A., Mosegaard, H., Payne, M. R., van Deurs, M.

1. Warming of the oceans and shifts in the timing of annual key-events are likely to cause behavioural changes in species showing a high degree of site-fidelity. While this is well-studied in terrestrial systems, there are fewer examples from the marine environment. Sandeel (*Ammodytes marinus*) is a small eel-shaped teleost fish with strong behavioural attachment to sandy habitats in which they are buried from late summer through winter. When spring arrives, the sandeel emerge to feed during the day for several of months before returning to the sand for overwintering refuge.
2. Using fisheries data from the North Sea, we investigated whether catch rates reflect the timing of emergence and if seasonal patterns are related to temperature and primary production.
3. Catch per unit effort (CPUE) was used to describe sandeel emergence. We developed indicators of the relative timing of the emergence from the winter sand refuge and the subsequent growth period. Different modelling approaches were used to investigate the relationship with bottom temperature and primary production.
4. Variation in emergence behaviour was correlated with variation in sea bottom temperature. Warmer years were characterized by earlier emergence. Significant warming over the last three decades was evident in all sandeel habitats in the North Sea throughout most of their adult life history, although no net shift in the phenology of emergence was detected. Minimum temperature during spring was a better predictor of emergence behaviour than for example degree-days.

Oral presentation

A SUMMARY OF ECOSYSTEM STATUS AND TRENDS FOR THE NORWEGIAN SEA

Ólafsdóttir, A., Arneberg, P., Planque, B., Anker-Nilsen, T., Bjarnason, S., Broms, C., Børsheim, K. Y., Eliassen, S., Frie, A. K., Hallfreðsson, E., Hansen, C., Homrum, E. Í., Høines, Å., Libungan, L., Liu, X., Lorentsen, S. H., van der Meeren, G., Mell

The Working Group on the Integrated Assessments of the Norwegian Sea (WGINOR) has for many years performed annual assessment of the state of the ecosystem. To facilitate dissemination of the assessment results, the group developed a template to deliver a short and easy-access ecosystem status summary of the assessment. The summary, is no longer than 10 pages, includes "highlight" statements, a graphical summary table, and short chapters for six major ecosystem components, which are ocean climate, primary producers, zooplankton, pelagic fish, seabirds and marine mammals. For each ecosystem component, the summary describes the overall trend for the last few decades, the situation in the current year, the possible causes for the observed changes, the certainty of the assessment and the possible implications of changes for the ecosystem as a whole. This summary was prepared for the first time in 2021. It can be disseminated widely to stakeholders, managers, the press, and the public. The template is generic and could serve as a model for developing similar ecosystem status summaries for other ecosystems in the North Atlantic and worldwide.

Poster presentation

BARENTS SEA PLANKTON PRODUCTION AND CONTROLLING FACTORS IN A FLUCTUATING CLIMATE

Sandøy, A. B., Mousing, E. A., Budgell, W. P., Hjøllo, S. S., Skogen, M. D., Ådlandsvik, B.

The Barents Sea and its marine ecosystem is exposed to many different processes related to the seasonal light variability, formation and melting of sea-ice, wind-induced mixing, and exchange of heat and nutrients with neighbouring ocean regions. A global model for the RCP4.5 scenario was downscaled, evaluated, and combined with a biophysical model to study how future variability and trends in temperature, sea-ice concentration, light, and wind-induced mixing potentially affect the lower trophic levels in the Barents Sea marine ecosystem. During the integration period (2010–2070), only a modest change in climate variables and biological production was found, compared to the inter-annual and decadal variability. The most prominent change was projected for the mid-2040s with a sudden decrease in biological production, largely controlled by covarying changes in heat inflow, wind, and sea-ice extent. The northernmost parts exhibited increased access to light during the productive season due to decreased sea-ice extent, leading to increased primary and secondary production in periods of low sea-ice concentrations. In the southern parts, variable access to nutrients as a function of wind-induced mixing and mixed layer depth were found to be the most dominating factors controlling variability in primary and secondary production.

Poster presentation

HOW BIOMASS DIEL MIGRATION AFFECTS THE RELIABILITY OF CURRENTS MEASUREMENTS IN THE STRAIT OF GIBRALTAR?

Sammartino, S., García-Lafuente, J., Nadal-Arizo, I., Sánchez-Leal, R.

Since 2004, high resolution profiles of the 3D velocity of the water column have been collected at the westernmost sill of the Strait of Gibraltar (Espartel Sill), with the aim of monitoring the Mediterranean water outflow and evaluate its short and long term variability. A 75 kHz up-looking Acoustic Doppler Profiler (ADP) and, more recently, another 500 kHz model installed in down-looking mode, have been embedded in a subsurface buoy, deployed ~20m above the seafloor at a depth of approximately 360m. The averaged profile of the observed along-strait current uses to show local minima ~50m above seafloor, which has been interpreted as the diurnal-semidiurnal interaction of tidal currents (Sammartino et al., 2015). The prevailing semidiurnal tide drives periodic accelerations of the westward Mediterranean current flowing at the bottom, whereas diurnal constituents slow them down, giving rise to a local minimum in amplitude, and prompting severe drops in measurements accuracy. In year 2019, the main ADP was replaced by a 100 kHz model sporting an additional vertical beam that collects high resolution echograms of the water column. This new information reveals the key role of scatterers concentration, which undergoes diel migrations, and affects the reliability of the velocity observations which rely on the amplitude of scattered echo recorded by the instruments. Actually, echo amplitude reaches average correlations of 0.7 with measurement uncertainties. In light of these new insights, an accurate update of the Mediterranean outflow calculations is performed and new values of trend and long-term variability, are estimated.

Poster presentation

INCREASED WARMING TREND OF THE MEDITERRANEAN OUTFLOW INTO THE NORTH ATLANTIC OCEAN

García-Lafuente, J., Sammartino, S., Sánchez-Leal, R., Nadal-Arizo, I., Naranjo, C.

Thermohaline properties of near-bottom (about 15m above seafloor) Mediterranean waters that form part of the Mediterranean outflow (MOW) have been monitored since 2004 at the Espartel Sill in the Strait of Gibraltar, the westernmost gate before the MOW spreads in the Gulf of Cadiz and the Atlantic Ocean (Sammartino et al. 2015; doi:10.1002/2014JC010674). Monitored near-bottom water shows a surprising warming trend of $0.339 \pm 0.008^{\circ}\text{C decade}^{-1}$ from 2013 onwards, which is one order of magnitude greater than the usual deep waters trends reported in the Mediterranean (García-Lafuente et al. 2021; doi:10.3389/fmars.2021.613444). The origin of such trend might be the concomitant warming of deep waters unnoticed so far, which is not likely taking into account the observational effort being carried out in the basin, or the progressive increase of the contribution of the warmer and saltier Levantine Intermediate Water (LIW) in the MOW at the expense of the colder and fresher Western Mediterranean Deep Water (WMDW) counterpart. ERA5 climatic reanalysis points at average negative buoyancy flux anomalies in the Mediterranean basin during the period 2013-to-present, which implies reduced WMDW formation rates in the convection areas. Increased volume of LIW in the outflow would compensate the WMDW deficit in the MOW, thus explaining the temperature trend. The warming, in turn, will produce a more buoyant MOW in the Gulf of Cadiz with consequences to be investigated in the future.

Poster presentation

THERMOHALINE AND TRANSPORT VARIABILITY IN THE GULF OF CADIZ IN THE 2010S

Sánchez-Leal, R. F., MJ. Bellanco. MJ., González-Pola, C., Sammartino, S., Garcia-Lafuente, J., Naranjo, C., Vargas-Yañez, M., Roque, D., Bruno, M.

Since July 2009 the Spanish Institute of Oceanography (IEO) manages the program Time Series of Oceanographic data in the Gulf of Cadiz (STOCA, in Spanish). STOCA maintains repeated observations along five across-shelf transects: three times a year from 2009 to 2012 and quarterly on hereafter. Additional observations are incorporated since 2013 within the frame of the Gulf of Cádiz Time-series Study (GoCaTS), to provide at least 6 occupations per year. STOCA/GoCaTS are part of the IEO Observing System (IEOOS, Tel et al., 2016). GoCaTS data are annually presented to the ICES Working Group on Oceanic Hydrography (ICES-WGOH) and contribute to the elaboration of the ICES Report on Ocean Climate (González-Pola et al., 2019).

In this work we used CTD and LADCP observations taken along the SP STOCA line from 2009–2021. These consisted of full-depth profiles acquired with a factory-calibrated Sea-Bird Electronics SBE 9+ probe and a RDI Workhorse Sentinel 300 kHz Lowered Acoustic Doppler Current Profiler mounted on a rosette frame. CTD and LADCP data were processed following the GO-SHIP guidelines (McTaggart et al., 2010).

Observations permitted to analyze the seasonal and longer-term thermohaline and transport variability regarding recent changes occurring in the Mediterranean and Atlantic basins. Variability appear to be related to the wind-driven seasonal alternation of vertical displacement of isopycnals and the seesaw between poleward-equatorward transports. Seasonal thermohaline changes of waters leaving the Mediterranean Sea are insufficient to explain the locally observed variations. Variability of Atlantic waters seem to dictate these differences.

Poster presentation

DECADAL TRENDS IN OCEAN ACIDIFICATION FROM THE OCEAN WEATHER STATION M IN THE NORWEGIAN SEA

Skjelvan, I., Lauvset, S., Johannessen, T., Gundersen, K., Skagseth, Ø.

The fixed station Ocean Weather Station M (OWSM) in the Norwegian Sea started in 1948 as one of 13 weather stations in the North Atlantic, with the aim of improved weather forecasts required by the increasing air traffic after the second world war. More than 7 decades later, one of the longest time series of deep-water hydrography exists from OWSM, and these data have evidenced warming of the deep water between 1985 and present. Here, we present 28 years of inorganic carbon measurements from OWSM, collected using both discrete samples covering the full water column and semi-continuous surface samples from a weather ship and a floating buoy. The carbon time series show that, over the years, the carbon content of Atlantic Water, Norwegian Sea Intermediate Water, and Norwegian Sea Deep Water have increased, and thus, ocean acidification has significantly influenced the Norwegian Sea water column from surface to bottom. Further, we will discuss the causes for the observed ocean acidification. The timeseries from OWSM contribute to our understanding of the area as a decreasing sink for atmospheric CO₂, and the results underpin the importance of long time series to be able to determine significant changes in the physical and biogeochemical system.

