WORKSHOP ON THE DEVELOPMENT OF PRACTICAL SURVEY METHODS FOR MEASUREMETNS AND MONITORING IN THE MESOPELAGIC ZONE (WKMESOMETH)

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International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

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Editors

Ciaran O'Donnell • Gavin Macaulay

Authors

Anibal Aliaga • Kevin M. Boswell • Guillermo Boyra • Andy Brierley • Pablo Carrera • Bram Couperus David Demer • Tomas Didrikas • Haraldur Einarsson • Pablo Escobar-Flores • Joe Freijer • Sven Gastauer • Stephane Gauthier • Maxime Geoffroy • François Gerlotto • Roudaut Gildas • Mariano Gutierrez Torero • John Horne • Jan Arge Jacobsen • J. Michael Jech • Zacharias Kapelonis • Rudy Kloser • Erin LaBrecque • Richard O'Driscoll • Geir Pedersen • Marian Peña • Jhon Robles • Jose Rojas Martin Santivañez Yuffra • Ben Scoulding • Aquiles Sepulveda • Chris Taylor • Rebecca Thomas Castillo Valderrama • Jeroen Van der Kooij

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Contents

i Executive summary

The Workshop on the development of practical survey methods for measurements and monitoring in the mesopelagic zone (WKMESOMeth) chaired by Ciaran O'Donnell (Ireland), and Gavin Macaulay (Norway), met in Galway, Ireland, 27-28 April 2019.

The workshop objectives were to catalogue current mesopelagic surveys, report on existing data and research findings, report on opportunities and limitations of mesopelagic surveys, evaluate and report on potential for mesopelagic surveys, and determine requirements for carrying out mesopelagic surveys.

Fifteen survey programs currently report acoustic density of fish in the mesopelagic zone, with nine more reporting the capacity to do so. In addition, five large-scale international mesopelagic research projects are underway.

The main additional effort required to obtain mesopelagic information on existing surveys were identified to be dedicated trawling for mesopelagic organisms using a trawl designed to catch such organisms, the use of more than one acoustic frequency (preferably several), and careful survey design modification to ensure that the addition of mesopelagic activities does not adversely affect existing surveying objectives.

Limitations in using acoustic techniques to quantify mesopelagic species from existing acous-tic surveys include the lack of acoustic target strength knowledge, the lack of operational range for the higher acoustic frequencies when operated from a surface vessel and obtaining adequate ground-truth information on the species-composition of the observed backscatter. Absolute biomass estimates require more survey and sampling effort and tools than do rela-tive biomass estimates.

An important aim of the workshop was to identify methods that could be used on the International blue whiting spawning stock survey (IBWSS). The IBWSS survey program has the capacity to do this without disrupting the core work program. However, additional time and resources are required. Suitable reporting structures, analysis tools and data repositories al-ready exist within ICES Working Group on International Pelagic Surveys (WGIPS). Similar considerations apply to other existing survey programs.

The development of protocols for the classification of mesopelagic fish during the IBWSS survey, through WGIPS, are encouraged and could also be used for the re-analysis of other existing acoustic survey data. This would provide acoustic density and distribution of meso-pelagic fish where none currently exists.

ii Expert group information

Expert group name	Workshop on The Development of Practical Survey Methods for Measurements and Monitoring in the Mesopelagic Zone (WKMESOmeth)
Expert group cycle	Annual
Year cycle started	[2019]
Reporting year in cycle	1/1
Chair(s)	Ciaran O'Donnell, Ireland
	Gavin Macaulay, Norway
Meeting venue(s) and dates	27-28 April, 2019, Galway, Ireland, (37 participants)

1 Terms of Reference

WKMESOMeth – Workshop on the development of practical survey methods for measurements and monitoring in the mesopelagic zone

2017/2/EOSG22 The **Workshop on the development of practical survey methods for measuring and monitoring in the mesopelagic zone** (WKMESOMeth), chaired by Ciaran O'Donnell*, Ireland, and Gavin Macaulay*, Norway, will meet in Galway, Ireland, 27-28 April 2019 to:

a) Catalogue current open ocean surveys, in a global context that undertake, or have the capacity to undertake, acoustic measurements and biological sampling of animals within the mesopelagic zone. (Science plan code 3.2)
b) Report on example data and research findings for discussion to determine what is achievable from described vessel, platform and vehicle based surveys for the development of mesopelagic biomass monitoring programs. (Science plan codes 3.3, 3.4)
c) Examine and report on the opportunities and limitations associated with measurements of abundance including acoustic detection criteria, species discrimination and biological sampling, in the context of existing routine acoustic surveys. (Science plan code 2.3)
d) Evaluate and report on the potential to develop methods to establish abundance monitoring of mesopelagic fishes during open ocean surveys within ICES coordinated surveys, including, WGIPS and WGMEGS, given the complexity involved and equipment currently in use. (Science plan code 4.1)
e) Determine the minimum requirements in terms of resources, hardware and sampling equipment required for meaningful abundance measurements, and determine the components of the mesopelagic zone to which this applies. (Science plan codes 5.2, 6.6)

WKMESOMeth will report by 10 June 2019 for the attention of the EOSG Committee.

2 Final Report on ToRs, Work Plan and Science Implementation Plan

2.1 Workshop origins

2.1.1 Survey standardisation and harmonisation of methods

The Working Group of International Pelagic surveys (WGIPS) is one of the ICES coordination groups involved with reporting on national and international acoustic survey effort carried out in the NE Atlantic. As part of its core program, WGIPS maintains a regular internal review process to harmonise methods used for the collection and analysis of survey data used to calculate biomass and abundance from acoustic trawl surveys coordinated by the group (ICES, 2012, ICES, 2015, ICES 2015b, ICES, 2015c).

This workshop forms part of this ongoing process focussing specifically on the development of a structured approach on how to report on abundance and biomass of mesopelagic fish from open ocean survey data collected during WGIPS coordinated surveys.

The focus of the WK was to draw on international expertise to help develop structured methods for the collection of acoustic data and biological sampling procedures. The information from the WK will be used to develop methods to collect data on the abundance and distribution of mesopelagic fish resources during future surveys coordinated by WGIPS.

2.1.2 Review and development within the IBWSS survey

The International Blue Whiting Spawning Stock Survey (IBWSS) survey was first established in 2004. The survey is carried out annually over a three-week period in March/April by vessels from Ireland, Norway, Russia (2004-2016), Faroes, the Netherlands and most recently Spain (ICES, 2018). The survey reports the 'global' distribution and age stratified abundance of the Northeast Atlantic blue whiting stock during the spawning season to the west of Ireland and Britain. Survey results are submitted annually to WGWIDE (Stock assessment WG of Widely Distributed Stocks) and survey data are submitted to online database(s) hosted by the Faroe Islands (NAPES database) and ICES (Acoustic trawl database). Coordination and planning is undertaken during a post-cruise meeting (April) and reported to WGIPS in January of the following year.

During the 2017 meeting discussions were had relating to the *ad hoc* submission of acoustic allocations categorised as 'mesopelagic fish' to the survey database (2004-present). A review of methods reported that at a national level all nations scrutinise echograms to include mesopelagic fish and krill (ICES, 2017). However, in reality only two nations (Ireland and Faroes) consistently submit data. To date over 10,200 individual records exist in the database, binned by depth (50m) and elementary sampling distance unit (EDSU). However, no agreed protocol exists for the definition of what constitutes allocations to this generic 'mesopelagic' category, such as time of day or vertical depth and is therefore highly subjective.

It was agreed that a workshop was required to assist in the process of developing methods for future meaningful data collection and to devise a structured approach based on the experience of others working in this field.

2.2 Current open ocean surveys in a global context

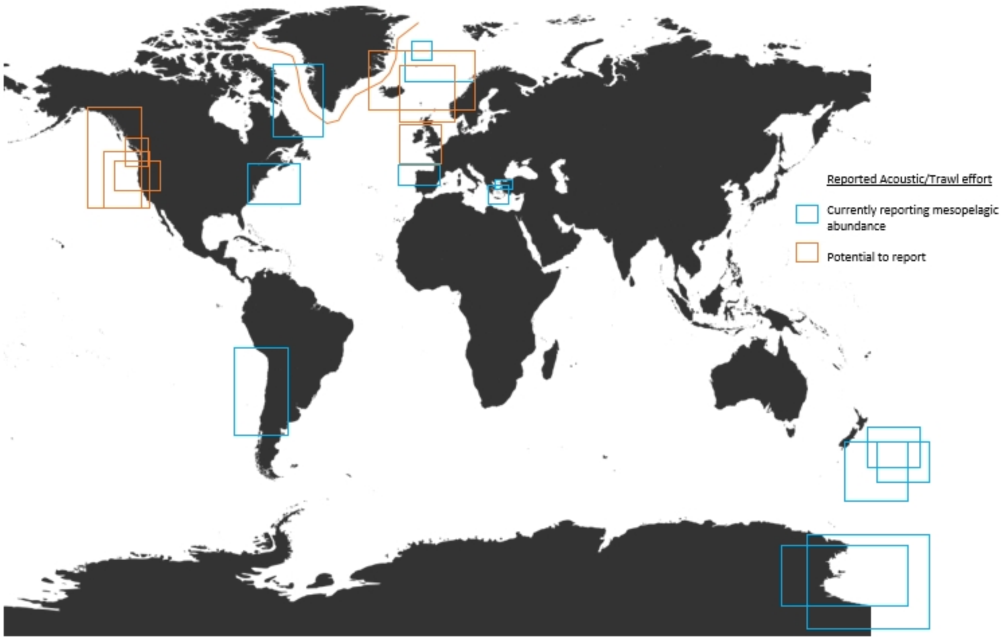

Figure 2.2.1 Overview map of generalised global coverage of current acoustic surveys reporting the acoustic density of mesopelagic fish (blue) and surveys with the potential to do so in the future (orange).

2.2.1 Surveys currently undertaking acoustic measurements and biological sampling within the mesopelagic zone

A summary table of individual survey details is provided in Annex 3, Table 1.

2.2.1.1 JUVENA survey in the Bay of Biscay

The JUVENA survey estimates the abundance of juvenile anchovy in the Bay of Biscay since year 2003. In year 2013 *Maurolicus muelleri* was add to the list of target species, and the survey started to provide tentative estimates of abundance of this species among the rest of assessed small pelagics.

The survey is conducted onboard the chartered R/V *Ramon Margalef* and the R/V *Emma Bardán*, both equipped with scientific echosounders. The acoustic equipment includes Simrad EK60 split beam echo sounders. In the *Ramon Margalef*, the 18, 38, 70, 120, 200 and 333 kHz transducers are installed looking vertically downwards, 6.5 m deep, at the drop keel, whereas at the R/V *Emma Bardan* the 38, 120 and 200 kHz transducers are installed at the hull.

The water column is sampled to depths of 450 m. Acoustic back-scattered energy by surface unit (Sa, MacLennan et al. 2002) is recorded for each geo-referenced ESDU of 0.1 nautical mile (185.2 m). Fish identity and population size structure is obtained from fishing hauls and echotrace characteristic using pelagic trawls. About 20 direct trawls are used specifically for mesopelagic species in each survey. Acoustic data, thresholded to -60 dB, is echointegrated by depth layers and converted to biomass using the post-stratification methodology described in (Boyra, 2018). Processing software was Movies+ until 2017 and Echoview since 2018. As *M. muelleri* is found normally in monospecific aggregations, no particular species differencing procedures are applied apart from standard multiple species echointegration conversion factors based on the TS-length relations of each species and their mean proportions and lengths per strata (as described in Simmonds and MacLennan, 2005). For *M. muelleri*, so far the TS value by (Scoulding et al., 2015) is used, although there is ongoing work to estimate a local TS-length relationship for this species.

