

Biomass, biodiversity, and ecosystem services in the mesopelagic zone

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This session evolved from discussions during the 5th Ocean Outlook meeting and the BIARRITZ (Bridging International Activity and Related Research Into the Twilight Zone) workshop in May and July 2019, respectively.

Synopsis from the call

Recent acoustic estimates suggest that the mesopelagic zone might harbour 10,000 million metric tonnes of unexploited fish biomass, far exceeding global fisheries catches in the epipelagic zone. This has attracted renewed attention to the utilisation of mesopelagic resources. With the global demand for food projected to increase by 60% by 2050, the sustainable exploitation of mesopelagic resources represents a potential game changer.

The fundamental biological knowledge needed for sustainable resource management and an understanding of the vital role of mesopelagic communities in global processes e.g., biogeochemical cycling, is however lacking. Therefore, renewed research efforts on this largely unexplored and unexplained ocean realm are timely.

This theme session provides an opportunity to review and report on the extensive ongoing international activities in mesopelagic research. Empiricists, modelers, experimentalists, and theoreticians are invited to present studies, share findings from recent cruises, and exchange ideas on the structure, function, and change of mesopelagic ecosystems and interactions with other ocean realms.

Contributions are invited that relate to the mesopelagic zone and:

- biomass and biodiversity
- life histories and behaviour
- foodweb interactions
- the biological carbon pump and climate regulation
- technological advances to study the ocean twilight zone

Specific examples of interest include:

- the estimation of mesopelagic biomass
- species composition, population structure, and complex biogeography of mesopelagic communities
- drivers of its biomass and interactions with epipelagic and bathypelagic communities
- physiological measurements of vital rates
- studies of life histories and behaviours
- the importance of midwater species in the diet of oceanic top predators and commercial fish stocks

- the fraction of mesopelagic organisms that migrate and controls on their migration
- consequences of deoxygenation for mesopelagic biota
- implications of harvesting midwater organisms.

Session format

The session attracted 26 high quality research contributions from 10 countries (Brazil, Denmark, Germany, Greece, Ireland, Norway, Russia, Spain, United Kingdom, USA), thereof 16 by early career scientists. Pre-recorded videos for 10 talks and 16 poster presentations were available for on-demand viewing through the conference app Whova.

The submissions spanned a wide range of topics, including all the main thematic aspects highlighted in the session call (i.e., biomass and biodiversity, life histories and behaviour, foodweb interactions, the biological carbon pump and climate regulation, technological advances to study the ocean twilight zone). The submissions may be grouped broadly into the following four overarching research themes: spatio-temporal interactions between individuals or communities (12 submissions), (ii) carbon fluxes through the mesopelagic zone (4 submissions), (iii) technological advances to study life in the mesopelagic zone i.e., eDNA, acoustics or optical systems (7 studies), and (iv) fisheries and food for human consumption (3 studies).

For the live session, we had an additional open call for project pitches. The aim of these short (max. 5 minutes) and informal pitches was to spark discussions, invite collaborations, or make colleagues aware of recent methodological advances. We aimed for forward-looking pitches to complement the recordings that summarised past research. Pitches were intended to act as conversation starters, and each was followed by an hourlong virtual meet where everyone was invited to engage in follow-up discussions. No rapporteurs were assigned for these virtual meets to keep the threshold for discussions as low as possible.

The following 8 pitches were presented:

Henrike Andresen *et al.* (Thuenen Institute of Sea Fisheries, Germany): *“Functional traits to analyse mesopelagic fish communities”*

Naiara Rodríguez-Ezpeleta (AZTI, Spain): *“Current research on mesopelagic genomics and potential new projects and collaborations”*

Joel Llopiz *et al.* (WHOI, USA): *“Opportunities to collaborate on basin-scale variability and mesopelagic fish and zooplankton ecology”*

Natalya Gallo *et al.* (University of Bergen, Norway): *“Examining the effects of hypoxia on mesopelagic fish in Norwegian fjords using otolith microchemistry and lab rearing”*