Poster presentation

ASYMMETRIC ATLANTIFICATION IN THE BARENTS SEA AND ITS EFFECT ON THE ECOSYSTEM

Assmann, K. M., Husson, B., Ingvaldsen, R. B., Fossheim, M., Primicerio, P.

The Barents Sea forms an important gateway and interface between the Atlantic Ocean regime and the Arctic Ocean. Here, Atlantic Water loses heat to the atmosphere and is freshened by and subducted under cold, fresh polar water as it encounters the sea ice edge. The Barents Sea has undergone large physical changes in recent decades differing from east to west. Part of the main circulation pathway, the eastern Barents Sea has experienced rapid Atlantification becoming ice-free in winter, warming, and losing stratification. The more isolated northwest the cold and fresh Arctic Water has also warmed and become more saline, but has retained the layer structure and stratification associated with the Arctic water column. The asymmetry in the response of the physical ocean is reflected in the ecosystem by the retention of a polar species assemblage in the northwest and the expansion of boreal fish species into the eastern Barents Sea. The underlying response of species may be heterogeneous. Some followed the retreating sea ice northeast, possibly carried by advection, e.g., zooplankton or fish larvae. More mobile species migrated towards the Arctic refugium of the northwest, potentially a migration dead end for species not adapted to the greater depths of the Arctic Basin. Joint Russian-Norwegian surveys of the Barents Sea have included a comprehensive ecosystem survey since 2004 allowing us to investigate changes in the system between recent and previous decades and to explore the heterogeneity in the ecosystem response to the asymmetric physical changes in more detail.

Poster presentation

ON THE PROLONGED SUMMER SPRING BLOOM PERIOD IN THE NORWEGIAN SEA DURING 2010-2019.

Wakamatsu, T., Raj, R.

In this study, we have analysed decadal change of the summer bloom (July-September) in the Norwegian Sea and investigated its connection with large-scale climate patterns. Principle component analysis of the mean sea level pressure anomaly over the high-latitude North Atlantic from 1999 to 2019 shows that phase relation between PC1 (NAO: the North-Atlantic Oscillation) and PC2 (SCAN: the Scandinavian Pattern) changes and variance of NAO has been increased after 2010. Composite analysis of the post and pre 2010 surface Chl-a concentration based on satellite data shows significant increase of primary productivity over the Lofoten Basin in August and September during the post 2010 decade, suggesting the length of the summer bloom has been prolonged significantly compared to the pre 2010 decade. After 2010, the long summer bloom condition occurs more frequently, and we found the condition is supported by stable atmospheric condition represented by lower 10m wind speed and weaker surface ocean heat loss due to latent and sensible heat flux. It is recently reported that the length of the spring bloom in the Norwegian Sea has been prolonged by about 20 days since 2010 compared to the previous decade. Our analysis suggests that the recent increase in the net primary production in the Norwegian Sea is contributed by both the prolonged spring and summer blooms.

Poster presentation

SEPARATING ANNUAL, DECADAL AND REGIONAL CHANGE IN SEA SURFACE TEMPERATURE IN THE NORTHEASTERN ATLANTIC AND NORDIC SEAS

Saes, M., Gjelstrup, C. V. B., Stedmon, C. A.

Sea surface temperature (SST) in the Northeastern North Atlantic and Nordic Seas exhibits pronounced variability across seasonal to decadal time scales. These changes can be expected to be driven by a combination of altered local conditions, shifts in seasonality and large scale regional oceanographic change. Separating the contribution from each of these offers insight into how the region is changing and also offers factors which each can be linked to or drivers of additional shifts in distribution and diversity of marine organisms, from phytoplankton up to marine mammals.

Here we present the result of an analysis of weekly SST from 1979 to 2020. Simple regression analysis reveals clear regions of warming in winter in the Nordic Seas and cooling in summer months in the Irminger Sea. An empirical orthogonal function analysis allows us to go further. Now we can clearly allocate changes observed in SST to that driven by changes in seasonality, change connected to the North Atlantic subpolar gyre, change linked to local sea ice melt along the Southeast Greenland shelf and that linked to influx of warmer water with the the North Icelandic Irminger Current.

Each of these isolated signals differ considerably in their contribution to driving the regional trends in SST found in the regression analysis. The isolated signals offer a high resolution long time series of valuable indicators of oceanographic change which will likely be reflected in biogeochemistry, plankton, fish, mammals and seabirds in the region.

Poster presentation

LONG-TERM SHIFTS IN MAIN DRIVERS OF COASTAL FOOD WEBS

del la Barra, P., van Leeuwen, S., Bijleveld, A., Bom, R., Camphuysen, K., Dekinga, A., Dekker, R., Ens, B., Jan van Gils, J., Holthuijsen, S., ten Horn, J., van Leeuwen, A., van der Molen, J., Peck, M., Piersma, T., Philippart, K., van der Veer, H

The Wadden Sea, the largest coherent intertidal area in the world and a UNESCO world heritage site since 2009, has been subject for at least 1000 years to a suite of human pressures that left increasing traces on biodiversity and ecosystem functioning. Long-term field observations (50-150 years) on water quality, phytoplankton, benthic invertebrates, fish and birds showed the impact of habitat transformations, eutrophication, fisheries, invasive species and climate change on the interactions within the coastal food web. During our presentation, we compare means, variations and extremes in values of abiotic variables and indices of most trophic levels of the 2010-2019 decade with those of the decades before (down to the 1860s for salinity and temperature). We will then explore various working hypotheses on structuring factors of coastal food webs, including large-scale developments (e.g., Wadden Sea and North Sea fisheries, increasing sea water temperature, etc.) and cumulative impacts of human activities, and examine how the importance of these drivers have changed in time.

Poster presentation

WATER MASS PROPERTIES AND DISTRIBUTION IN THE NORDIC SEAS DURING THE 2010S, AND IN RELATION TO THE CHANGES DURING THE LAST 50 YEARS

Mork, K. A., Skagseth, Ø., Søiland, H.

The changes in the properties and distributions of Atlantic, intermediate and deep/bottom waters are explored and reviewed with focus on the last decade, 2010-2019. This study includes historical hydrographic observations at fixed sections and at other locations, together with Argo data from the last two decades. In the last decade, the Atlantic water has experienced a freshening trend while it still is warmer than the long-term mean. In contrast, the intermediate water mass has become less fresh. In the deep/bottom layer a warming trend is observed. These changes are related to longer time scales during the last 50 years. Processes responsible for these changes are discussed.

Poster presentation

OCEAN CLIMATE CHANGES IN THE NORTH-EASTERN GREENLAND SEA FROM SYNOPTIC AND LAGRANGIAN MEASUREMENTS

Walczowski, W., Merchel, M., Wieczorek, P.,

Studies in the region of Atlantic Water inflow into the Arctic Ocean show that water temperature is increasing at all levels. Temperature of the surface layer increases the fastest, but the intermediate and deep layers are also subject to this process. Undoubtedly, this has significant ecological and climatic consequences. The ocean's heat content in this region increases many times faster than in other waters, higher temperature leads to a lower solubility of oxygen and CO₂.

Oceanographic data obtained from research vessels mainly cover the summer season, the data coverage in winter is much weaker. Therefore, measurements with autonomous, profiling Argo floats are playing an increasingly important role. While coverage by Argo array of the northern regions is still weak, Argo data may already be used to assess ocean climate change south of Fram Strait. Their additional advantage is the possibility of studying seasonal cycles of water properties.

For processing and interpretation of Argo data, different tools than for synoptic measurements are used. Nevertheless, comparison of time series obtained by Institute of Oceanology Polish Academy of Sciences during the AREX cruises with the Argo floats data confirms the increase of temperature and heat content in the water column to 2000 m.

Research with Argo is progressing rapidly. Standard Argo operates up to 2,000 m, deep-Argo operating up to 4,000 and even 6,000 m are introduced. Especially in the Arctic - such important, but difficult to study region, increased international cooperation in Argo deployment and data using is needed.

Poster presentation

DECADAL TREND AND SEASONAL VARIABILITY OF THE ARAGONITE SATURATION IN THE ROCKALL TROUGH, NORTHEAST ATLANTIC

Büscher, J. V., McGrath, T., McAleer, A., Fennell, S., McGovern, E., Cusack, C., Rachel R. Cave, R. R.

Over the last decade, in the NE Atlantic region, a transect of CTD stations across the Rockall Trough (RT) from the Irish shelf west of Ireland (53°N) to Rockall Bank (54°N) was conducted on a near-annual basis by the Marine Institute and NUI Galway in either winter or summer. The hydrographic and water chemistry data shows considerable variability in water mass properties each year and between seasons. The aragonite saturation horizon, particularly relevant to organisms that build their shells and skeletons from calcium carbonate, shows a clear trend of shoaling in the RT over the last ten years, with a particularly strong shift in summer in recent years. In winter 2010, the aragonite saturation horizon of $\Omega_{Ar}=1$ was at 2400 m, while in spring 2019 it averaged 2260 m. The data demonstrates that benthic ecosystems in the RT dependent on carbonate such as cold-water corals (1) must adapt to seasonal fluctuations in carbonate chemistry and availability of carbonate ions and (2) may already be experiencing aragonite undersaturation and will likely face continued environmental change in the near future.

Hydrographic studies show that the extent of penetration of water masses into the RT in any given year varies depending on the variability of driving mechanisms such as the AMOC. It is clear that many organisms are adapted to variability in water chemistry. It is not clear, however, whether the current trend of ocean acidification is likely to exceed the tolerance limits of organisms adapted to life in the RT.

Poster presentation

MODIFICATIONS OF ATLANTIC INFLOW ALONG THE FRAM STRAIT BRANCH TO THE ARCTIC OCEAN FROM SHIP-BORNE AND MOORED OBSERVATIONS IN THE LAST TWO DECADES

Beszczynska-Möller, A., Walczowski, W., Grynczel, A.

Understanding variable properties and dynamics of the Atlantic water (AW) poleward inflow is one of key prerequisites to elucidate mechanisms behind the new, warmer regime of the Arctic Ocean. As the AW progress northwards, its properties are modified by ocean-air interactions, mixing and lateral exchanges. Warm anomalies reaching the Arctic Ocean result from smaller heat loss during the AW northward passage and/or from an increased oceanic advection. Vertical structure of the Atlantic water layer implies the depth of winter convection and access to oceanic heat carried by the inflow.

During the last two decades warming of the Atlantic inflow has progressed into the Arctic Ocean, however with strong interannual variations. We present results from 20 years of hydrographic surveys, covering the Atlantic water inflow in the eastern Norwegian and Greenland seas, Fram Strait up to the southern Nansen Basin. Changes in the AW properties are analyzed with a focus on the en route modifications of AW inflow in the Fram Strait Branch and varying ocean heat content.