The preliminary abundance estimations of *M. muelleri* obtained have ranged between 130,000 tonnes (in 2016) and 315,000 tonnes (in 2017) with an average of 220,000 tonnes. The species distributes horizontally from the outer part of the continental shelf until oceanic waters, the bulk of the population occupying water depths between 25 and 300 m (Figure 2.2.1.1.1). They have been observed to describe daily vertical migrations of about ~75 m (from ~125 m in daytime to ~50 in night time).

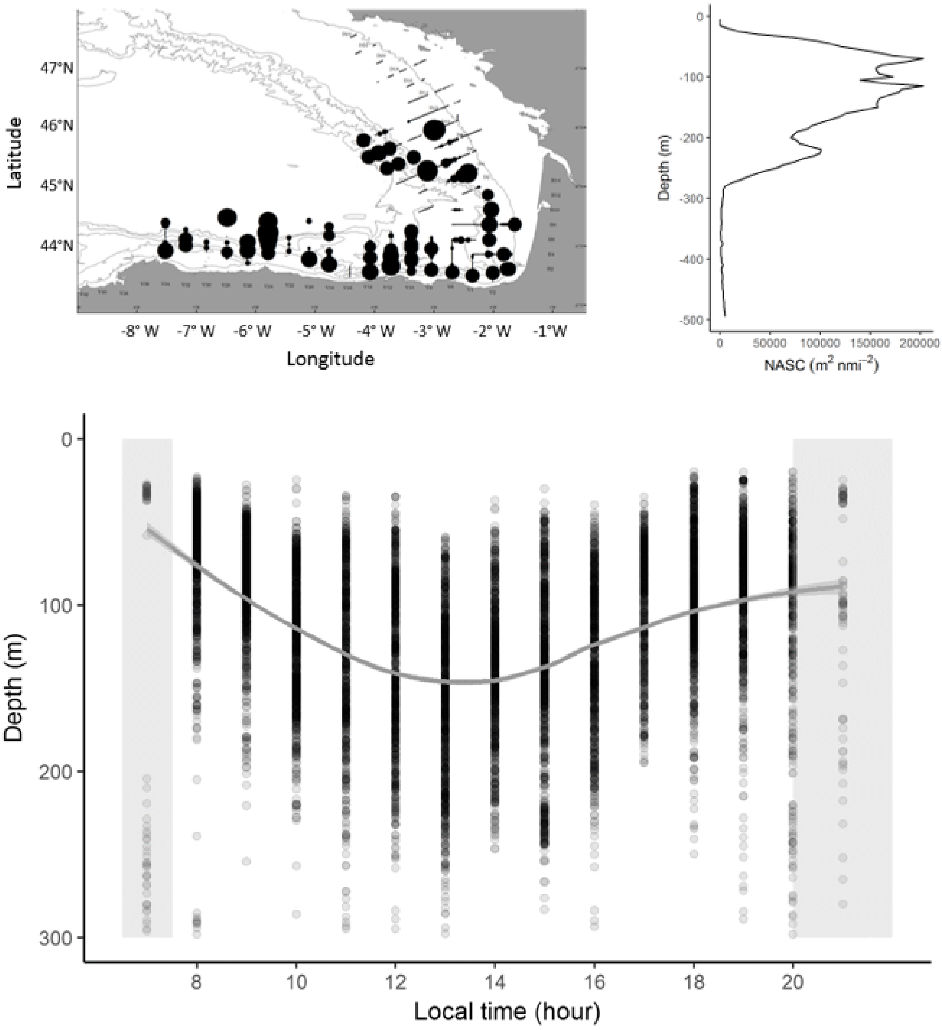

Figure 2.2.1.1.1 Top: Horizontal (left) and vertical (right) distribution of the Nautical Area Scattering Coefficient (NASC; m2 nmi-2) of *M. muelleri* in the JUVENA 2018 survey. Bathymetric lines drawn in grey. Bottom: Diurnal vertical migration patterns of *M. muelleri* with mean depth (m) plotted against local time of day in hours. The density of points is proportional to NASC (m2 nmi-2). Loess smoother represented as solid line.

2.2.1.2 Chatham Rise & Sub-Antarctic Surveys, New Zealand

Time series of acoustic indices of mesopelagic fish abundance were developed for the Chatham Rise and Sub-Antarctic (Figure) from acoustic data collected during random bottom trawl surveys from 2001 to 2018 (O'Driscoll et al. 2011, Stevens et al 2018). Data were collected from the National Institute of Water and Atmospheric Research (NIWA) research vessel *Tangaroa.* From

2001–08 data were from 12 and 38 kHz CREST echosounders with hull-mounted transducers. From 2009 onwards data were from 18, 38, 70, 120, and 200 kHz Simrad EK60 echosounders with hull-mounted transducers.

Limited data on species composition are available from other projects (Robertson et 1978, McClatchie & Dunford 2003, Gauthier et al. 2014, Section 2.2.1.3). Common mesopelagic groups include myctophids (*Lampanyctodes hectoris*, *Symbolophorus* spp.) and pearlside (*Maurolicus australis*). Mesopelagic schools and layers typically occur at 100–500 m depth during the day, and migrate into the surface 200 m at night (O'Driscoll et al. 2009). Acoustic indices of the vertically migrating component were based on the total 38-kHz backscatter observed during the day multiplied by the proportion observed in the upper 200 m at night. Indices on the Chatham Rise were corrected for an estimated 20% of mesopelagic fish migrating into the acoustic deadzone (within 14 m of the sea surface) (O'Driscoll et al. 2009), but this deadzone correction was not necessary in the Sub-Antarctic.

Although there were no clear trends in mesopelagic fish biomass over the last 18 years, there were clear and consistent spatial patterns in mesopelagic fish distribution over all years (O'Driscoll et al. 2011, Stevens et al. 2018). Abundance in areas of high mesopelagic fish density tended to be more variable between years. Spatial patterns in mesopelagic fish abundance closely matched the distribution of hoki (McClatchie e al. 2005, O'Driscoll et al. 2011). There was also a strong positive correlation between hoki condition (liver condition index) and "food per fish" (calculated from acoustically derived index of mesopelagic abundance divided by trawl estimates of hoki abundance) (Stevens et al. 2018).

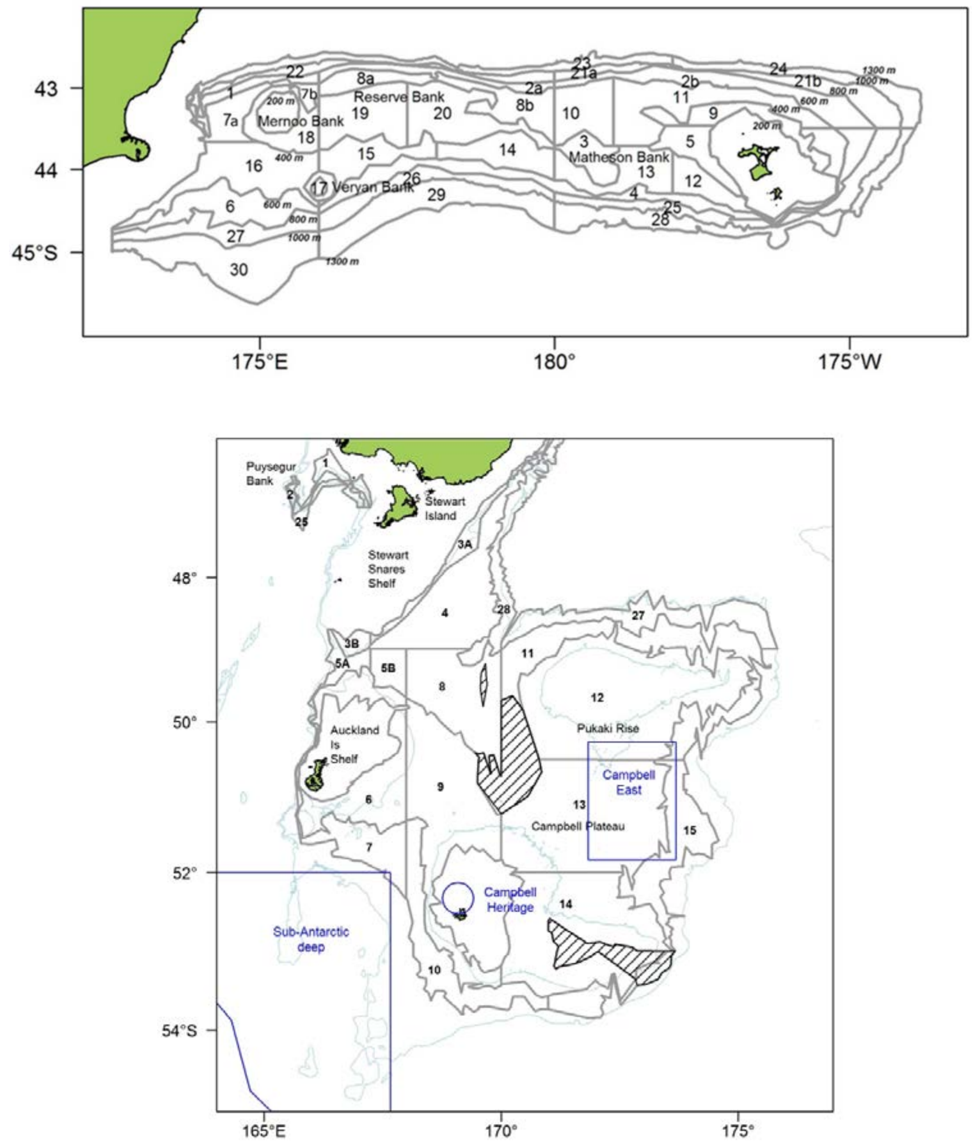

Figure 2.2.1.2.1 Maps showing locations of New Zealand demersal trawl survey areas on the Chatham Rise (upper panel) and in the Sub-Antarctic (lower panel).

2.2.1.3 Fisheries Oceanography Survey, Chatham Rise Survey, New Zealand

Four multidisciplinary fisheries oceanography research voyages were carried out on the Chatham Rise east of New Zealand between 2008 and 2015, to better understand the food-web structure of the Chatham Rise ecosystem and the functions of its different components. These voyages, funded New Zealand government through the Ministry of Business, Innovation and Employment (MBIE), had as one of their objectives the collection of information on the distribution and abundance of mid-trophic level functional groups (e.g., mesopelagic fish), using active acoustics and perform species' identification trawls ("mark ID trawls") on the acoustic targets. Acoustic data were collected from research vessel (RV) Tangaroa in May-June 2008, November 2011, August 2015 and December 2015 (voyage codes TAN0806, TAN1116, TAN151 and TAN1516), at 18, 38, 70, 120, and 200 kHz with Simrad EK-60 echosounders with hull-mounted transducers. Biological information on species composition was collected with a fine mesh mid-water trawl net, with a 10 mm cod-end mesh, a headline height of 12-15 m and a door spread of around 140-160 m. This mid-water gear is similar to the IYGPT (International Young Gadoid Pelagic Trawl).

Acoustic data collected during daytime mark ID trawls was used to develop a classification tree model for dominant species of mesopelagic fish and euphausiids, using the acoustic descriptors derived from multi-frequency data, vertical distribution of school and layers (i.e., minimum and maximum depth) and bottom depth. Acoustic recording from mark ID trawls were split into a model training and validation dataset. The resulting model was applied on the acoustic dataset from the Chatham Rise trawl survey time series from 2009-2010 to assess the temporal and spatial variability of mesopelagic fish community composition in the area. All the acoustic analyses were done using **ESP3,** an open-source software developed at NIWA (Ladroit 2017, ESP3 download | SourceForge.net), for visualising and processing active acoustics data as well as applying school detection algorithms. We also implemented the application of the classification tree model in ESP3.