Anna Belcher (BAS, UK): *“Measuring respiration of mesopelagic nekton: approaches and challenges”*

Maxime Geoffroy (Memorial University of Newfoundland, Canada): *“Mesopelagic organisms in the Arctic: possibilities to compare the Canadian and European Arctic”*

Melina Kourantidou & Di Jin (WHOI, USA): “*Integrating mesopelagic science into policy*”

Adrian Martin (NOC, UK) & Kelsey Bisson (Oregon State University, USA): “*JETZON - Joint Exploration of the Twilight Zone Ocean Network*”

Scientific take-home messages

The key take-home messages from the four research themes that we identified above can be summarised as following.

Spatio-temporal interactions between individuals or communities

Contributions to this research theme were highly diverse. Several studies were focused on biogeographical patterns and variations (García-Seoane *et al.*, Wiebe *et al.*, and Receveur *et al.*). These studies highlight large spatial variability but also consistent patterns e.g., in diel vertical migrations, and emphasize the complexity of disentangling underlying drivers beyond correlations. Receveur *et al.* developed a correlative modelling framework that succeeded in reconstructing backscatter temporally, spatially, and vertically. Dolgov *et al.*, Duncan *et al.*, Kapelonis *et al.*, and Eduardo *et al.* presented studies on the diet and trophic relations, assemblage structure and functional composition of mesopelagic communities from the Irminger Sea, the Mediterranean Sea, Tropical Atlantic and Canary and Benguela Currents. An important stride to consolidate knowledge from community and distributional studies is the initiative to build a trait database for mesopelagic fish, presented by Andersen *et al.* Further, two studies by Yebra *et al.* and Langbehn *et al.*, stressed that mesopelagic-demersal coupling might be an important, but often overlooked mechanism structuring energy fluxes from surface waters to the deep ocean and from offshore to coastal systems. Christiansen *et al.* pointed to another knowledge gap, the role of individual behaviour in structuring the behaviour of the ubiquitous sound scattering layers. In their work, they demonstrate how stationary echosounders can be used to study the individual swimming behaviour of single mesopelagic fish.

Carbon fluxes through the mesopelagic zone

Mesopelagic diel vertical migrators play a potentially significant role in the sequestration of carbon to the deep ocean. However, to date our estimates of fish-mediated carbon export are highly uncertain and spatially patchy. Here, the work by Pinti *et al.*, Cook *et al.*, Eduardo *et al.* and McMonagle & Essington make valuable contributions. Pinti *et al.* estimated carbon export for different functional groups using a global game-theoretic trait-based mechanistic model. They concluded that mesozooplankton and macrozooplankton account for most of the total export below the euphotic zone, estimated at 11.2 PgC/yr, while fish account for roughly 20%. They further estimated that the export flux mediated by zooplankton is more important than export fluxes mediated by fish, but that the sequestration potential of the fish pathways is relatively higher than that of the zooplankton pathways — resulting in longer sequestration times for carbon exported via fish excretion or mesopelagic fish respiration. However, these and other model estimates of fish mediated carbon export remain highly uncertain. McMonagle & Essington ask, “How precisely do we know the parameters that govern fish carbon flux?” and “What is the consequence of imprecision on ecosystem carbon flux estimates?”, on their poster they propose a way forward to characterise these uncertainties. The studies by Cook *et al.* and Eduardo *et*

al. are regional process studies of carbon export, that add biological realism to the global model predictions and are invaluable source for model validation.