After leaving Fram Strait, the part of AW enters the Arctic Ocean along different pathways north of Svalbard. The strongest ocean-air-ice interactions and lateral exchanges in this region lead to substantial local modification of the Atlantic inflow before it continues farther eastward. Observations from year-round moorings deployed since 2013 are used to describe changes in the AW properties, vertical structure, and dynamics on monthly to seasonal and interannual time scales and their links to the upstream conditions and atmospheric forcing.

Poster presentation

DECADAL TRENDS IN THE NORTH ATLANTIC SUBPOLAR GYRE AND THEIR IMPACT ON MARINE ENVIRONMENT OF THE BARENTS SEA

Koul, V., Brune, S., Baehr, J., Schrum, C.

The Barents Sea is a key region in the Earth System and is a highly productive shelf-sea. An integrated approach for sustainable management of marine resources in such shelf-sea marine ecosystems requires, among many other aspects, a robust understanding of the impact of climate on local oceanic conditions. In this work we combine observational and modelling approach and show that decadal climatic trends associated with the North Atlantic Subpolar Gyre (SPG), within the period 1960-2019, have an impact on oceanic conditions in the Barents Sea. We relate hydrographic conditions in the Barents Sea to the decadal variability of the SPG through its impact on the Atlantic Inflow via the Faroe-Shetland Channel (FSC) and the Barents Sea Opening (BSO). When the SPG warms, an increase in the throughput of subtropical waters across the Greenland-Scotland ridge is followed by an increase in the volume of Atlantic water entering the Barents Sea. These changes are reflected in pronounced decadal trends in the sea-ice concentration and primary production in the Barents Sea, which follow the SPG after an advective delay of 4-5 years. This impact of the SPG on sea-ice and primary production provides a dynamical explanation of the recently reported 7-year lagged statistical relationship between SPG and cod (*Gadus morhua*) biomass in the Barents Sea. Overall, these results highlight a potential for decadal ecosystem predictions in the Barents Sea.

Poster presentation

DECLINING SILICATE AND NITRATE CONCENTRATIONS IN THE NORDIC SEAS

Gundersen, K., Lien, V. S.

A comprehensive analysis of nutrient data in three regions of the Nordic Seas between 1990 and 2019, shows a statistically significant decline in surface silicate and nitrate. Surface nutrient concentrations in the region appear to be regulated by the Subpolar Gyre situated south of Greenland and Iceland. The Subpolar Gyre Index has been in a decline for most of the period investigated, which means that the gyre has moved westward allowing more subtropical, nutrient depleted, water into the Nordic Seas. The largest decline in silicate occurred from 1990-2000. We also found a statistically significant decline of silicate in Arctic Water in the Greenland Sea, with a time-lag of about one decade relative to the Atlantic Water. Nitrate on the other hand, did not decline as uniformly and only had a significant drop midway through the time-series (2005-2009) and only in the Norwegian Sea, followed by a recovery to previous levels. Decline of nitrate in the Greenland Sea also had a time-lag of about one decade. The molar nitrate:silicate ratio however, showed a steady increase throughout the thirty-year period. Less access to silicate in the Nordic Seas may shorten the spring diatom bloom period and potentially hamper zooplankton growth and community composition, which may have consequences for growth and development of commercially important fish stocks in these waters.

Poster presentation

A BOREAL BREEZE IN THE FUNCTIONAL STRUCTURE OF ARCTIC ZOOPLANKTON

Gluchowska, G., Ormańczyk, M.R., Patuła, W., Strzelewicz, A., Kwaśniewski, S.

The fjords of Svalbard are facing a significant increase in the influx of Atlantic waters (AW) as a result of a progressive climate change, affecting all components of ecosystems. Earlier studies showed limited inflow of AW to Hornsund fjord (SW Spitsbergen), possibly due to physiographic and hydrographic barriers, remaining its ecosystem relatively unchanged. In recent years, however, AW has been present not only in the foreground but also in the main Hornsund basin.

On the basis of the data gathered as a result of multi-year research on zooplankton and hydrography of the Spitsbergen fjords, conducted by the IO PAS in 2001-2016 in the Hornsund fjord, we assessed the taxonomic and functional structure of zooplankton and their diversity in different temperature regimes. The zooplankton community's response to the increasing impact of warm AW was examined in terms of taxonomic diversity and community structure, but we also analyzed zooplankton functional structure in order to understand how the functional role of arctic zooplankton may evolve in light of future global change scenarios.

Knowing how the Atlantification of the environment and Borealization of fauna in the Arctic will proceed is important both for predicting the effects of changes in the functioning of marine ecosystems, as well as for preparing administrative decisions necessary for modern resource management and area governing.

Poster presentation

DECLINE IN PRE-BLOOM CALANUS FINMARCHICUS EGG PRODUCTION ON THE FAROE SHELF SINCE THE 1990S

Jacobsen, S., Gaard, E., Hátún, H.

Calanus finmarchicus is a key secondary producer in northern marine ecosystems. During winter *C. finmarchicus* hibernates at depth across the North Atlantic. In spring the animals ascent to surface waters, where they are advected to shelves including the Faroe shelf. Shortly after emergence the females spawn partly based on winter lipid reserves. In the Faroe area, *C. finmarchicus* eggs dominate the diet of first feeding fish larvae inhabiting the shelf during early spring. Thus, the initial reproduction of *C. finmarchicus* is essential for Faroe shelf fish larval survival. Comprehensive late April surveys have been carried out on the Faroe shelf for more than two decades in order to investigate the critical match-mismatch between the spring bloom development, zooplankton reproduction and occurrence of first-feeding fish larvae. Temporal and spatial variability in bloom development and zooplankton abundance have been reported, while the actual zooplankton reproduction has drawn less attention. In this study we examine spatial and interannual changes in pre-bloom reproductive activity of *C. finmarchicus* on the shelf using a unique dataset of almost 8000 examined females sampled during the period 1997-2020; a time of considerable climate variability. We observe a decline in the individual egg production as well as the fraction of spawning females throughout the shelf area during the study period. We attribute this decline to climatic changes including changes in *C. finmarchicus* phenology resulting in earlier emergence from diapause. The declining egg production may have consequences for first-feeding fish larvae.

Poster presentation

TRANSPORTATION AND PREDATION CONTROL STRUCTURES THE DISTRIBUTION OF A KEY CALANOID IN THE NORDIC SEAS

Aarflot, J. M., Hjøllø, S. S., Strand, E., Skogen, M. D.

One of the largest *Calanus* species in the Nordic Seas is also the copepod for which we have the poorest knowledge. Recent studies have shown that *C. hyperboreus* is more likely of sub-Arctic rather than Arctic origins, and the Nordic Seas are part of its core distribution areas worldwide. Large size and high fat content make *C. hyperboreus* important prey for planktivores, and the Nordic Seas serve as main feeding grounds for large stocks of planktivorous fish. We develop an individual-based model (IBM) of *C. hyperboreus* which is coupled to an existing ecosystem model system encompassing physics, primary production and an IBM of the Atlantic congener *C. finmarchicus*. Given the main circulation routes in the region, a key question we address is why *C. hyperboreus* is measured in low abundances within the Norwegian Sea. We show that the core population of *C. hyperboreus* in the Greenland Sea supplies individuals to both the Iceland and Norwegian Seas, and that most copepods presumably visit more than one of these regions during their lifetime. Advective pathways through environmental gradients creates intraspecific variation in development rates as reported by in situ observational studies. Moreover, we suggest that low abundances in the Norwegian Sea are more likely controlled by top-down processes (predation) rather than bottom-up limitations on growth/reproduction or interspecific competition with *C. finmarchicus*.

Poster presentation

PATTERNS OF VARIATIONS IN THE NERITIC COPEPOD COMMUNITY OF THE BASQUE COAST (BAY OF BISCAY) DURING THE LAST TWO DECADES (1998-2020) IN RELATION TO CLIMATE TELECONNECTION AND LOCAL ENVIRONMENTAL VARIABLES

Uriarte, I., Iriarte, A., Villate F., Barroeta, Z., Bidegain, G.

Understanding the mechanisms that govern copepod long-term dynamics may serve to forecast future changes in food availability for fish larvae and in fish recruitment. We analysed the changes in composition and abundance of the neritic copepods of the Basque coast (Bay of Biscay) for the 1998-2020 period and their relationships to the main climatic teleconnection patterns in the North Atlantic (North Atlantic Oscillation; East Atlantic pattern; Atlantic Multidecadal Oscillation). Similarly, relationships to local environmental factors (water temperature, salinity, chlorophyll a, precipitation, river flow, salinity stratification, and upwelling index) were also considered. We used the pooled time-series data of copepods from the neritic areas of Bilbao and Urdaibai, performed Principal Component Analyses of the absolute and relative abundances of the copepod assemblage, and conducted Spearman rank correlations to examine the relationship to climate and water environmental variables. We used Rodionov's test to detect shifts in the main modes of community variability. The results showed that the main modes of copepods' variability for absolute and relative abundances were related to different combinations of teleconnection indices and local environmental factors. Community shifts were detected in 2006-2008 and 2013-2015. The variability in copepod species absolute abundance showed opposite interannual patterns between spring-summer species (*Acartia clausi* and *Centropages typicus*) and summer-autumn species (*Temora stylifera*, *Oithona plumifera*, *O. nana*, *Ditrichocorycaeus anglicus* and *Oncaea media*). In copepods' relative abundance the main changes were primarily driven by the opposite variations in the percentage of *A. clausi* and *Paracalanus parvus*.

Poster presentation

HELGOLAND ROADS – A STEPWISE APPROACH TO UNRAVEL POTENTIAL ZOOPLANKTON INDICATORS

Ndah, A. B., Kirstein, I. V., Meunier, C., Wiltshire, K. H., Boersma, M.

Global change places coastal marine systems under great pressure, threatening ecological community structure and functioning. In particular, plankton communities, which play a crucial role in the overall function of marine food webs, are sensitive to environmental change. However, the assessment of the environmental status of these coastal systems still presents as a major challenge. Aside from system complexity, only a few high-resolution data series are available and then with limited comparability between each other. To tackle this issue, zooplankton have been suggested as potential additional indicator organisms for use as a tool for pelagic assessments in context of the Marine Strategy Framework Directive. Using data from the renowned Helgoland Roads time series which covers more than five decades, we aimed to develop new zooplankton indicators for the assessment of the German North Sea. We used a stepwise approach using multivariate statistical tools to unravel potential zooplankton indicator taxa/communities. We tested for distinct group structures over time within the multivariate space and identified the main discriminating taxa for different periods. The zooplankton community was seen to have changed over time in response to environmental conditions. Concomitantly, distinct zooplankton assemblages were found to be associated with specific abiotic regimes. Our results provide a strong basis for the implementation of locally pre-defined zooplankton indicator communities for assessment of the environmental status of the North Sea in the future.