Using the methodology developed we were able to separate acoustically the sternoptychid *Maurolicus australis* and euphausiids, but we were constrained by the number of samples and uncertainty to confidently assign classes of mesopelagic fish to acoustic marks due to gear limitations, to extend our classification to other mesopelagic fish species. Backscatter associated with *M. australis* varied between years and showed a decreasing trend from 2011. Likewise, backscatter associated with euphausiids showed a statistically significant negative trend between 2009 and 2018. Future work should aim to increase the sample size of acoustic and biological information, and to formally relate changes to mesopelagic fish and euphausiids abundance to environmental changes on the Chatham Rise. This work is under revision on Frontiers of Marine Science (Escobar-Flores et al submitted).

2.2.1.4 Ross Sea Survey, Southern Ocean, New Zealand

Mid-trophic level (MTL) organisms link primary and tertiary consumers and play a key role in pelagic open-ocean marine ecosystems. In the Ross Sea the key mid-trophic level groups are krill, lanternfishes (Myctophidae), and Antarctic silverfish (*Pleuragramma antarctica*). Despite their importance, relatively little is known about the distribution and abundance of these groups on the Ross Sea shelf and slope, hence targeted sampling on MTL organisms has been identified as a priority in the research and monitoring plan of the recently established Ross Sea Marine Protected Area. Though the data collection stage has been completed, the analysis of this work is currently in progress. Data collected during six voyages between 2008 and 2019 will be used to determine the distribution and abundance of krill, lanternfishes, and Antarctic silverfish on the Ross Sea shelf and slope.

Data collection was done on board the *RV* Tangaroa, which is equipped with a suite of multi-frequency Simrad EK60 echosounders (18, 38, 70, 120, and 200 kHz). We collected acoustic data, including transiting to and from Antarctica. The echosounders ran autonomously but required a minimum of one scientific staff member on each watch to monitor data collection and observing acoustic marks of interest. The main objectives of these voyages were to collect opportunistic acoustics data throughout the voyage and biological samples from acoustic aggregations detected using midwater trawls. Targeted deployments on acoustic marks were done using a rectangular midwater trawl (RMT, dimensions 7x5 m, with 13 mm mesh size and PVC cod end) (Figure 2.2.1.4.1), and mesopelagic trawl (10 mm cod-end mesh, a headline height of 12-15 m and a door spread of around 140-160 m). The defined research objectives of these surveys are to identify and characterise acoustic marks of dominant pelagic organisms (e.g., mesopelagic fish, silverfish and krill), to establish spatial distribution patterns, undertake biogeography studies and assess changes in the ecosystem over time. Similarly, information and species composition and distribution will be used to explore the relationship between oceanography in the region which is poorly known (Escobar-Flores et al. 2018a).

Midwater trawls aimed different acoustic marks at various depths: a) pelagic schools: found in the top 500 m of the water column over deep water (> 1500 m) that were stronger at lower frequencies (i.e., 18 and 38 kHz); b) scattering layers: continuous layers present at different depths in the water column; c) mixed marks: weak aggregations typically within 300 m off the bottom where single targets were distinguishable; and two types of marks associated with krill due to their frequency response characterised by a stronger scattering at higher frequencies (i.e. 120 kHz): d) swarms: dense aggregations and e) diffuse krill marks: weaker marks without a well-defined structure. To date 71 target deployments have been carried out in the Ross Sea area (Figure 2.2.1.4.1). All fish and macroinvertebrate samples collected by the trawls was sorted where possible, identified, and species of interest were measured (length and weight). Biological samples are also used for isotope analyses and ecological studies.

The catch composition of the mark identification trawls varied between trawls but was relative consistent within trawls on the same aggregation types. For example, mark identification trawls on pelagic schools (Figure 2.2.1.4.2) provided compelling evidence to support that these marks correspond to the myctophid *Electrona carlsbergi*, where clean catches were obtained. Likewise, trawls aimed on swarms and diffuse krill marks yielded clean marks of Antarctic krill *Euphausia superba*. Ground-truthing information from acoustic mars will be used to characterise their frequency response, and assist the identification of acoustic marks to achieve the objectives defined for studying MTL organisms in the Ross Sea area.

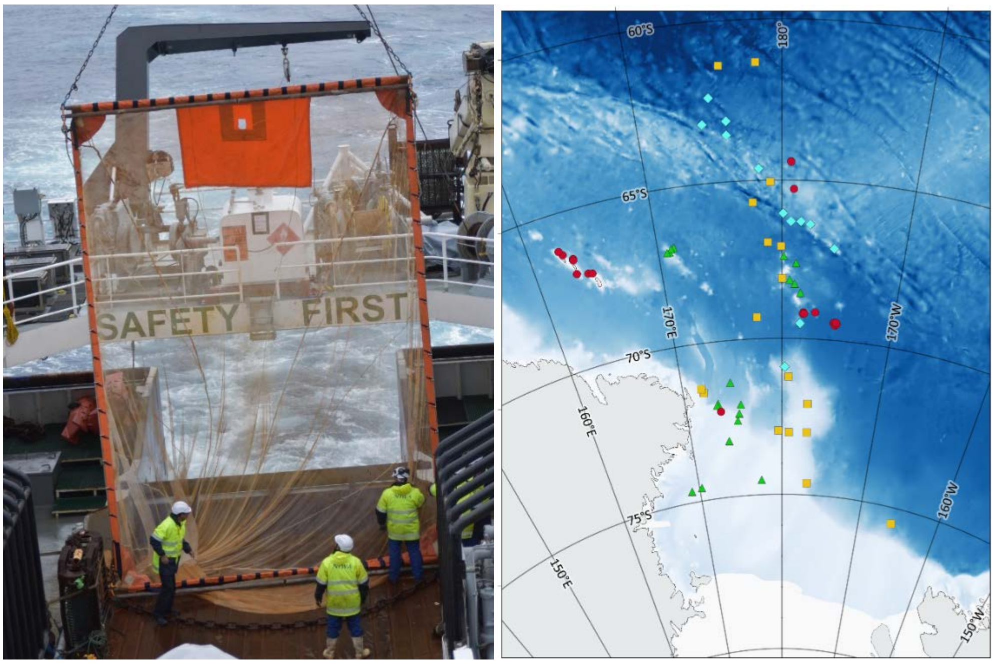

Figure 2.2.1.4.1. Rectangular midwater trawl (RMT) being prepared for deployment by the crew of the RV Tangaroa (left). Mark identification (Mark ID) trawls in the Ross Sea area from four Antarctic voyages: Tan2008 (red circles), Tan1502 (green triangles), Tan1802 (cyan diamonds), and Tan1901 (yellow squares).

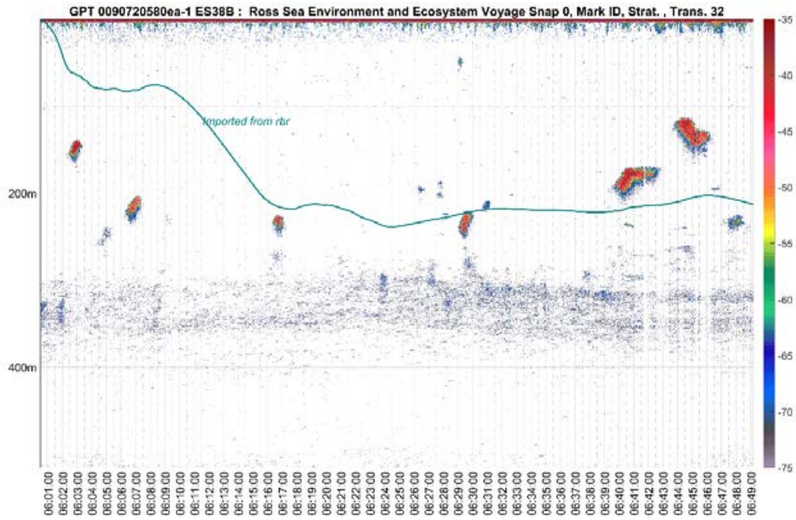

Figure 2.2.1.4.2. Echogram showing pelagic schools targeted on station number 32 using the mesopelagic trawl. Catch was dominated by the myctophid *Electrona carlsbergi* (inset in the figure). Green line shows the trawl path during the trawl as derived from the RBR temperature and depth data logger. Echogram shows volume backscattering coefficient (Sv) in decibels (dB) collected at 38 kHz. Y axis represents depth and x axis time/distance. Echogram threshold -75 dB.

2.2.1.5 Toothfish commercial vessel survey, Ross Sea, Southern Ocean, New Zealand

Mid-trophic level (MTL) organisms link primary and tertiary consumers and so play a key role in pelagic open-ocean marine ecosystems. Estimates of total biomass are uncertain, and basic ecological information, such as spatial distribution, abundance indices, and spatio-temporal variability are not yet established. Sampling difficulties posed by the vast areas of open-ocean and the biology of MTL organisms have led to initiatives to collect acoustic data opportunistically.

This approach can provide a starting point for the foundation of more advanced ecosystem indicators and models, and consistent monitoring strategies to generate long time series for detecting and interpreting changes in the ecosystem properties due to fishing and climate change (Escobar-Flores 2017).

A unique 7-year time series provided the opportunity to study the MTL of the pelagic open-ocean marine ecosystem in the New Zealand (NZ) sector of the Southern Ocean (SO). Twenty eight transects of mainly single frequency (38 or 18 kHz) but also multi-frequency (18, 38, 70, 120 and 200 kHz) acoustic data, were collected opportunistically during the transit of three toothfish fishing (San Aotea II, San Aspiring, Janas) and research vessels (*RV* Tangaroa) between NZ and the Ross Sea from 2008 until 2014 (Figure 2.2.1.5.1). Acoustic data was post-processed following the Integrated Marine Observing System (IMOS) protocols, with some modifications that improved signal processing.

Mean acoustic backscatter (s_a), a proxy for organism abundance, at 38 kHz varied between years, but overall was reasonably stable, and of the same order of magnitude across all transects. Vertical distribution showed clear diurnal vertical migration patterns, and seasonal differences. Large-scale horizontal distribution patterns of vertically summed backscatter were analysed and a consistent and significant decrease from north to south was detected. The deep scattering layers (DSL) detected in acoustic transects stopped north of the Ross Sea (Figure 2.2.1.5.1), which may be related to the temperature tolerance of DSL organisms (Escobar-Flores et al. 2018a).

Explanatory and predictive model for s_a were developed for the epi- and mesopelagic zone, using satellite-derived sea surface temperature and time of the day, and sea surface temperature and depth respectively. These models were tested in the NZ sector of the SO and also in an independent dataset in the Indian Ocean sector of the SO, and showed to perform well (Escobar-Flores et al. 2018b).

Catch information from research voyages on board RV *Tangaroa*, available literature on species-specific target strength-length (TS) relationships and TS from scattering models were used to convert s_a into biological density. Results suggested that changes in backscatter with latitude reflected different species' composition, rather than changes in biological density (Escobar-Flores et al. submitted).

This research based on opportunistic data collected initiatives provides the first time series of acoustic data on MTL organisms in the pelagic open-ocean marine ecosystem of the SO. The findings establish an excellent baseline for detecting and monitoring future changes in the SO ecosystem and its MTL component. This information can assist studies of top-predator population dynamics by providing insights into prey abundance. Consistent acoustic monitoring of the MTL can contribute useful ecosystem Essential Ocean Variables to observe and understand the status of the SO.