Technological advances to study life in the mesopelagic zone

Recent technological advances to study life in the mesopelagic zone have been made mainly in the field of eDNA and hydroacoustics. The presentations by Wieczorek *et al.*, Cotter *et al.*, and Khodabandeloo *et al.* were concerned with how acoustic observations can be translated into more accurate biomass estimates. Notable advances were presented in relation to acquiring and validating target strength measurements across a wider range of frequencies and developing target strength models that will enhance the characterization and identification of individual organisms from broadband acoustics. All presenters emphasized the critical importance of acquiring accurate target strength measurements to achieve reliable organism density estimates. Another key take home message is that broadband target strength measurements provide insights into the distribution of organisms in the mesopelagic. Further, Cotter *et al.*, presented in a second study the capabilities of Deep-See, an advanced towed instrumentation platform developed by WHOI that supports an array of broadband active acoustic transducers (1-450 kHz), a multibeam sonar (500 kHz), a stereo-optical camera system, a holographic camera, an eDNA sampler, and environmental sensors. The studies by Bucklin *et al.* and Canals *et al.* focus on eDNA and metabarcoding as emergent tools in mesopelagic research. Their consensus is that these molecular techniques can provide valuable information on deep-sea fish diversity, vertical structuring and diel vertical migratory behaviour, and trophic interactions. The study by Allen *et al.* presents a numerical model with particle tracking to simulate the release of eDNA from migrating and non-migrating organisms in the mesopelagic and qualitatively compare modelled patterns of vertical eDNA distribution to field observations. Linking such models to data will help us interpret and understand eDNA transport which is critical for moving eDNA forward as a viable tool to survey biomass in the mesopelagic.

Fisheries and food for human consumption

Payne & Hoagland take a look at historical exploitation of mesopelagic resources by the Soviet Union's Fishing Fleet concluded on their poster that "The extent of the ecological effects of the Soviet's Southern Ocean mesopelagic fishery are unknown, but any future exploitation of the mesopelagic zone [...] will require prudent and very likely precautionary management to prevent levels of harvest that could have far-reaching adverse ecological effects." This, and the low number of submissions related to management considerations, exemplifies the urgent need to create the knowledge needed to sustainably manage potential future fisheries in the mesopelagic. Wiech *et al.* compare nutrient composition and contaminant levels in six of the most abundant mesopelagic species in the North Atlantic. They show that "especially the fish species *B. glaciale* and *M. muelleri* were nutrient dense containing a high level of vitamin A1, calcium, selenium, iodine, EPA, DHA and cetoleic acid" and conclude that "mesopelagic species have the potential to contribute significantly to food and feed security, if a sustainable harvest is possible." However, concerns remain about the suitability of mesopelagic resources for direct human consumption and as fish feed for aquaculture. Bao *et al.* show that the "consumption of mesopelagic fishes raw, marinated or lightly cooked would pose a risk of anisakiasis" (a parasitic disease caused by anisakid nematodes). They also warn that "thermostable allergens may

pose a risk for sensitized consumers” and that “these allergens may potentially be transferred from fish feed based on mesopelagic fish to farmed fish.”

Conclusions and recommendations

According to the conference app Whova (as of 17.09.2021), 93 people have attended the session, and 201 individuals have watched the recorded videos. This demonstrates a large interest in the topic. Additionally, the virtual meets were generally well attended and have already resulted in new collaborations, proposal ideas, and data sharing opportunities. Generally, there appeared to be a large willingness of the community to work together and share insights and data. This is for example shown through the coordinated efforts made under the umbrella of JETZON, a UN Ocean Decade Programme, acting as an international coordinator and focal point for Twilight Zone studies, but also the project pitches presented during the live sessions.

While strides have been made across the board, reducing the uncertainties in biomass estimates and the contribution of mesopelagic organism to carbon sequestration remain a key challenge. It has also become clear that eDNA is an emergent tool with the potential to revolutionise observation in the twilight zone. Here, the key challenge is to move from presence absence data to quantitative estimates. While large scale patterns in community composition, distribution, trophic interactions, or migration behaviour have been the focus of many recent studies, there is a lack of studies on the role of individuals. It has also become clear that mesopelagic research is still a niche topic as studies have not yet penetrated into the other Theme sessions focused on e.g., management. It is timely to more closely link the structure and function of mesopelagic ecosystems to other parts of the oceans and consider their importance for commercially exploited fish stocks in surface waters. Therefore, one suggestion would be to establish an ICES working group on mesopelagic ecosystems as a more permanent arena for exchange and to facilitate more interactions with already existing ICES working groups.