Poster presentation

THE EVOLUTION OF THE ZOOPLANKTON COMMUNITY IN THE GULF OF CÁDIZ, SW IBERIAN PENINSULA

González Cabrera, C., Romero P., Moya F., García-Martínez M.C., Baldo P., Llopes M., Vilas C., González-Ortegón E, Jiménez M.P., Sánchez-Leal R.

The Spanish Institute of Oceanography (IEO) has been conducting a multidisciplinary study of the marine ecosystem in the Gulf of Cadiz (GoC; SW Iberian Peninsula) since 2009 within the frame of the program Time Series of Oceanographic data in the Gulf of Cadiz (STOCA, in Spanish). The program maintains repeated observations along five across-shelf transects: three times a year from 2009 to 2012 and quarterly on hereafter.

In this paper we present the temporal evolution of the zooplankton community in the GoC. In particular, we focused on samples from three stations located off the Guadalquivir river mouth: GD1 (20 m depth), GD3 (80 m) and GD6 (450 m). Samples were taken with bongo-40 cm paired zooplankton nets (mesh size 200 μ m). Double oblique hauls were conducted from top to bottom or to a maximum depth of 200 m while the ship was steaming at 2.5 kn. A total of 43 samples per station were included in the analysis. Samples were imaged with ZooScan. Full images were processed with ZooProcess which generated set of associated features measured on each identified object (Gorsky et al, 2010). These objects were sorted following a common taxonomic guide using the web application EcoTaxa (<http://ecotaxa.obs-vlfr.fr>). As a sanity check, a variable number of aliquots were directly identified by light microscopy. These results permitted the description of the mean and variable components of the plankton community, their seasonal in the context of the thermohaline and transport variability in the 2010s.

Poster presentation

PRIMARY PRODUCTION IN THE NORWEGIAN SEA

Børsheim, K. Y., Skagseth, Ø., Mork, K. A.

The Norwegian Sea annual net primary production averaged 13.2 mol C m⁻² year⁻¹ during 2003 to 2020 estimated from MODIS satellite sensed data. The interannual standard deviation of the mean was 1.9 (range 10.7-16.5). These estimates represent the area over the deep parts of the Norwegian Sea, the Norwegian Basin and the Lofoten basin. This area is not homogeneous, there were consistent gradients south to north and east to west. In the period monitored by the MODIS mission, there was a change in annual NPP. The average was 11.4 mol C m⁻² year⁻¹ between 2005 and 2012, and 15 mol C m⁻² year⁻¹ from 2013 and onwards. The change in NPP coincided with a change in salinity and temperature, reflecting changes in both the inflow waters as well as in the circulation of the Nordic Seas.

Poster presentation

ZOOPLANKTON VARIABILITY IN THE WATERS AROUND ICELAND

Petursdottir, H., Gislason, A., Silva, T.

The waters south and north off Iceland are very different both oceanographically and biologically with the rather stable and warm North Atlantic waters south and west of Iceland and the more variable and cold Arctic and sub-Arctic waters, north and east of Iceland. The Icelandic monitoring programme for zooplankton consists of a series of standard transects around Iceland perpendicular to the coastline. Zooplankton investigations, starting in the 1960s, are carried out on these transects every year in May and June. The zooplankton biomass has fluctuated rather irregularly with maxima being observed with several years (5-10) intervals. No unidirectional trend in the biomass has been observed, in contrast with large area far south of Iceland where decadal decline in copepod abundance has been observed. Copepods (mainly *C. finmarchicus* and *Oithona* spp.) generally dominate the zooplankton, comprising >60–70% of the plankton in most years. Among the copepods, *C. finmarchicus* tends to be more abundant south of Iceland (~20–70%) than in the north (~10–60%). Temperature and salinity are the most important environmental variables, in terms of explaining the differences in species composition north and south of Iceland. Increase in the abundance of *C. finmarchicus* at an oceanic site north of Iceland and a decrease of the larger Arctic species *C. hyperboreus* has been observed both on and off the shelf north of the island and is related to the observed increases in regional sea water temperatures in the area.

Poster presentation

PHYTOPLANKTON TRENDS IN THE NOORDWIJK TRANSECT

van Bortel, L., van den Oever, A.

In the context of a Dutch marine monitoring project named BIOMON (initiated by the Ministry of Infrastructure and Watermanagement, Rijkswaterstaat) phytoplankton has been sampled since 1990 in 41 fixed stations in Dutch coastal waters (including the Wadden Sea, the Delta areas and the North Sea). Analyses of fixed samples were completed using light microscopy and focused on species counts and composition. In this study, the decision was made to study the data collected in 2000-2019 from the Noordwijk- transect (a transect with 4 stations ranging from 10, 20, 50 and 70 kilometers off the Dutch coast in north-west direction towards the UK).

The aim of this study was to describe what species and species groups could be found in this dataset and possible trends in phytoplankton numbers and composition (genera and groups) during the last two decades in the Noordwijk-transect, including abiotic parameters such as N, P, Si, temperature and salinity.

Results are derived from data analysis using box plots and “One Way Anova” tests. Results analysis show the following: the total amount of phytoplankton shows an upward trend in all four stations. Secondly, when comparing phytoplankton groups, dinoflagellates are relatively low in number. Out of the three examined classes/genera, Dictyocha and Raphidophyceae show an increase in numbers whereas Phaeocystis sp. decreases during seasonal blooms. Lastly, the species diversity seems to decrease in the last twenty years.

Poster presentation

VERTICAL DISTRIBUTION OF ZOOPLANKTON AND CLIMATE VARIABILITY – A DECADAL GLIMPSE FROM THE WEST SPITSBERGEN CURRENT

Kwasniewski, S., Gluchowska, M., Olszewska, A., Walczowski, W., Carstensen, J.,

The West Spitsbergen Current (WSC) is the end stretch of the North Atlantic oceanic circulation and main conduit of Atlantic water into the Arctic Ocean. The current transports great amounts of energy and mass, both inorganic and organic, influencing all important ecosystem processes in the Arctic Ocean domain.

Zooplankton has been clearly affected by recently observed climate changes, resulting in observed changes in its spatial distribution and phenology.

In this presentation we show the main results of long-term observation (2001-2016) of vertical distribution of mesozooplankton in the epipelagial (0-200 m) of WSC, from 75 to 79 °N in Fram Strait. The study is based on data on the abundance of zooplankton species, including the life stages of the main copepods, obtained from vertical stratified sampling using the WP-2 net (0.180 mm) and on hydrography, including over 900 samples collected at more than 40 pseudo-permanent stations from s / y Oceania at the beginning of summer as part of the IO PAN research program.

The presentation will focus on showing prevalent patterns in the vertical distribution of predominant taxa (*Calanus finmarchicus*, *Oithona similis*, *Eukrohnia hamata*) in relation to hydrography (WSC structure) and other factors (geography, phenology). The developed statistical analyses will describe the present distribution patterns and assess their variability. Such information makes an important contribution for predictive ecosystem models.

Poster presentation

PHENOLOGICAL VARIATIONS OF ZOOPLANKTON IN THE CENTRAL BALTIC SEA DURING A DECADE OF WARMING

Dutz, J., Huwer, B., Dierking, J.

Changing phenology is an important mode of the zooplankton response to climate variability and has important consequences for the energy transfer and food web dynamics in ecosystems. While most studies suggest a dominant role of temperature in driving phenological variation, biotic interactions may also play a significant role. Zooplankton time series in the open water of the Baltic Sea have already achieved a considerable length, but an insufficient understanding of the phenological responses caused by a low temporal resolution hampers the understanding of the observed trends and their underlying environmental forcing. We, therefore, analysed the phenological variations of zooplankton in the central Baltic Sea during a decade of intense warming (2009-2019). Changes in the seasonal timing were analysed in relation to the spring bloom timing and the seasonal warming. Our results indicate short-term and long-term variation in timing that was taxa- and habitat specific. While temperature played a dominant role in driving phenological variation in those taxa in upper mixed layer, there was a relevant interaction with the timing of the spring bloom. The study highlights the need for time series of higher frequency in the Baltic Sea in order to foster a better understanding of the zooplankton dynamics

Poster presentation

PLANKTONIC OSTRACODS AT THE GATEWAY TO A CHANGING ARCTIC: DECADAL VARIABILITY OF ABUNDANCE, BIODIVERSITY, AND VERTICAL DISTRIBUTION IN KONGSFJORDEN

Chen, E. Y.S., Błachowiak-Samołyk, K., Trudnowska, E.

As an interface between the Arctic and Atlantic marine systems, the Kongsfjorden waters in Svalbard constitute an established site for international, multidisciplinary science projects and environmental monitoring. However, the lack of studies focusing on planktonic ostracods indicates a need for comprehensive research on Arctic microcrustaceans, especially since ostracods are sensitive to any changes in their environment. Because ostracods are important links in the marine food web, understanding their spatiotemporal distribution will help determine what is driving biogeographical shifts of microcrustaceans, whether it is correlation with retreating sea ice or changes in ocean circulation patterns. The biodiversity, abundance, and distribution of pelagic ostracods were examined in order to track changes within the last decade and to test the hypothesis that progressive atlantification also concerns deep-water species. Zooplankton samples were collected annually during summer cruises along a transect of Kongsfjorden from 2011 to 2019, with a total of 139 samples from 6 deep-water stations (>1000m) preserved for downstream analyses. Photos and morphometric measurements of ostracods were taken using a microscope imaging software for subsequent identification. Although species diversity of Kongsfjorden ostracods was rather low, a clear pattern in their distribution structure was obtained. Moreover, the results allow for mapping ostracod dispersion at the entrance to the deep Arctic Ocean. A preliminary approach of merging taxonomy and genetics to create an exhaustive database of Arctic ostracods will also be discussed. Ultimately, the analysis of this time series will form a foundation to predict how ostracod ecology will shift over the coming decades.

Poster presentation

SEASONAL AND DECADAL VARIATION IN ZOOPLANKTON COMMUNITY COMPOSITION IN COASTAL NEWFOUNDLAND WATERS

Bélanger, D., Cyr, F.