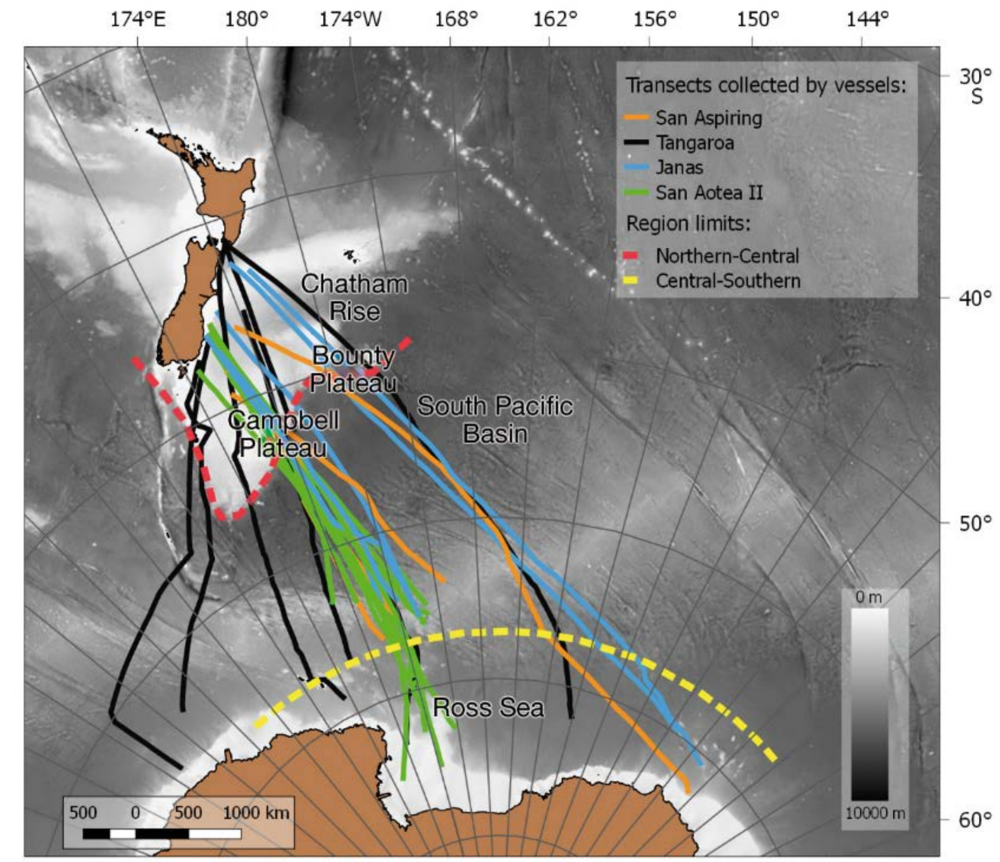

Figure 2.2.1.5.1. Total number of acoustic transects (n = 28) between New Zealand and Antarctica. Source: Escobar-Flores et al 2018a

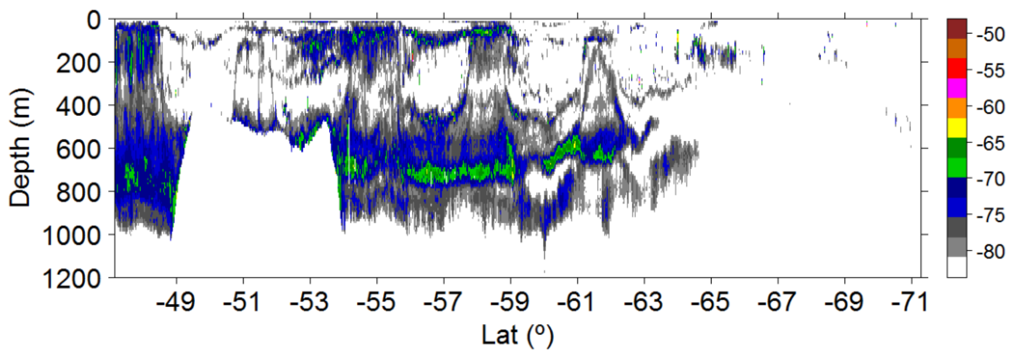

Figure 2.2.1.5.2. Acoustic echogram of transect collected by vessel 'San Aotea II' in 2010 between the Southern Ocean (right) and New Zealand (left), showing volume backscattering strength (S_v) in decibels (dB) echo-integrated in 1 km long and 10 m depth bins. Source: Escobar-Flores et al 2018a.

2.2.1.6 Deep-See, Northwest Atlantic

A collaborative research project between the Woods Hole Oceanographic Institution (WHOI) and the NOAA Northeast Fisheries Science Center (NEFSC) to study the deep scattering layers of the mesopelagic realm was initiated in 2017, with the inaugural cruise in August 2018 (Figure 2.2.1.6.1) and subsequent research surveys set until 2024. A sophisticated suite of acoustical, optical, biological, and oceanographic sensors comprise "Deep-See", which was developed at

WHOI with US National Science Foundation funding and is now providing data and information to WHOI's Ocean Twilight Zone (OTZ) research project. Deep-See can be lowered to depths of down to 1500 m collecting data in and amongst the layers of the mesopelagic fish, cephalopods, crustacea, and gelatinous organisms. By positioning Deep-See close to the animals, individual animals can be studied acoustically and optically in conjunction with concurrent measurements of eDNA and the environment. Oceanographic instruments include a conductivity-temperature-depth (CTD) sensor, transmissometer, and dissolved oxygen sensor; optical sensors include stereo high-resolution cameras, a LAPIS imaging system, a holographic camera, and a colour video camera; biological sampling include a pump and filter for collecting depth-specific eDNA; and acoustic systems include a 1-m2 8-element split-beam polyvinylidene fluoride-(PVDF) receive array for the Edgetech 1-6 kHz and 5-24 kHz and Airmar 18-45 kHz transmitters (the Airmar can be both a transmitter and a transmit/receive transducer), Simrad broadband split-beam systems at 70, 120, 200, and 333 kHz, and a Simrad/Mesotech M3 multibeam sonar. In addition to fine-scale Deep-See measurements, the 18, 38, 70, 120, and 200 kHz Simrad EK60 split-beam transducers mounted on a retractable keel on the NOAA ship HB Bigelow provide water column measurements over a broad scale.

Biological sampling with midwater trawls, Multiple Opening and Closing Nets and Environmental Sensing System (MOCNESS), and eDNA is conducted in concert with Deep-See measurements and observations to provide a full suite of data on the biology, ecology, and behaviour of the animals that make up the deep scattering layers. Biological samples are used for species identification, length and weight measurements, maturity, sex, age, diet composition, and verification of the sources of acoustic backscatter.

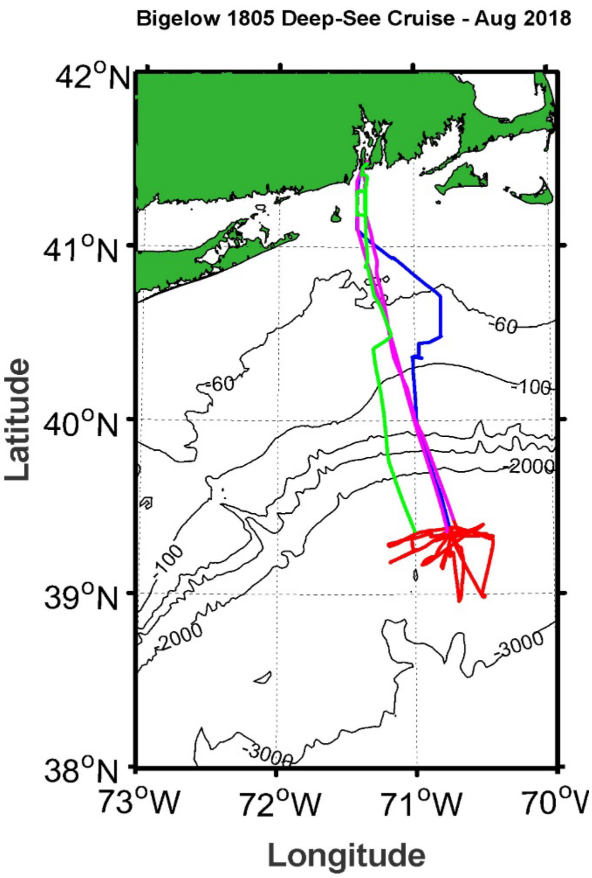

Figure 2.2.1.6.1 Cruise track for the inaugural Deep-See cruise on the NOAA Ship HB Bigelow in August 2018. Cruise tracks are colour coded to show transit (blue, green, and magenta) and Deep-See, MOCNESS, and midwater trawl tracks (red).

Initial processing has started on the data from Deep-See's acoustic and optical systems. CTD profiles have been merged with the Bigelow-mounted EK60 data to begin matching and comparing eDNA samples collected from the water bottle samples to acoustic layers. Midwater trawl hauls profiles have been merged with Bigelow-mounted EK60 data to begin matching species composition with acoustic layers. EK60 data are processed and analysed using Echoview, and custom-built Python and R statistical software programs. Classification is being done as a mix of visual scrutinization and algorithms based on dB-differencing and other multi-frequency methods (e.g., MFSBI by Wall et al. (2016) and MFI by Trenkel and Berger (2013)).

2.2.1.7 MEDIAS. Mediterranean Sea

HCMR carries out mesopelagic-specific surveys in the context of the ongoing MesoBED project (http://mesobed.hcmr.gr), which aims to explore the mesopelagic community at different locations of the Aegean and Ionian seas. MesoBED started on October 2018 and has a duration of 30 months. At the time of this report, MesoBED has completed two cruises (Figure 2.2.1.7.1) in Korinthiakos Gulf (10-16 Nov. 2018 and 13-18 Apr. 2019) and one cruise in eastern Saronikos Gulf (18-21 Apr. 2019), both located at south-central Greece. The project has also collected opportunistic acoustic data during transits of the R/V over the deep Sea of Crete (south Aegean). At least two more surveys are planned and the analysis of collected data (biological samples and acoustics) is at a preliminary state.

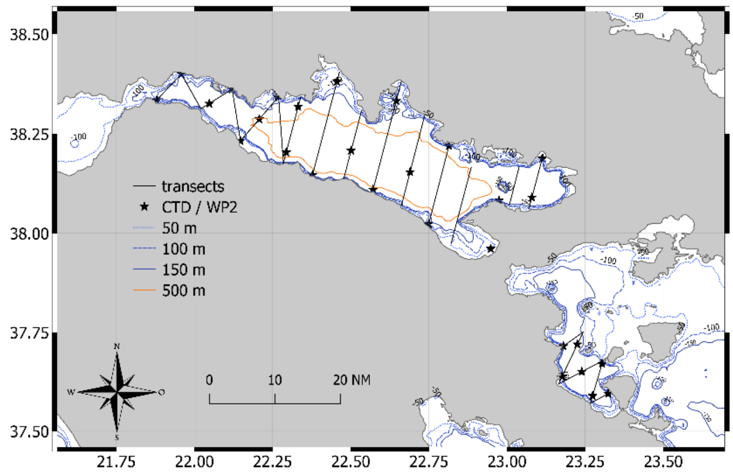

Figure 2.2.1.7.1. MesoBED Korinthiakos and eastern Saronikos Gulf surveys.

Due to limited prior knowledge on species composition, the survey areas were/are chosen based on a larval fish study indicating mesopelagic hot-spots (Somarakis et al., 2011), as well as opportunistic data, taking also into account topographical properties. MesoBED target species include all members of the mesopelagic communities in the study areas. Mesopelagic fish encountered and identified until this point include members of the Sternoptychidae (*Argyropelecus hemigymnus* and *Maurolicus muelleri*), Myctophidae (*Benthosema glaciale*, *Ceratoscopelus maderensis*, *Diaphus* spp., *Hygophum* spp., *Lampanyctus crocodilus*, *Lobianchia dofleini*, *Myctophum punctatum* and *Notoscopelus elongatus*), *Paralepididae* (*Arctozenus risso, Lestidiops* sp.), and *Stomiidae* (*Stomias boa*) families.

Research cruises are carried onboard R/V PHILIA of HCMR. Acoustic data are collected with a SIMRAD EK80 echosounder operating four hull-mounted transducers at 38, 120, 200 and 333 kHz. Only the 38 kHz frequency is operable at all surveyed depths (maximum depth is approximately 1000 meters), while 120 and 200 kHz are also usable for the shallower detected layers or aggregations. All frequencies are usable when observing migrating species near the surface during the night.

For biological sampling, the following equipment is used:

- Pelagic trawl with vertical opening of 7 meters and horizontal 12 meters; cod-end is 8x8 mm. Typical tow speed is 4 knots. This is the trawl also used for the small pelagic surveys by HCMR.
- SARDONET juvenile trawl with vertical opening of 2 meters and horizontal 4 meters; cod-end is 5x5 mm.
- Methot frame trawl with a frame 1.5 by 1.5 meters, net 2 mm leading to a large bottle with a fine mesh. Typical tow speed is 3 knots.
- Multinet plankton sampler with five 300 micrometer nets leading to bottles with the same mesh. Typical tow speed is 3 knots.
- WP2 double net with 200 micrometer nets and bottles with the same mesh.

The pelagic trawl is the go-to gear for echotrace identification. The small opening allows for accurate sampling of even small structures, such as thin layers, and also minimizes bycatch while hauling (no cod-end closing mechanism is available). The rest of the biological sampling equipment is used to characterize the ecosystem at smaller scales ranging from plankton to larval fish. At the same time, information from this gear is necessary to identify scatterers other than fish which contribute to mesopelagic acoustic layers, or produce separate echotypes. The sampling locations are decided ad-hoc, based on the observed echotraces. The typical approach is to first use the pelagic trawl for each characteristic echotype and then repeat sampling with other equipment (typically starting with multinet, then methot, then SARDONET), taking into account expectations for species composition of the targeted echotrace and time constraints.

A Sea-Bird SBE 19plus V2 SeaCAT Profiler CTD is used to collect water column measurements conductivity, temperature, dissolved oxygen, fluorescence, and irradiance at predefined stations.

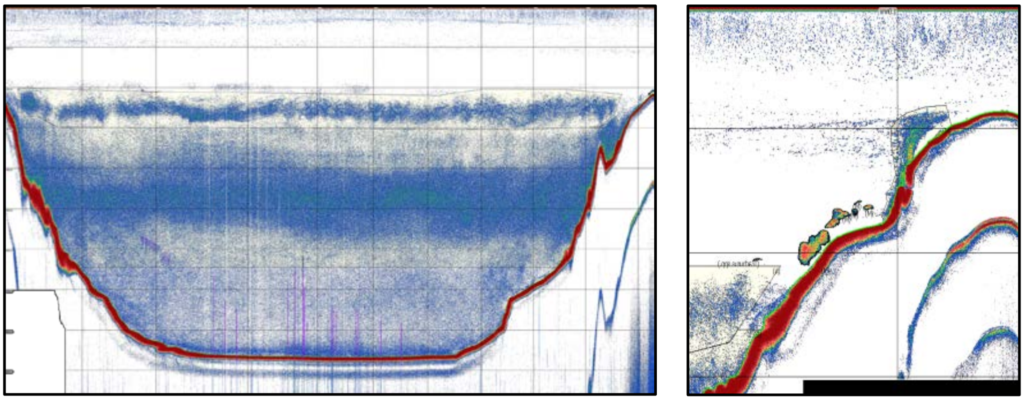

Figure 2.2.1.7.2. Characteristic scattering layers (left) and mesopelagic schools (right) from the 2018 MesoBED Corinthian Gulf survey, vertical grid spacing is 100 m.

During the autumn 2018 MesoBED survey which took place on 10-16 November in Korinthiakos Gulf, three main echotrace types where detected (Figure 2.2.1.7.2), spatial distribution and depth profiles shown in Figure 3: 1) Cloud-like schools at 50-125 meters, typically associated with well-defined schools below them at 125-225 m, along the shelf break; biological sampling indicated that these respectively correspond to small and large M. muelleri. 2) A thin scattering layer at 160-250 m found throughout the Gulf; biological sampling indicated that the layer was dominated by A. hemigymnus. (Figure 2.2.1.7.3) A thick deep scattering layer at 200-500 m, found throughout the Gulf; biological sampling found a mix of Myctophidae, S. boa, and Paralepididae, lab work pending for the exact composition.

Continuous monitoring of various echotraces along with biological sampling during day and night, indicated that the thin layer attributed to A. hemigymnus was non- migratory, the M. muelleri aggregations performed diel vertical migration, and the deep scattering layer migrated partially with the same species found both at surface and at depth during the night (lab work pending for quantitative results).

Echogram processing is performed using Echoview software. Awaiting lab results for the biological sample analysis, and taking into account TS related complicacies (Davison et al. 2015, Proud et al. 2018), only preliminary acoustic analysis has taken place. This includes standard pre-processing steps (calibration, bottom detection, noise removal), definition of regions of interest for the encountered echotypes and integration. No attempt for species discrimination based on echogram processing has been made.

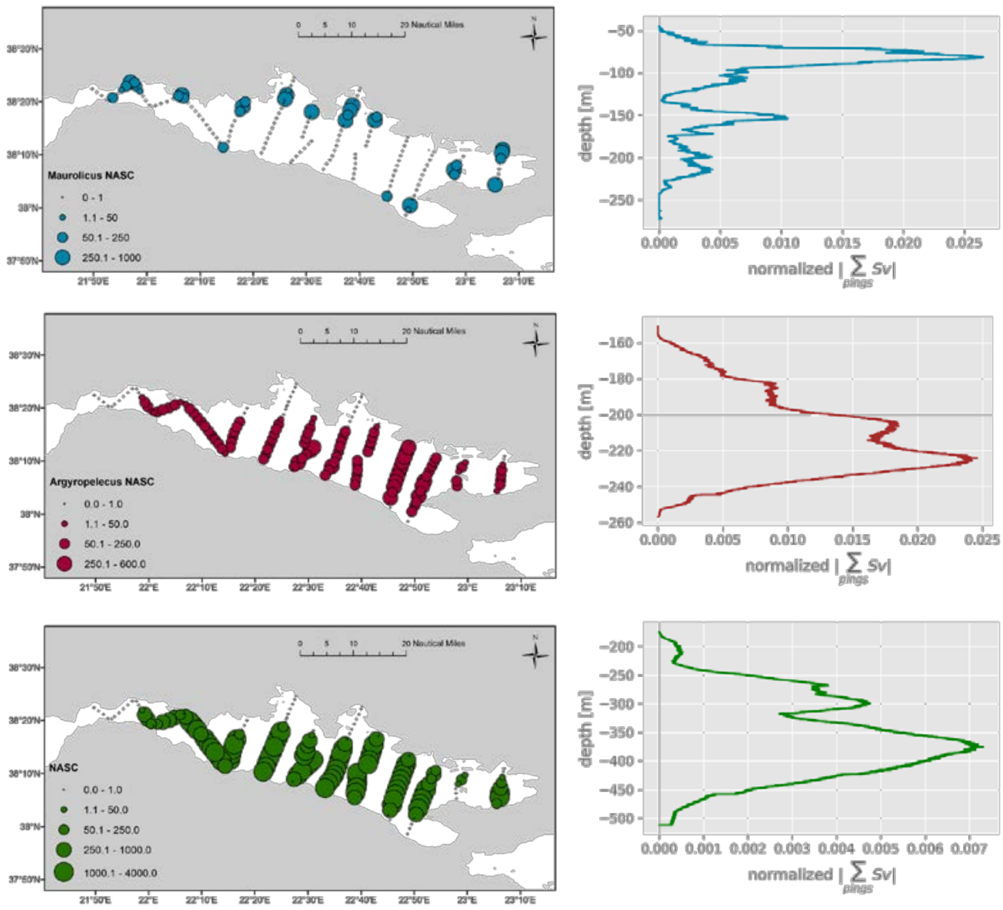

Figure 2.2.1.7.3. Spatial distribution of NASC (1 nmi EDSU) and vertical distribution for echotraces attributed to M. muelleri (top), A. hemigymnus (middle), and Myctophidae mix (bottom), from data collected in the 2018 MesoBED Corinthian Gulf survey.

The spring 2019 survey that took place in Korinthiakos Gulf on 13-18 April, exposed significant seasonal variations, especially at the deep parts of the basin. At least four well separated scattering layers were detected none of which could be directly associated with any of the two layers encountered during the 2018 autumn survey. Acoustic analysis and lab work is currently underway.

2.2.1.8 Atlantic Marine Assessment Program for Protected Species (AMAPPS), Northwest Atlantic

Active acoustic and biological data were collected during the Atlantic Marine Assessment Program for Protected Species (AMAPPS) large-cetacean surveys conducted on and off the continental shelf along the east coast of the United States (Figure 2.2.1.8.1). AMAPPS is an interagency (Bureau of Ocean Energy and Management (BOEM), NOAA, US Fish and Wildlife, and the US Navy) funded program lead at the NEFSC to collect data on and estimate abundance of large cetacean species and explore alternative platforms and technologies to improve population assessments. Visual sightings and passive acoustics are the primary data for abundance estimates. Beyond abundance, there is interest in the prey of these charismatic megafauna to better understand their ecology and behaviour. To address these interests, multi-frequency echosounder, video plankton recorder, oceanographic, and nets (e.g., midwater trawl, Isaacs-Kidd, bongo, neuston) have been used to characterize the prey field. These surveys were conducted biennially from 2009 through 2016.

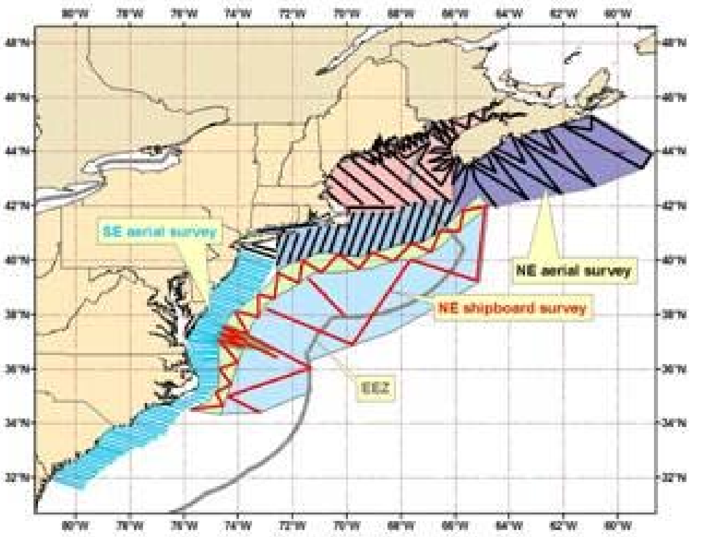

Figure 2.2.1.8.1. Survey coverage (aerial and shipboard) of the AMAPPS surveys.