Zooplankton are key organisms in marine food webs. They effectively transfer energy from primary producers to the upper trophic levels through predation from selective planktivores and other heterotrophs that primarily target specific species or taxa. Here twenty years (2000-2019) of data collected on average twice monthly by the Atlantic Zone Monitoring Program at a coastal monitoring station served to describe mesozooplankton intra- and interannual signals in Newfoundland coastal waters. Multivariate and univariate methods were applied to abundance data for eleven copepod and four non-copepod taxa to quantify seasonal (spring, summer, and fall) and semi-decadal variations in zooplankton community composition. Zooplankton assemblage was dominated by small cyclopoid *Oithona* (~50%) and calanoid *Pseudocalanus* (~20%) copepods year round. Summer assemblages were characterized by a 4.5x increase in the abundance of *Calanus finmarchicus* compared to spring, while fall assemblages are characterized by 2-4x increase in *Oithona*, *Centropages*, and *Temora longicornis* copepods and pteropods, along with a 50-90% decrease in large *Calanus glacialis* and *C. hyperboreus* copepods and cladocerans relative to summer. Zooplankton assemblages also varied on a semi-decadal to decadal scale. The abundance of *C. finmarchicus* increased ~1.5x between the early and the late 2000s while that of *Pseudocalanus* and *Oithona* copepods increased ~1.7x between the mid-2000s and late 2010s, particularly in the fall. The abundance of appendicularians more than tripled during the 2010s compared to the 2000s. More work is needed to understand how the changes in zooplankton community structure affects energy flow to upper trophic levels.

Poster presentation

DECADAL TRENDS IN GELATINOUS ZOOPLANKTON ALONG THE NORWEGIAN SKAGERRAK COAST

Falkenhaug, T., Johannessen, T.

Gelatinous plankton are critical components of marine ecosystems. During the past several decades, increasing blooms of gelatinous zooplankton have been reported in many coastal areas worldwide. Climate variability has been suggested as one driver for changes in the abundance and distribution of gelatinous plankton. A shift towards dominance of gelatinous plankton can have profound effects on the flow of carbon and nutrients, ecosystem structure and functioning. However, their fragile nature often excludes gelatinous zooplankton from regular monitoring programs, and most time series on gelatinous plankton are generally too short to document trends or conclude on the mechanisms behind blooms. In this study, we present a uniquely long and continuous time series on gelatinous zooplankton in the coastal areas of Skagerrak, Northern North Sea. Since 1919, annual beach seine surveys have been conducted by the Institute of Marine Research to assess fish assemblages, covering more than 130 stations along the Skagerrak coast off southern Norway. Bycatch of non-targeted species have been systematically recorded in the surveys, including scyphozoan jellyfish and Ctenophora. We analyzed the 1919 to 2019 time series on the scyphozoan jellyfish (*Aurelia aurita*, *Cyanea* sp) and ctenophores to identify interannual variability and long-term trends in abundance. The observed variations are related to environmental and climatic variables. The temporal variability differed between taxa, suggesting species specific responses to environmental changes. Spatial variations in variability indicates that both local and large-scale climatic factors are affecting the temporal variations in abundance of gelatinous zooplankton.

Poster presentation

DECENNIAL PHYTOPLANKTON DYNAMICS IN THE STRAIT OF DOVER BY APPLYING AN AUTOMATED IN VIVO APPROACH

Hubert, Z., Epinoux, A., Gallot, C., Cornille, V., Louchart, A., Bonato, S., Crouvoisier, M., Bruaut, M., Lebourg, E., Delarbre, J., Dédécker, C., Caillault, E. P., Hébert, P. A., Wacquet, G., Artigas, L. F.

Global change and anthropogenic pressure affect phytoplankton composition and dynamics which in turn have repercussions on biogeochemical cycles, climate and food webs. Long-term observation of phytoplankton communities at appropriate space-time scales is fundamental to understanding their complexity and monitoring the functioning and health of marine ecosystems. The use of automated in vivo techniques (fluorometry, automated flow cytometry) allow to obtain information, in near real-time, on the entire size spectrum of phytoplankton. Since 2011, these techniques have been applied weekly on a 9-point coast-wide transect in the northern limit of a Marine Protected Area by the Strait of Dover. By processing data, it was possible to characterize spatio-temporal variability in phytoplankton communities at high spatial resolution (~1 km). Manual and automated clustering on pulse shape-recording flow cytometry enable to show changes in phytoplankton communities. Considering their optical properties, up to thirteen functional groups were described. Variability in total cell abundance, biomass and phytoplankton composition was characterized and could be related to changes in environmental parameters (inorganic nutrient concentration, temperature, salinity). A significant inter-annual decrease in chlorophyll a concentration addressed by both in vivo bulk fluorescence and the sum of the fluorescence of all cells counted by flow cytometry was highlighted, as well as a regular but nonetheless fluctuating seasonal pattern. A coast-width gradient was also evidenced. Phytoplankton abundance, on the other hand, showed a more complex pattern by changes in the dominant size- optical classes, which spatial distribution and phenology showed some common but also different patterns the last decade.

Poster presentation

DECADAL VARIABILITY 2010-2021 OF ZOOPLANKTON COMMUNITY AT THE GUADALQUIVIR ESTUARY (SOUTHERN SPAIN).

Vilas, C., Baldo, F., Gonzalez-Ortegon, E., van Berjeijk, S., Cabrera, S., Ramirez, A., Cardenas, P., Cañavate, P.

A Long Term Ecological Research Program has been monitoring the Guadalquivir estuary meso- and macro- zooplankton community monthly since January 2010. As an important nursery area for many marine species (fish and crustacean) from the Gulf of Cadiz, whose juveniles and recruits depend on zooplankton as main prey, understanding how abiotic and biotic factors determine zooplankton community structure it's necessary to unreveal recruitment variability. We sampled throughout the whole salinity gradient, 2 locations, the two diurnal ebb and flood tides during the new moon days using a 100 µm zooplankton net. Zooplankton community is mainly composed by copepods and mysids. While the exotic *Acartia tonsa* calanoid copepod is the most abundant specie by abundance, mysid *Mesopodopsis slabberi* contribute the most to total biomass, followed by mysids *Rhopalophthalmus tartessicus* and *Neomysis integer*. Other abundant groups were copepods *Acartia bifilosa* and *Acartia clausii*, *Calanipeda aquaedulcis*, *Paracalanus parvus* and *Acanthocyclops robustus*, cladocera *Pleopis polyphaemoides*, together with veliger larvae, Cirripeda and Ostracoda, and Decapoda larvae. About total biodiversity, we found up to 183 species, estimating a total mean Species Richness of 9.7 (minimum 2- maximum 33) per sample, mean Shannon Diversity Index 3.27, Pielou Evenness 0.50 and mean betadiversity 0.630. While copepods area abundant form fall to early spring and summer, mysid density peaks form spring to fall. Community is structured by Salinity, but Temperature, Turbidity, Nitrate, Nitrite and Dissolved Oxygen were also important variables leading spatio-temporal variability, mainly when estuary recives high freshwater discharges from Alcalá del Río dam.

Poster presentation

REVIEW OF CHANGES IN PHYTOPLANKTON SPECIES OCCURRENCE, ABUNDANCE AND DISTRIBUTION IN IRISH COASTAL WATERS 2010-2019.

Clarke, D., Yamanaka, T., Cusack, C., Kelly, J.,

The Marine Institute, Ireland has been operating the national monitoring programme (NMP) for phytoplankton species identification and enumeration since the 1980's and now has over 40 years of time-series data. This dataset is derived from the analysis by light microscopy of preserved water samples collected and submitted from in-shore shellfish and finfish aquaculture producing bays around the Irish coastline. In the early years of monitoring, the sampling and analytical focus was targeted to the identification of species associated with Harmful Algal Blooms (HAB) and events which impact aquaculture production.

For this decadal review, it is observed that the NMP was dramatically upscaled to include the identification of all species present, and the sampling frequency was increased to weekly throughout the year for all production areas, giving rise to approximately 3,500 samples per annum. The Water Framework Directive also came into force in this decade yielding additional results from coastal and transitional waters.

Additionally, the data has been examined and reveals a number of changes in the observed patterns of species associated with HAB events and impacts observed on aquaculture through changes in phytoplankton type, abundance and distribution as regards their intensity, duration and timing. Heatmaps also demonstrate changes in diatom/dinoflagellate abundance ratios. This data is used in Gradient Boosting Machine modelling simulations which give an indication of predictive changing geographical niche of phytoplankton species under RCP 8.5 climate change scenarios. This is used to predict future species abundance with changes in temperature, salinity and potential energy deficit.

Poster presentation

HOW DOES THE DYNAMICS OF PRIMARY PRODUCTION AFFECT THE AVAILABILITY OF FOOD FOR SEABIRDS IN THE FLUCTUATING HIGH-ARCTIC ENVIRONMENT?

Bałaży, Kaja, Balazy, K., Trudnowska, E., Boehnke, R., Dąbrowska, A. M., Jakubas, D., Wojczulanis-Jakubas, K., Darecki, M., Szeligowska, M., Błachowiak-Samołyk, K.,

The European Arctic is currently undergoing Atlantification, resulting in alteration of local marine ecosystems towards a more boreal state. This phenomenon includes sea temperature rise and shifts in the timing of phytoplankton blooms, which turn out to be particularly important for the functioning of food webs, especially at higher trophic levels. Here, we present results showing how variability in timing and magnitude of primary production in summer harmonizes with zooplankton abundance, distribution and structure and finally, how this is reflected in the food requirements of planktivorous seabird, the little auk *Alle alle*. This study was performed annually in one of the Svalbard fjord, the Hornsund area. Detailed analyses of protists and zooplankton samples from five summer seasons (2015-2019) show that small copepods such as *Oithona similis* react differently to the spatio-temporal variability in distribution and availability of chlorophyll a and protists than larger *Calanus* copepods, which are a preferred component of little auks diet. This pattern is confirmed by data from laser optical plankton (LOPC) surveys (2010-2021), which high resolution measurements show the extent of spatio-temporal match and mismatch between concentration hotspots of smaller plankton fractions, *Calanus* copepods and layers of chlorophyll fluorescence peaks. All this has consequences for the choice of feeding grounds by birds, as the analysis of foraging trips of GPS-tracked little auks compared with satellite data implies that the birds in the studied area may be headed also by the ocean colour, shaped by the variations in chlorophyll a concentrations.