Simrad EK60 (18, 38, 70, 120, and 200 kHz) data were collected during these surveys to full ocean depth on the NOAA Ships HB Bigelow, Gordon Gunter, and Pisces. The split-beam transducers were mounted on a retractable keel (Bigelow and Pisces) or the hull (Gunter). Midwater trawl hauls profiles have been merged with Bigelow-mounted EK60 data to begin matching species composition with acoustic layers. EK60 data are processed and analysed using Echoview, and custom-built Python and R statistical software programs. Classification is being done as a mix of visual scrutinization and algorithms based on dB-differencing and other multi-frequency methods (e.g., MFSBI by Wall et al. (2016) and MFI by Trenkel and Berger (2013)).

Biological sampling of nekton (fish, cephalopods, macrozooplankton) used a midwater trawl with 8x8 m mouth opening and ¼" knotless liner. In some cases, and codend aquarium was used to keep animals in good condition during the tow. Trawl hauls were directed at acoustic scattering layers. Biological samples are used for species identification, length and weight measurements, and verification of the sources of acoustic backscatter.

2.2.1.9 ArcticNet/ISECOLD, Labrador Sea

Data on mesopelagic fish and macrozooplankton of the northern Labrador Sea and Baffin Bay are collected during acoustic-trawl surveys (Figure 2.2.1.9.1) as part of the projects ISECOLD and ArcticFish, a collaboration between the Marine Institute of Memorial University of Newfoundland, Fisheries and Oceans Canada, ArcticNet, and the Centre for Environmental Genomics Applications. Sampling is conducted from the Canadian research icebreaker CCGS *Amundsen* during summers (June-August) 2018-2021. The vessel is equipped with a multifrequency (38, 120 and 200 kHz) hull-mounted echosounder and fish are discriminated from zooplankton based on the multifrequency classification detailed in Bouchard et al. (2017)1. Acoustic data are groundtruthed using an Isaac Kid Midwater Trawl, a multinet (1 m^2 and 200 um mesh), and water samples analysed for eDNA. In addition, a Wideband Autonomous Transceivers (nominal frequencies of 38 and 333 kHz) is deployed within the mesopelagic layer as an acoustic probe to record the Target Strength and frequency response curve of mesopelagic organisms in situ.

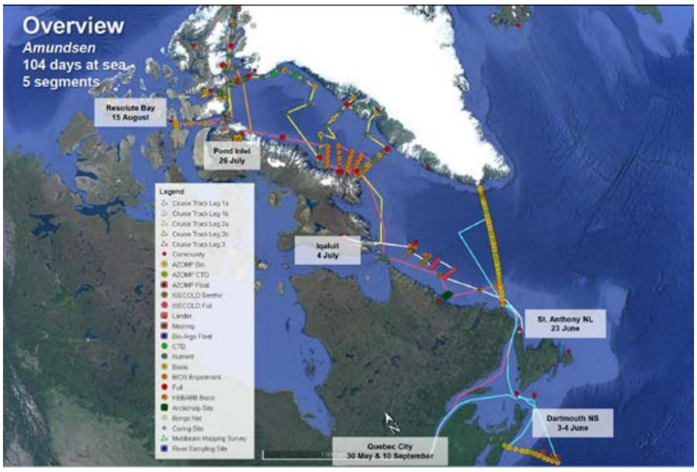

Figure 2.2.1.9.1. Example of the Amundsen cruise track for 2019

Preliminary results from 2018 indicate the occurrence of several Sound Scattering Layers between 100 and 700 m, with higher backscatter over the slope and an average integrated NASC of 351 m^2 nmi^{-2} (Figure 2.2.1.9.2). Myctophidae dominated the pelagic fish assemblage. Variations in eDNA counts from the surface, bottom and SSL water samples suggest that this approach could provide some insight on the species assemblage within SSL, although the presence of some functional groups, such as chaetognatha, seem to elude detection by eDNA analyses.

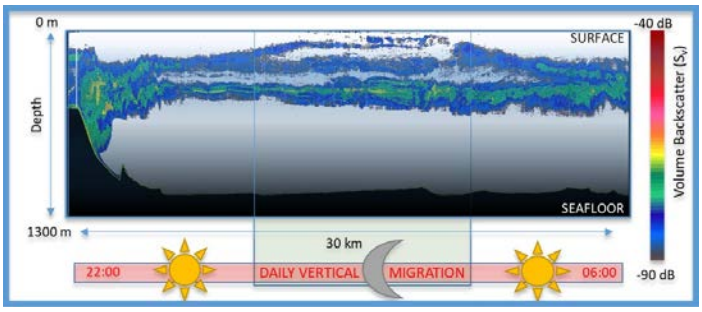

Figure 2.2.1.9.2. Example SSL detected in the northern Labrador Sea in July 2018 (38 kHz)

2.2.1.10 UiT/UNIS, Arctic Ocean (Svalbard)

Data on mesopelagic fish and macrozooplankton of the northern Barents Sea, North of Svalbard, were collected during acoustic-trawl surveys (Figure 2.2.1.10.1) as part of a collaboration between UiT. The Arctic University of Norway and UNIS. Surveys were conducted on board the R/V *Helmer Hanssen* in January 2016 and 2017, and in August 2017. The transects aimed northwards from Rijpfjorden (22.3°E, 80.2°N), crossed the shelf and slope, and stopped at >81°N before heading south toward Smeerenburgfjorden (11.0°E, 79.8°N; Figure 2.2.1.10.1). Bottom depth ranged from <50 m close to shore to ~2,000 m at the end of the transects. The keel-mounted Simrad EK60 split-beam echosounder continuously recorded hydroacoustic data at 18, 38, and 120 kHz. The acoustic signal was classified based on the multi-frequency classification tree by D'Elia et al. (2016). A Harstad pelagic trawl was deployed within the SSL to groundtruth the acoustic signal. Five to six pelagic trawl deployments were conducted for a period varying from 20-80 minutes at ca. 3 knots during each survey. The Harstad trawl had an opening of 18.28 m x 18.28 m and an effective height of 9-11 m and width of 10-12 m at 3 knots. The mesh size of the inner liner of the cod end was 10 mm.

Juvenile beaked redfish (*Sebastes mentella*) dominated the fish assemblage in January and Arctic cod (*Boreogadus saida*) in August. The macrozooplankton community mainly comprised the medusa *Cyanea capillata*, the amphipod *Themisto libellula*, and the euphausiids *Meganyctiphanes norvegica* in August and *Thysanoessa inermis* in January. The SSL was located in the Atlantic Water mass, between 200-700 m in August and between 50-500 m in January. In January, the SSL was shallower and weaker above the deeper basin, where less Atlantic Water penetrated (Geoffroy et al. In Press).

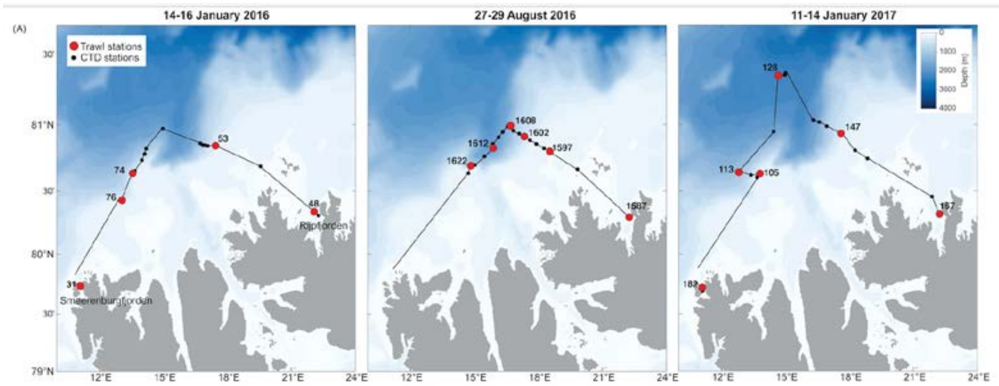

Figure 2.2.1.10.1. Transects conducted in the Northern Barents Sea and Arctic Ocean in January 2016 and 2017, and August 2017.

2.2.1.11 IMARPE, Peru

The Peruvian Marine Research Institute (IMARPE) is performing hydroacoustic surveys to evaluate pelagic species in the northern Humboldt system since 1983. Acoustic data files exist since 1999. These surveys are performed at least two times per year (one in summer and another in winter-spring), covering the entire Peru's coastal marine ecosystem up to 100 nautical miles as an average (Figure 2.2.1.11.1). Assessed species are epipelagic (mainly focused on anchovy *Engraulis ringens*) and mesopelagic fish (focused in panama light fish *Vinciguerria lucetia*). Acoustic assessment also includes giant squid (*Dosidicus gigas*). Currently used echosounders are SIMRAD EK80 hull mounted transducers operating five frequencies (18, 38, 70, 120 and 200 kHz) up to 500 m depth in three research vessels. Typical separation among transects is 10 n.mi. For biological sampling pelagic trawl nets are used and usually directed to layers. Up to three industry vessels deploying ES60, ES70 or ES80 systems (120 kHz) participate in acoustic surveys by covering assigned parallel transects and performing fishing casts. Mesopelagic fish is found out of the shelf beyond deeper areas than 180 m though denser aggregations of *V. lucetia* are usually observed in the central and south zones of the surveyed area. Peak biomass larger than 10 million of tonnes have been measured during warmer seasons (e.g. during El Nino events), when the Subtropical Superficial Waters extends its area, suggesting an association between lightfish and these water masses. Mesopelagic fish perform daily migration from different scattering layers, and no migrating organisms are also observed in echograms. *V. lucetia* has been observed to perform a vertical migration forming large schools before other species such members of the family Myctophidae. Biomass estimations of *V. lucetia* and myctophidae are calculated using NASC from 38 kHz. Many zooplanktonic crustaceans (mainly the euphausiid *Euphausia superba* and copepods of the order Calanoida) also perform diel migrations and constitutes an important fraction of the mesopelagic community. For data analysis Echoview is the most used software though open source software such as Matecho are also used to determine some ecosystem features derived from acoustic data, like the oxycline depth. The multi-frequency capacities for classification is still in a development stage. However bi-frequency analysis (120 and 38 kHz) is used for species scrutinisation and fluid-like macrozooplancton quantification.

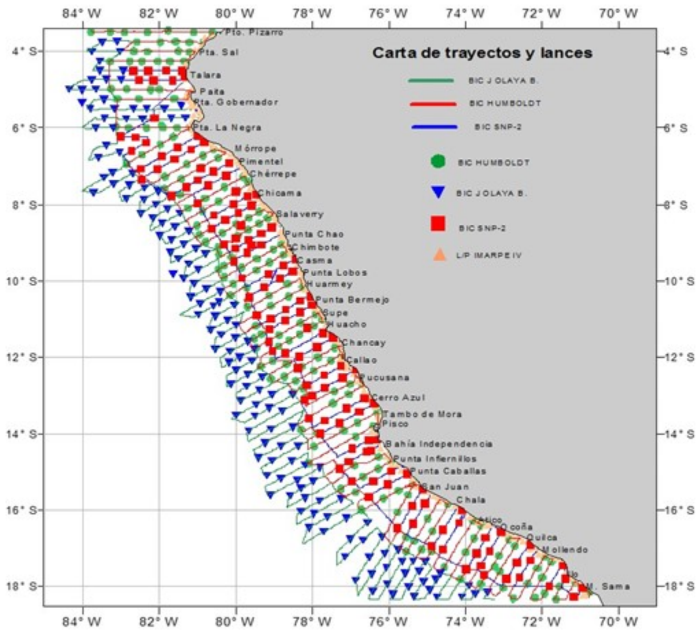

Figure 2.2.1.11.1. Map of typical acoustic surveys in Peru. Surveys focused in pelagic and mesopelagic species usually covered the area up to 100 nmi. off shore. Colour symbols indicate fishing casts performed by different vessels including industry and research vessels

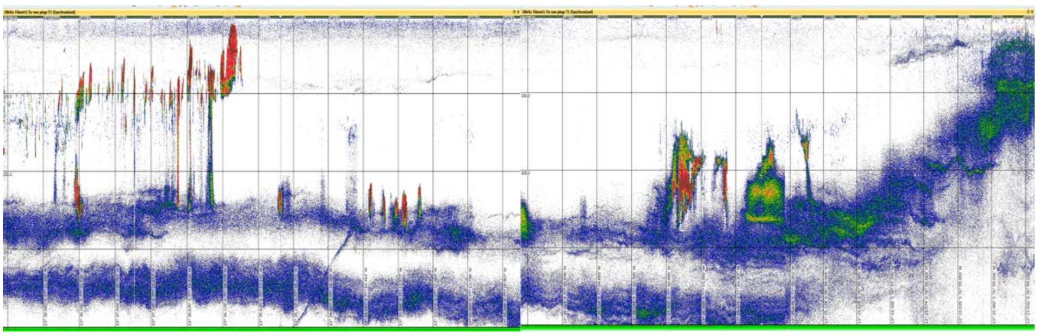

Figure 2.2.1.11.2. Sv echograms (38 kHz) collected by EK80 echosounder of R/V *José Olaya Balandra* in March 2015. Left: Echogram collected in the day (red, well-defined echotraces are *V. lucetia* schools). Right: Echogram collected in the dusk, in which the diel migration is appreciated.

2.2.2 Surveys with the potential to undertake future acoustic measurements and biological sampling within the mesopelagic zone

A summary table of individual survey details is provided in Annex 3, Table 2.

2.2.2.1 International blue whiting spawning stock survey (IBWSS)

Background

The IBWSS survey is an annual multi-vessel survey program that has been carried annually in March-April since 2004. The survey provides quasi-synoptic coverage of open ocean areas covering the Rockall Trough and offshore Banks including the Porcupine, Rockall and Hatton areas along with shelf slopes where blue whiting aggregate during spawning migration (Figure

2.2.2.1). In 2019, acoustic survey effort covered a region of over 121, 390 nmi² in 26 days, using 7,610 nmi of acoustic transect (ICES, 2019). Close temporal and temporal alignment was achieved between the 5 survey vessels through twice daily communications via the survey coordinator.

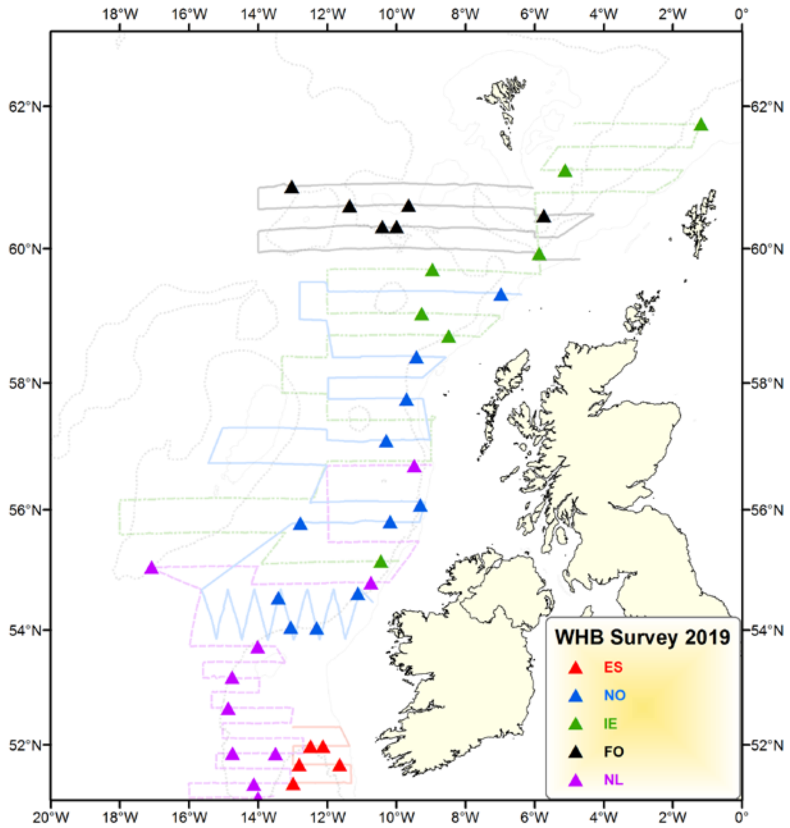

Figure 2.2.2.1 IBWSS trawl acoustic survey effort by nation and showing directed pelagic trawl effort targeting blue whiting.

<u>Acoustic data acquisition</u>

All vessels are equipped with ship based echosounder installed on the ship's hull or on a moveable drop keel. Of the five participant vessels, four are dedicated research vessels (*RV*) and one is a charted commercial fishing vessel (*FV*)with a high acoustic specification including drop keel (Table 2.2.2.1).

The number of calibrated frequencies varies between vessels from two to six frequencies. All estimates of acoustic abundance for blue whiting are produced using 38 kHz data using the TS-length relationship proposed by Pedersen et al. (2011). Currently the lower limit of data acquisition is set at 750m, deemed as the lower limit of blue whiting vertical distribution.

Table 2.2.2.1 Acoustic instruments and settings for the primary frequency

	Celtic Explorer	Magnus Heinason	Tridens	Kings Bay	Miguel Oliver
Echo sounder	Simrad	Simrad	Simrad	Simrad	Simrad
	EK 60	EK60	EK 60	EK 80	EK 60
Frequency (kHz)	**38**, 18, 120, 200	**38**, 200	18, **38**, 70, 120, 200, 333	18, **38**, 70	**38**, 18, 70, 120, 200
Primary transducer	ES 38B	ES 38B	ES 38B	ES 38B	ES 38B
Transducer installation	Drop keel	Hull	Drop keel	Drop keel	Hull
Transducer depth (m)	8.7	3	8	8.5	6.5
Upper integration limit (m)	15	7	15	15	15
Absorption coeff. (dB/km)	9.9	10.1	9.5	9.59	9.2
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.425	2.43	2.43	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	23	21.9
2-way beam angle (dB)	-20.6	-20.8	-20.6	-20.7	-20.6
Ts Transducer gain (dB)	25.65	25.64	26.52	24.06	24.68
s_A correction (dB)	-0.66	-0.66	-0.76	0.008	-0.54
alongship:	6.91	7.02	6.79	7	6.9
athw. ship:	6.98	7	6.81	7	7.1
Maximum range (m)	750	750	750	750	1000
Post processing software	Echoview	Echoview	LSSS	LSSS	Echoview

Echogram Scrutinisation and species discrimination

Echogram partitioning is carried out using established routines within LSSS (Korona) and Echoview software packages from survey data. Blue whiting are most frequently encountered from 250-650m and are not known to perform diel vertical migration during this survey. Due to the depth at which blue whiting are most commonly encountered this limits the use of higher frequencies (120 & 200 kHz) for species discrimination. However, blue whiting form high density schools often over several miles and up to 100m in vertical profile leading more to issues with signal extinction than difficult in species discrimination. Latitudinal migration is underway during the survey as post spawning aggregations migrate northwards back to the summer feeding grounds in the Norwegian Sea.

Mesopelagic fish

Mesopelagic fish are frequently encountered in the open ocean and at the shelf break zone as distinct schools and aggregations during daylight hours. Such aggregations are most commonly encountered from 50-300m and distinct from the DSL (Figure 2.2.2.2). At the onset of nightfall, migration and dispersion of schools and aggregations into surface waters is clearly evident and joined with migratory components of the DSL. As a result, it is not possible to discern this component from other migrating animals due to near surface position (surface blind zone) and species mixing and dispersion.

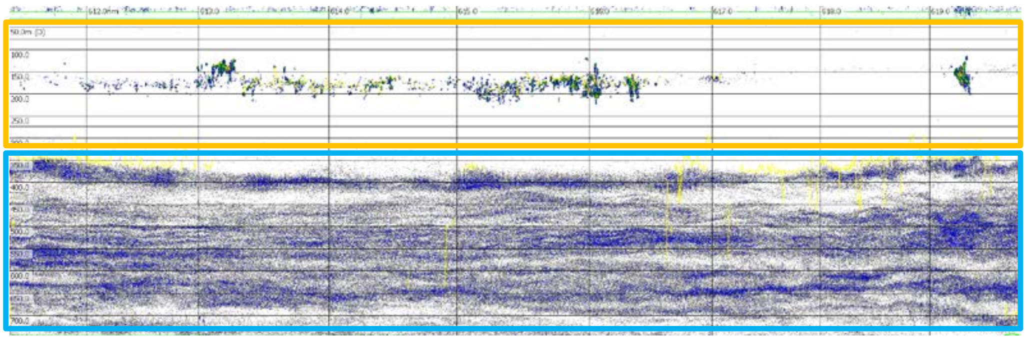

Figure 2.2.2.2 Typical distinct daytime aggregations of mesopelagic fish, depth range 50-300m (orange) distinct from the DSL (blue) as observed during the IBWSS. Echogram shows 50m vertical depth bins and EDSU of 1 nmi recorded on 38 kHz.

Biological sampling

Directed pelagic trawls targeting blue whiting often contain mesopelagic fish species as an incidental bycatch. Trawl type varies between vessels with vertical opening ranging from 30-70m and codend liners of either 20 or 40mm (Table 2.2.2.2) By-catch is thought to be dominated by animals caught as the trawl passes through the upper mesopelagic zone (100-350m) as well as during trawling at blue whiting target depth (250-650m). Bycatch species are recorded as components of the catch and usually reported in the national cruise reports (Ireland). Ad hoc trawl sampling within the mesopelagic zone is carried out but not as part of routine operations and as such entries of species and species metrics are highly limited in the survey database. Such trawls are mostly for trace recognition purposes and/or to collect biological samples for independent studies.

The efficiency of large mesh pelagic trawls in representatively sampling small mesopelagic fish is unknown in terms of species selectivity. Trawls targeted at specific schools and layers often yield little catch indicating escapement and/or avoidance.

Table 2.2.2.2 Sampling equipment by vessel.

	Celtic Explorer	Magnus Heina-son	Tridens	Kings Bay	Miguel Oli-ver
Trawl dimensions					
Circumference (m)	768	640	860	832	752
Vertical opening (m)	50	42-45	30-70	45	30
Mesh size in codend (mm)	20	40	40	40	20
Typical towing speed (kn)	3.5-4.0	3.2-3.6	3.5-4.0	3.5-4.0	3.5-4.0
Plankton sampling					
Sampling net	-	WP2	-	-	
Standard sampling depth (m)	-	200	-	-	
Hydrographic sampling					
CTD Unit	SBE911	SBE911	SBE911	SBE25	SBE25
Sampling depth (m)	1000	1000	1000	900	520

2.2.2.1 International Ecosystem Survey in the Norwegian Sea (IESNS)

The IESNS survey has the objective to investigate the distribution and migrations of Atlantic herring, blue whiting and other pelagic fish, and to produce a biomass index for herring and a recruitment index for blue whiting. This is done using a quantitative acoustic survey from several vessels in May. Hydrographic and zooplankton stations are also carried out.

2.2.2.2 International Ecosystem Summer Survey in the Norwegian Sea (IESSNS)

The main objective of the IESSNS survey is to provide reliable and consistent age-disaggregated abundance indices of North East Atlantic mackerel in July-August. This is obtained from pelagic trawling, although calibrated quantitative echosounder data is also collected, along with hydrographic and zooplankton stations. Other major pelagic species are also considered (e.g. herring and blue whiting). Survey coverage is extensive (see Figure 2.2.2.2.1).