Poster presentation

TRENDS IN THE SPECIES COMPOSITION AT THE SOUTHERNMOST ESTUARY OF THE ATLANTIC COAST OF EUROPE

González-Ortegón, E., Cuesta, J. A., Baldó, F., Vilas, C.

Climate change may enhance the establishment of introduced species, as well as the poleward shift in distribution of numerous species over decades. Long-term research and monitoring of an ecosystem at the southernmost point of the Atlantic coast of Europe should be an important priority in order to detect and understand trends in species composition and the related environmental changes. The Guadalquivir estuary (South Spain) is more likely to suffer the exacerbated effects of climate change due to its location in the Mediterranean-climate zone. The long-term data set between 1997 and 2015 in this estuary has allowed us to analyse the variability of the natural and anthropogenic stressors, especially in some dry years and how records of new species have been stabilised as a consequence of expanded connectivity (shipping) and “African Creep”. The mean interannual dissimilarity of the estuarine fauna (Bray–Curtis dissimilarity index) has showed important differences throughout the years, and the species that most contributed to these differences were the exotic species capable of completing their life cycles. Their average annual density has shown a continuous increase during the years of study in a period of expansion. This long-term monitoring of the estuarine community has allowed us to anticipate future events and ecological risk assessment in Europe due to climate change. Management implications are mainly related to the catching of exotic species to control their impact on native communities and reduce the shipping in this sort of ecosystem, which have been especially sensitive in the last 10 years.

Poster presentation

BARENTS SEA COD RECRUITMENT LESS AFFECTED BY TEMPERATURE VARIABILITY WHEN SPAWNING STOCK INCLUDES OLD, LARGE FISH

Ottersen, G., Holt, R. H.

Many fish populations produce an enormous number of offspring per cohort; still only a small and highly variable fraction survives long enough to enter into the fisheries as recruits. It is thus intuitive that the size of the spawning stock is important for recruitment. Additionally, environmental conditions can greatly influence survival through vulnerable early life stages until recruitment. To understand what regulates recruitment it is consequently necessary to explain the impact of fluctuations in both spawning stock and environment, including interactions. Here we investigate if the impact of year-to-year environmental fluctuations on recruitment is affected by the state of the spawning stock, including age structure and biomass. Specifically, we examine if the effect of variability in sea temperature on recruitment is more pronounced for a spawning stock dominated by young fish and few age classes. This is a relevant state for many populations as a natural consequence of prolonged intense fishing. While we propose that this mechanism is of a more general nature, we study the Barents Sea stock of Atlantic cod (*Gadus morhua*). By analyzing Virtual Population Analysis based stock data from 1913-2020 and Russian Kola section sea temperature from 1921-2019 we find: i) the mean age in the cod spawning stock decreased from ca 11 years to 7 years around 1990, since increasing to ca 10 years now; ii) the moving correlation between recruitment and sea temperature displayed clear decadal scale variation, and iii) the correlation was indeed higher in the period with low mean spawners' age.

Poster presentation

IMPACTS OF CLIMATE CHANGE ON COMMERCIAL FISH STOCKS IN IRISH WATERS.

Vaughan, L., Minto, C., Reid, D., Cusack, C., Poole, R., Stokes, D., Lynam, C., Brophy, D.,

The impacts of climate change on marine ecosystems are well documented. Impacts on fish communities may be displayed by changes in distribution, phenology, growth, and survival. Several major commercial fish stocks in Irish waters are found at the northern and southern extremes of their habitat ranges which may exacerbate climate change impacts. To effectively plan, mitigate, and adapt to the effects of rising sea temperatures and ocean acidity over the next 50 years, the fishing industry, managers, and policymakers need detailed knowledge of how fisheries will be impacted by climate change. In this study habitat preferences of key commercial species were examined and their distributions mapped. Previous assessments of temporal trends in distribution and climate impacts on Ireland's fisheries were updated using bottom trawl survey, stock assessment, and environmental data. Distributional changes were explored using advanced time series and spatial modelling. Preliminary results indicate distributional changes in key fishing areas with some Lusitanian fish species increasing while Boreal fish species have been declining. Further analysis will focus on species of particular concern identified in the initial investigation.

Poster presentation

MULTIDECADAL (1997-2020) TELECOUPLING OF WATER MANAGEMENT FOR TERRESTRIAL AGRICULTURE AND A MARINE FISHERY AT SOUTHERN SPAIN

Vilas, C., Simon, F.W., Baldo, F., Ramos, F., Gonzalez-Ortegon, E., Drake, P., Vasseur, D.

Climate change is decreasing water supplies globally while water demand is rising, making water access and distribution essential for sustainability, equity, and efficiency. In response, water management has shifted towards practices that improve water efficiency. However, links between geographically separated socioecological systems, known as telecouplings, can obscure the potential consequences of water use. This study focuses on a telecoupling between terrestrial water use and marine fisheries for the period 1997 to 2020. We develop a case study in southern Spain using multidecadal time series of the Guadalquivir river's hydrology, its estuarine community, and the European anchovy (*Engraulis encrasicolus*) fishery in the Gulf of Cadiz. We found that water extracted to irrigate crops decreased the river's flow and seasonality. However, anchovies used the estuary as a nursery before recruiting to the ocean, where they were harvested. Anchovy recruitment improved when estuary hydrology matched the Guadalquivir River's historical hydrology (i.e., high discharge and seasonality). Then using hydro-economic modeling, we explored the outcomes of different water policies on the telecoupled socioecological systems. Our models predicted that improved water efficiency incentivized agricultural expansion. In contrast, continued marine fishery yields required management values that supported the value of the marine fishery. We highlight estuaries' critical role in driving marine systems; yet, upriver processes drive estuaries dynamics. Overall, marine-terrestrial telecouplings provide evidence that marine fisheries that rely on estuarine reliant species would benefit of water policy and management being extended beyond the water basin.

Poster presentation

SPATIAL DISTRIBUTION OF DIFFERENT AGE GROUPS OF HERRING IN NORWEGIAN SEA, MAY 1996-2020

Eliassen, S. K., Eydna í Homrum, E. Í., Jacobsen, J. A., Kristiansen, I., Óskarsson, G. J., Are Salthaug, A., Erling Kåre Stenevik, E. K., I

The commercially important Norwegian spring spawning herring is characterized by its extensive annual migrations and, on a decadal timescale, large shifts in migration patterns. These changes are not well understood, but have previously been linked to temperature, food availability and size and composition of the stock.

Data from the International Ecosystem Surveys in the Nordic Seas were used to analyze the spatial distribution of herring age classes in the period 1996-2020. The analysis shows that in May the youngest age classes are generally found close to the Norwegian shelf, whereas the older age classes display larger variations in where they are distributed. During the period 1996-1998, the oldest age classes were found in the central and western Norwegian Sea. During the period 1999-2004, the whole stock migrated north after spawning, leaving the regions in the southern Norwegian Sea void of herring. Since 2005 the oldest herring has again congregated in the south-western Norwegian Sea, in the frontal zone between the cooler East Icelandic Current and the warmer Atlantic water. There was a significant positive relationship both between stock size and distribution area and between stock size and density. Moreover, it is likely that the strong year classes 1991/1992 and 1998/1999, which were relatively old when the respective changes in migration patterns occurred, were important contributors to the changes observed in 1999 and 2005, respectively. The observed shifts in migration patterns are discussed in relation to prey abundance and ocean climate.

Poster presentation

DIET COMPOSITION OF REDFISH (SEBASTES SP.) DURING PERIODS OF COLLAPSE AND MASSIVE RESURGENCE OF THE GULF OF ST. LAWRENCE STOCK

Brown-Vuillemin, S., Chabot, D., Nozères, C. Tremblay, R., Robert, D. Sirois, P.

Over the past three decades, the Gulf of St. Lawrence (GSL, Canada) ecosystem has undergone profound changes. In the 1990s, several groundfish collapsed as a result of overfishing during a period of low productivity associated with exceptionally cold water temperatures. After a relative stability over two decades, deep waters rapidly warmed during the 2010s, resulting in a decline of dominant cold water invertebrates and the unprecedented recruitment of the redfish (*Sebastes mentella*) in 2011. During the 2019 annual research survey conducted by the Department of Fisheries and Oceans (DFO), redfish were by far the most common taxon in the GSL, accounting for 90% of the total demersal biomass, compared to 15% in 1995–2012. The trophic implications of this massive resurgence remain unknown. Taxonomical analysis of 3690 redfish stomachs, collected during a period of low redfish abundance (1993–1999) and the recent period of surging abundance (2015–2019), was carried out to determine decadal changes in diet composition during both periods. Results showed that redfish predation on shrimps represents a major concern for the dynamics of this forage species, especially the northern shrimp *P. borealis*, which supports a valuable fishery in the GSL but has been declining in abundance in recent years. By offering new insight into the decadal temporal variability that exists in the diet composition of redfish, this study provides novel information on the implication of redfish predation pressure in the GSL ecosystem.

Poster presentation

DECADAL TRENDS IN THE NORWEGIAN AND BARENTS SEA ECOSYSTEM, 2010-2018

Surma, S., Skaret, G., Pitcher, T. J., Lam, M. E.,

The Norwegian and Barents Seas (NorBar) are linked by physical oceanography (Arctic and Atlantic Water) and the life histories of several ecologically and commercially important fish stocks, notably Norwegian spring-spawning (NSS) herring (*Clupea harengus*) and Northeast Arctic cod (*Gadus morhua*). This paper reconstructs NorBar ecosystem dynamics between 2010 and 2018 and attempts to disentangle the roles of physical forcing, trophic control, and fishing pressure in these dynamics. A mass-balanced ecosystem model was fitted to biomass and catch time series across all trophic levels from phytoplankton to whales. The nature and quality of fits to time series were employed to characterize the effects of climate, trophic interactions, and fisheries on ecosystem dynamics. Ecosystem trends were also quantified using indices of functional diversity (Kempton's Q) and trophic structure. Results revealed mixed control of ecosystem dynamics by climate, predator-prey interactions, and fisheries. Depth-integrated (0-200 m) ocean temperature trends directly and strongly influenced fish stock and ecosystem dynamics. The Atlantic Meridional Oscillation was correlated positively with sea surface temperature and primary production and negatively with salinity and wind speed, suggesting a positive effect of climate-driven increased stratification on phytoplankton. Deep-sea redfish (*Sebastes mentella*), and perhaps mackerel (*Scomber scombrus*) stock biomasses increased since 2010, while those of NSS herring and golden redfish (*S. marinus*) decreased, with large fluctuations in many other stocks. Functional diversity declined and "fishing down the food web" occurred since 2010. These results suggest that climate, trophodynamics, and fishing pressure should all be considered in fisheries management in the NorBar ecosystem.

Poster presentation

SETTLEMENT VARIABILITY OF ARCTIC CRYPTIC BENTHIC COMMUNITIES (BETWEEN 2010 AND 2020) AS A RESULT OF NATURAL ENVIRONMENTAL FLUCTUATIONS

Sowa, A. M., Bałazy, P., Chelchowski, M., Kukliński, P.

Predicting changes that the environment will undergo due to influence of climate change requires possession of in-depth knowledge of past and current state of ecosystem. The goal of presented study was to understand cryptic benthic communities variability over 10 years' time and monitor potential colonization by lower latitude inhabitants in order to understand impact of increasing Atlantification of the European Arctic sector.

Using artificial colonization plates deployed at 6 and 12 m depth at two locations in the high Arctic fjord – Isfjorden we were able to show significant variability in species composition and abundance between not only years but also among sites and depths. Settled epifauna was relatively rich and was represented by around 80 different taxa. Bryozoa was the most species-rich phylum while species belonging to Spirorbinae (Polychaeta) were most abundant. No new comers from lower warmer latitudes were recorded in spite of Atlantic water masses in the study area to be present in high proportion. Generally recorded fauna could be considered as typical for that region.

Although within plankton or other macrofaunal benthic communities we see clear impact of Atlantification (e.g. new species appear) in the study area yet when it comes to cryptic habitats observed significant variability in species composition and abundance seems to be driven by local environmental processes (eg. seasonality).

Poster presentation

NEST-SITE ATTENDANCE OF NORTHERN FULMAR (FULMAREUS GLACIALIS) REFLECTS MARINE ECOSYSTEM PRODUCTIVITY BASED ON MONTHLY COUNTS OVER A 26 YEAR PERIOD

Højgaard, D. P., Danielsen, J., Steingrund, P.

Monitoring at a Northern Fulmar colony from 1996 to 2021, revealed a considerable variation throughout the year in the nest-site attendance of the Northern Fulmar on the Faroe Islands. The attendance was consistently highest during April, followed by a sharp decline during the “exodus” or honeymoon at the end of May, after which the number of birds attending the colony increased again. We assume that the attendance during April is driven by the birds decision to be at the nest-site during this critical pair-binding period, while the attendance the rest of the breeding period is governed by various environmental factors e.g. productivity in the surrounding marine ecosystems or distance to feeding areas, i.e. staying longer at the nest when environmental factors are favorable. The attendance during the breeding period was related to various production measures of plankton and fish in the ecosystem as well as physiological variables like wind and sea temperature changes in order to highlight ecosystem dynamics and potential effects of climate change.

Poster presentation

LONG TERM DYNAMICS OF THE FAROE SHELF ECOSYSTEM AND POTENTIAL EFFECTS OF ZOOPLANKTON ADVECTED FROM THE NORWEGIAN SEA

Steingrund, P., Matras, U., Kristiansen, I., Broms, C. T., Pétursdóttir, H., Jansen, T.

The Faroe Shelf ecosystem has undergone dramatic changes the last seven decades with regards to declines of demersal fish and seabird species. Century long growth chronologies of *Arctica islandica* on the Faroe Shelf likely reflect the amount of fresh phytoplankton that reaches the bottom and therefore provide a proxy of the production of benthic organisms that serve as food for demersal fish. There is a negative correlation between the growth of *A. islandica* and zooplankton concentration measured in July indicating that mid-summer zooplankton has a negative effect on the growth of *A. islandica*. Even though the local zooplankton dynamics on the Faroe Shelf is much influenced by the top-down predation by demersal fish larvae, an attempt is made to link zooplankton in the Norwegian Sea to this dynamics in order to better understand ecosystem dynamics on the Faroe Shelf.

Poster presentation

DRIVERS OF THE SHIFTING RECRUITMENT DYNAMICS OF REDFISH (SEBASTES MENTELLA) IN THE GULF OF ST. LAWRENCE, CANADA

Burns, Corinne M, Burns, C. M., Plourde, S., Lehoux, C., Pepin, P., Sirois, P., Robert, D.

After 30 years of poor recruitment, stock collapse and fishery moratorium, the Gulf of St. Lawrence (GSL) deepwater redfish (*Sebastes mentella*) stock has produced an exceptionally strong year class in 2011, followed by at least two additional successful cohorts within the last decade. This shift in recruitment dynamics in the 2010s has sparked a massive return of this groundfish, which currently accounts for 90% of the demersal biomass in the GSL. Recruitment success in fish is primarily driven by survival during the larval stage, when individuals are highly vulnerable to prey availability and variability in their abiotic environment. First, we identified the key prey taxa of larval redfish and investigated the relationship between feeding success and growth, to assess the potential biological recruitment drivers. Based on the diet composition of larval redfish sampled over 4 consecutive years, we found that eggs from the calanoid copepod *Calanus finmarchicus* represented the most frequently consumed prey, and contributed the largest proportion of carbon ingested. Even though *C. finmarchicus* eggs constitute a preferred prey for redfish larvae, we also found that individuals that had consumed naupliar stages of copepods were deeper-bodied and grew more quickly than their conspecifics feeding on eggs. Relying on these elements, we investigate through a GAM approach the effects of biological (e.g. prey abundance and phenology) and physical (e.g. temperature, volume of the cold intermediate layer, timing of ice breakup) factors over the 1967-2016 redfish recruitment time series to reveal the primary recruitment drivers.

Poster presentation

SPATIOTEMPORAL VARIABILITY IN OTOLITH ELEMENTAL FINGERPRINT AND THE POTENTIAL TO DETERMINE REDFISH (SEBASTES MENTELLA) ORIGINS IN THE GULF OF ST. LAWRENCE, CANADA

Coussau, L., Robert, D., Sirois, P.

After a moratorium of 25 years, the reopening of the redfish fishery in the Gulf of St. Lawrence (GSL), Canada, is imminent. Following unprecedented recruitment events in the early 2010s, redfish currently accounts for about 90% of total demersal fish biomass in the GSL. A major management issue for this recovering stock is the lack of knowledge of redfish population structure and connectivity. Monitoring redfish movement through conventional or electronic tagging is challenging due to the systematic barotrauma suffered by individuals captured at sea. To overcome this constraint, we use otolith chemistry as natural tag of redfish origins and movements. We specifically targeted *Sebastes mentella* juveniles from the 2011 strong cohort sampled sequentially in 2016 and 2018 over the full management unit. Relying on laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS), elemental fingerprints were extracted from otolith core (proxy for larval origin) and edge (proxy for pre-capture location). The observed East-West spatial variations in the elemental fingerprint of the otolith edge confirmed the discriminating power of otolith chemistry in the GSL, although evidence of temporal variation between 2016 and 2018 was also detected. Cluster analysis of the core fingerprint revealed the existence of two chemically distinct natal sources in the population. The variable contribution of the two sources between the western and the eastern GSL suggest limited dispersal of redfish within the system. This new insight on the structure of redfish in the GSL at an ecologically-relevant scale constitute important knowledge for the robust assessment of a key resource

Poster presentation

EFFECTS OF CLIMATE AND DEMOGRAPHIC STRUCTURE OF SPAWNERS ON GROWTH AND SURVIVAL OF OFFSPRING

Kajiya Endo. C. A., Skogen, M. D., Hjøllø, S. S., Stige, L. C., Vikebø. F. B.

Global climate change and ocean variability are expected to affect marine organisms through all life stages. In the case of fish populations, climate change and fisheries are pointed as the main causes for modifications in dispersal, distribution, abundance, and population dynamics patterns. Northeast Atlantic (NEA) cod, or Barents Sea cod, is a heavily fished species that inhabits and feed in the Barents Sea, a highly impacted ecosystem by the global warming temperatures. Both, high fishing pressure and climate change act on the adult cod stock, by influencing the age composition and the condition of the spawning stock. Demographic changes in the spawning stock have been associated with different use of the spawning areas over time and with changes in the spawning season. As both climate change and harvesting pressure result in temporal and spatial variability in spawning and in adult spawning condition, survival of offspring and thereby recruitment variability are expected. Here, by using a coupled physical-biological model including an individual based model for NEA cod, we will analyse different scenarios for climate- and fisheries-induced changes in the use of spawning areas and duration of the spawning season. We analyse the survival of the offspring from spawning until the 0-age group arrival in the Barents Sea. We hypothesize that fisheries and climate induced changes in the spawning stock will have an impact over survival through the early life stages, and we expect that these results will help us better understand processes affecting survival and recruitment of this key commercial species.

Poster presentation

LONG-TERM SPATIAL AND TEMPORAL PATTERNS IN THE NORWEGIAN MACKEREL FISHERY FROM 1900 TO 2020

Tøsdal, T. G. H., Folkvord, A., Iversen, S. A., Skagseth, Ø., Nøttestad, L.

The North-East Atlantic (NEA) mackerel (*Scomber scombrus*) is one of the most abundant and valuable fish species in the Atlantic Ocean. During the last decade both abundance and geographical distribution of NEA mackerel has been the largest on record. This fishery has been expanded northwards along the Norwegian coastline since 2010 compared to the previous 100 years. A major aim of this study was to provide an overview of the historical large-scale variations in spatial and temporal patterns in the Norwegian mackerel fishery, by investigating mackerel landing data for the period 1900-2020. Overall trends in the Norwegian mackerel fishery from 1900 to 2020 consist of two very different periods; 1) a traditional coastal fishery with small catches from 1900 to 1963 and 2) a highly efficient purse seine fishery in open waters with large catches from 1964 to 2020. Time series on Atlantic Multidecadal Oscillation (AMO), Norwegian coastal temperature, and the North Atlantic Oscillation (NAO), may suggest environmental influence on the recent northern expansion of mackerel along the Norwegian coast. In this study we investigate and discuss the spatial and temporal patterns found in the Norwegian mackerel fishery in relation to stock abundance, fishery regulations, technological development and environmental dynamics. Both periodic and interannual variations in the observed spatial and temporal patterns of mackerel landings in Norway is complex and may indeed be influenced by several different factors.

Poster presentation

QUANTIFYING SPATIAL DYNAMICS AND STOCK STRUCTURE OF ATLANTIC HALIBUT WITHIN THE GULF OF ST. LAWRENCE TO IMPROVE SUSTAINABLE EXPLOITATION AND MANAGEMENT

Gauthier, C., Robert, D., LeBris, A., Fisher, J. A. D., Sirois, P.

In the decade 2010 to 2019, landed value of Canadian Atlantic halibut (*Hippoglossus hippoglossus*) tripled, ranking it now as the most valuable groundfish resource where it contributes one-third of total groundfish landed value. Halibut also exhibit the highest landings volumes in 60 years. Given these dynamics, halibut is now a key socio-economic resource in Atlantic Canada. Within this decade of strong return, improving knowledge of larval ecology and habitat use throughout halibut ontogeny continue to be crucial inputs to sustainable management of the stock. From 2013 to 2018, 114 Pop-up Satellite Archival Tags (PSAT) were deployed on adult halibut throughout the Gulf of St. Lawrence. The movement tracks reconstructed with a geolocation model revealed that spawning occurs in the deep channels of the Gulf, and PSAT detachment locations revealed specific summer site fidelity. More recently, otolith chemistry has also been used to offer a view of the entire life of the fish and information on the early-life history. Margins and cores of over 450 otoliths and transects of 200 otoliths were analysed by LA-ICP-MS to determine the number and the location of nurseries, and to infer migratory patterns using multivariate analysis of otolith trace elements on adults and juveniles. Our results suggest that Atlantic halibut in the GSL forms a philopatric population with multiple nurseries and that multiple contingents coexist in this population. With geolocation information, these results reveal the current extent of habitat use during a period of rapid population rebuilding over the past decade.

Poster presentation

MODELED SPECIES DISTRIBUTIONS AND CHANGES IN WATER TEMPERATURE AND ICE COVERAGE IN THE BARENTS SEA IN THE LAST DECADE

Nascimento, M. C., Husson, B., Guillet, L., Torstein Pedersen, T.

An increase in the water temperature in boreal and arctic seas has been observed in the last few decades, and it can dramatically impact the whole ecosystem. In the Barents Sea, the last decade (based on Kola section 0-200 m measurements) was on average 0.26°C warmer than the previous decade (2000-2009) and 0.72 °C warmer than the decade from 1990 to 1999. We used an Ecopath with Ecosim (EwE) model with 108 functional groups (FG) representing the Barents Sea (BS) ecosystem (Pedersen et al., 2021). Then we created a spatial model using the Ecospace plugin of the EwE software. We parameterized our spatial model with the habitat capacities calculated from observed distributions for warm and cold years based on published literature and survey information provided by the Institute of Marine Research. We observed a high correspondence between the modeled and observed spatial distributions when comparing the predicted and natural distribution's center of gravity and other measures in a given year. Then we projected the distributions of the same FGs for 1998 (average bottom temperature 0.25°C) and 2019 (average bottom temperature 1.1 °C), and we observed that the centers of gravities for the projected distributions in 2019 on average differed about 150 km from the projected distribution in 1998. In general, the changes were towards a more northern and northeastern distribution, showing that with the increase in temperatures and reduction in the ice coverage in the Barents Sea, many ecological groups are moving north.

Poster presentation

CLIMATE CHANGE AND NEW POTENTIAL SPAWNING SITES FOR NORTH EAST ARCTIC COD

Stiansen, J. E., Sandø, A. B., Johansen, G. O., Aglen, A., Renner, A.,

The talk will address both historical and potential future changes in the spatial distribution of spawning habitats for Northeast Arctic cod (NEA cod) based on a literature study on spawning habitats and different physical factors from a downscaled climate model. The approach uses a high-resolution regional ocean model to analyze spawning sites, which provides more details about crucial physical factors than a global low-resolution model. The model is evaluated towards observed temperature along the Norwegian coast during the last decades. However, the model does not take into consideration biological or evolutionary factors which also have impact on choice of spawning sites. Our results from the downscaled RCP4.5 scenario suggest that the spawning sites will be shifted further northeastwards, with new location at the Russian coast close to Murmansk over the next 50 years. The regional model gives future temperatures above the chosen lower critical minimum value in larger areas than today and indicates that spawning will be more extensive there. Dependent on the chosen upper temperature boundary, future temperatures may become a limiting factor for spawning habitats at traditional spawning sites south of Lofoten. Observed long-term latitudinal shifts in spawning habitats along the Norwegian coast the recent decades may be indirectly linked to temperature through the latitudinal shift of the sea ice edge and the corresponding shift in available ice-free predation habitats, which control the average migration distance to the spawning sites. Physical limitations for defining the spawning sites might be proxies for other biophysically related factors.

Poster presentation

TRANSBOUNDARY COOPERATION AND MECHANISMS FOR MARITIME SPATIAL PLANNING

Gómez-Ballesteros, M., Cervera-Núñez, C., Campillos-Llanos, M., Quintela, A., Sousa, L., Márcia Marques, M., Lopes Alves, F., Virto C. M., Neil Alloncle, N., Sala, P., Capote, A. L., Simao, A. P., Costa, A., Carval, D., Bailly, D., Nys, C., Henry, S.

SIMNORAT project, Supporting Implementation of Maritime Spatial Planning in the Northern European Atlantic region (SIMNORAT), was a cofounded EU MSP project developed in the Atlantic region. The aims of the project were to support the Member States (MS) to implement the Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for Maritime Spatial Planning (MSP); and launch and carry out concrete and cross-border MSP initiatives between MS involved in the project (Spain, France and Portugal). To develop and test aspects of MSP in order to produce useful guidelines and recommendations in a transboundary context, the Competent Authorities of the countries were also involved in the project. The results of SIMNORAT, as the development of conceptual methodology for transboundary MSP, analysis of tools and data applied in MSP processed, assessment of spatial demands and trends from maritime sectors, engaging stakeholders; helped to identify best practices on scientific, technical and social aspects of MSP for an effective cooperation, especially in transboundary case study areas, to improve the implementation of the MSP Directive in each country with collaborative efforts and a common vision. This in turn, can support the creation of the appropriate framework to develop sustainable blue economy in the region, managing the associated social-ecological system in a changing environment.

Poster presentation

MARITIME SPATIAL PLANNING TRANSBOUNDARY PILOT PROJECTS AND THEIR IMPLICATION IN THE NATIONAL PROCESS IN SPAIN

Gómez-Ballesteros, M., Cervera-Núñez, C., Campillos-Llanos, M., Algarra, S. A., Capote, A. L., Virto C. M.

Maritime Spatial Planning (MSP) processes are already being implemented in many parts of the world being Europe a hot spot due to the approval of the Directive 2014/89/EU of the European Parliament and of the Council of 23 July 2014 establishing a framework for MSP, which obliged every coastal Member State (MS) to have approved plans by March 2021. To facilitate this, specific European funds are allocated to support the development of MSP transboundary projects among neighbouring countries. These projects have mainly two objectives, one is to provide states with knowledge, capacity and methodologies to apply in MSP national processes, and another one is to facilitate the coherence among plans of countries sharing the same sea basin. As biological and ecological processes in the marine environment are not limited by administrative borders, the transboundary component of MSP is of extremely importance to manage marine resources in a sustainable way. MSP provides then the framework to manage social-ecological systems (SES) in the marine domain throughout an adaptive management model that should be able to accommodate both, social and ecological changes. In this sense, pilot transboundary projects aim to develop and test these characteristics of MSP (among others) in order for the MS to apply them in their MSP national processes as well as to incorporate issues whose scope go beyond national borders. This work presents an overview of the Spanish MSP process, and how some of the outputs that emerged from these pilot projects may be incorporated in the national process.

Poster presentation

EFFECTS OF “EL CACHUCHO” MPA IMPLEMENTATION ON FISHING EXPLOITATION PATTERNS

Verisimo, Patricia, Verisimo, P., Fernández-Arcaya, U., Rodríguez-Basalo, A., Polo, J., Rodríguez, J., Ceballos, E., Ruiz, M., Sánchez, F., Punzón, A.

The establishment of Marine Protected Areas (MPAs) is one of the management tools to achieve the protection of marine biodiversity, as well as to fight against the collapse of fishing stocks, and thus to achieve the sustainability of the fisheries. While there is scientific evidence showing that the implementation of MPAs enhances habitat conservation, biodiversity and biomass within its boundaries, evidence of their effect on fishery resources and adjacent fisheries remains scarce. In addition, there are few estimates of the economic yield of the fishing fleet associated with these areas.

The aim of the present study was to assess the effect of the first offshore MPA declared in Spain, “El Cachucho” (Cantabrian Sea, NE Atlantic), on the spatial dynamics of the fleet, in terms of fishing effort and landings (kg), and on the economic yield (euros) of the main target species of the MPA and its area of influence. For this, the logbooks and VMS (Vessel Monitoring System) data from 2005 to 2019 were coupling and analyzed in order to describing potential changes in the spatial distribution of fishing activities and relationship between catch/values of landings by the different habitats.

The results showed that the implementation of the MPA causes changes in the spatial distribution of effort in the main fishing tactics, especially the concentration of the gillnet monkfish effort in some fishing grounds south of the MPA. Likewise, a change in the composition of landings was observed, notably the increased presence of *Molva macrophtalma*.

Poster presentation

BUILDING CONCEPTUAL MODELS OF MARINE SOCIO-ECOLOGICAL SYSTEMS WITH STAKEHOLDERS

Mikkelsen, N., Planque, B., Arneberg, P., Skern-Mauritzen, M., Hansen, C., Fauchald, P., Holsman, K. K., Haynie, A., Ottersen, G.

Marine ecosystems are under pressure due to impacts from climate change and other anthropogenic pressures. In the Barents Sea (BS), new areas become available for human activities as sea ice retreats. A northward expansion of industrial fisheries is already observed. Multiple, often interacting, stressors and ecosystem complexity, call for Ecosystem-Based Management (EBM). In EBM, stakeholder involvement is considered a key principle for implementation. In the BarentsRisk project, we aim to assess cumulative impacts of the main operating sectors in the BS; fisheries, petroleum, tourism and shipping by applying an Ecosystem Risk Assessment (ERA) approach. A first step of the ERA is the ‘scoping’ phase. During scoping, scientists and stakeholders jointly determine what are the key focal issues of concern, and the relevant components and interactions involved. Here we examine how an open and flexible multi-stakeholder approach can inform EBM priorities. We invited stakeholders to develop conceptual network models of the BS socio-ecological system. Six sectorial-based stakeholder groups constructed directed graphs. Then, a collective conceptual model was constructed to capture common understanding across groups. The stakeholders' representation of the BS socio-ecological system was complex and often group specific. Nevertheless, the collective model can strengthen prioritisation in ERA and support the development of qualitative network models which allows for exploration of perturbations and can inform cross-sectoral management.

Poster presentation