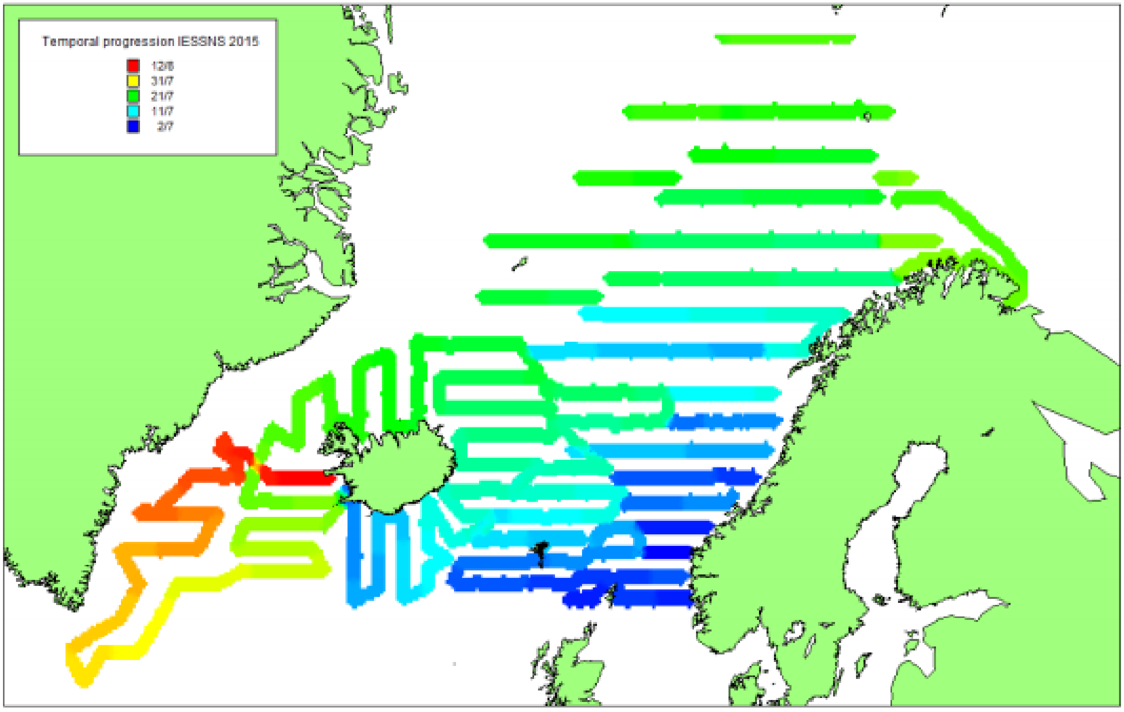

Figure 2.2.2.2.1. Survey path during the 2015 IESSNS survey.

2.2.2.3 The California Cooperative Oceanic Fisheries Investigations survey (CalCOFI)

The California Cooperative Oceanic Fisheries Investigations (CalCOFI; calcofi.org), a partnership of the California Department of Fish and Wildlife, NOAA Fisheries, and Scripps Institution of Oceanography, conducts seasonal (Jan., Apr., Jul., Oct.) cruises off southern and central California. During these cruises, conducted since 1949, hydrographic and biological data are collected at stations and along transects, spanning from San Diego to Point Conception or San Francisco, California (Figure 2.2.2.3.1). Data are available at: https://coastwatch.pfeg.noaa.gov/erddap/index.html. Since 2009, multi-frequency echosounder data (Simrad EK60; 18, 38, 70, 120, 200 kHz) have also been collected during most of the quarterly surveys, to depths ranging from 250 m to 1000 m, depending on the survey. These echosounder data (.raw format) are, or will be available at maps.ngdc.noaa.gov/viewers/water_column_sonar/.

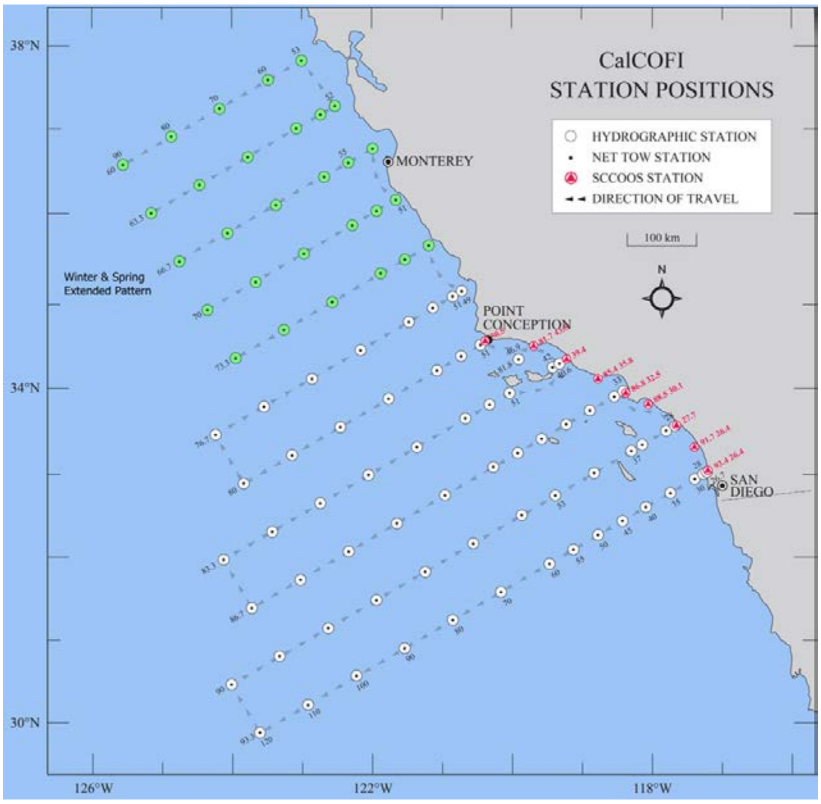

Figure 2.2.2.3.1. CalCOFI station and transect positions, off the west coast of southern and central California.

2.2.2.4 Coastal Pelagic Species (CPS), NE Pacific

NOAA Fisheries Southwest Fisheries Science Center conducts acoustic-trawl surveys of the California Current Ecosystem Survey (CCES) aboard NOAA Fisheries Survey Vessels. The primary objectives are to survey the distributions and abundances of coastal pelagic fish species (CPS), their prey, and their biotic and abiotic environments in the California Current between the northern extent of Vancouver Island, Canada, and the U.S.-Mexico border (Figure 2.2.2.4.1).

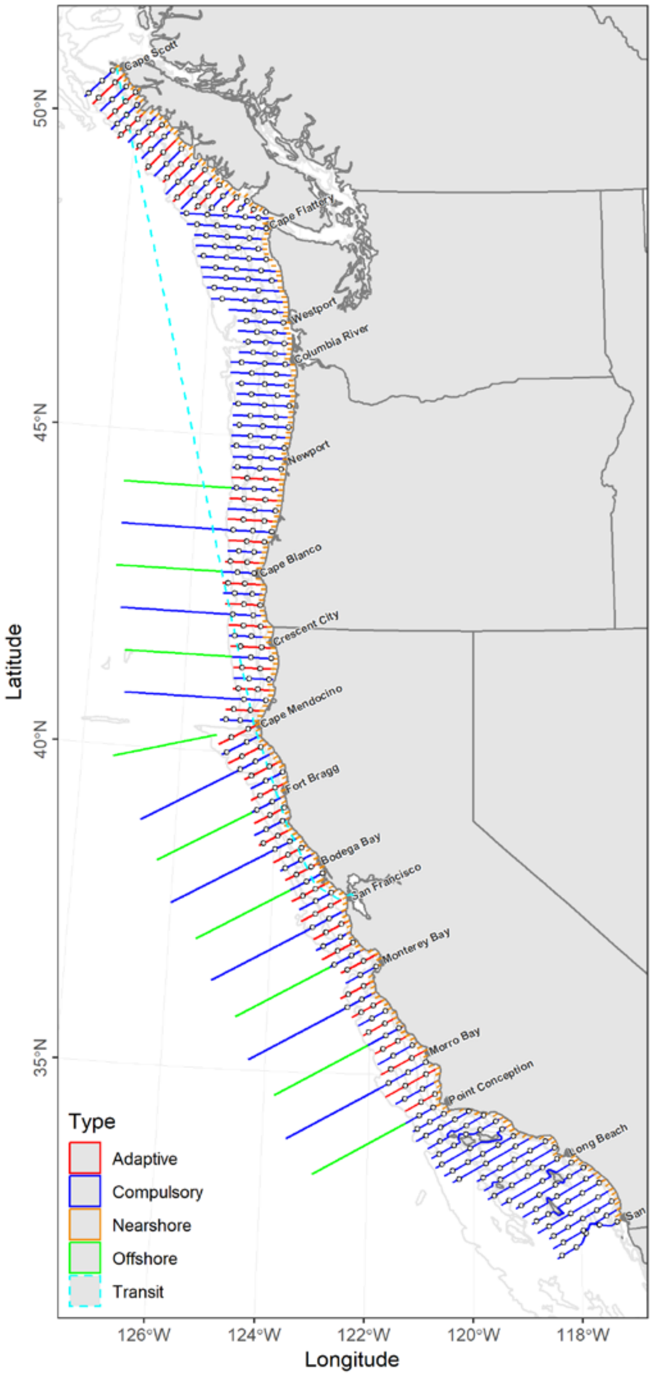

Figure 2.2.2.4.1. Example set of transects for surveying the California Current Ecosystem (CCE). Planned compulsory (blue) and adaptive (red) acoustic transects; unmanned surface vehicle (USV) offshore transects (green), USV and fishing vessel (F/V) nearshore transects (orange), and underway CTD (UCTD) stations (white circles). Compulsory transects are generally spaced 20-nmi apart, with adaptive transects between, every 10 nmi, except off Washington and Oregon and in the Southern California Bight, where compulsory lines have 10-nmi spacing. Transects begin at a water depth of ca. 20 m and extend offshore at least 35 nmi or to the 1000 fathom isobath (light gray), whichever is greatest, with extensions as far as 50 nmi offshore where CPS are present.

The survey domain encompasses the anticipated distributions of the northern sub-population of Pacific Sardine (*Sardinops sagax*), northern and central sub-populations of Northern Anchovy (*Engraulis mordax*), and portions of the stocks of Pacific Mackerel (*Scomber japonicus*) and Jack Mackerel (*Trachurus symmetricus*). Where compulsory transects have a 20-nmi spacing and CPS are abundant, adaptive transects are added with 10-nmi spacing. The transects extend as close to shore as navigable (usually 20 to 40-m depth), and as far offshore as necessary, but not to exceed an additional 50 nmi, to map the western extent of CPS, based on the presence of CPS.

Since 2006, multi-frequency echosounder data (Simrad EK60; 18, 38, 70, 120, 200 kHz) were collected during these surveys, to depths ranging from 250 m to 1000 m, depending on the survey. These echosounder data (.raw format) are, or will be available at maps.ngdc.noaa.gov/viewers/water_column_sonar/ .

2.2.2.5 GLACE, Greenland circumnavigation

As part of a collaboration between the Marine Institute of Memorial University of Newfoundland, The Greenland Institute of Natural Resources, the Swiss Polar Institute and the University of St. Andrew's, multi-frequency acoustic data and biological samples of the mesopelagic sound scattering layers will be collected during the Greenland Circumnavigation Expedition (GLACE; Figure 2.2.2.6.1). A 12 kHz broadband EK80 echosounder and a 200 kHz narrowband EK60 echosounder will be continuously operated during the circumnavigation (August 4 - September 24). Water samples for eDNA will be collected at up to 30 stations to obtain absence and occurrence information about mesopelagic organisms within the sound scattering layers.

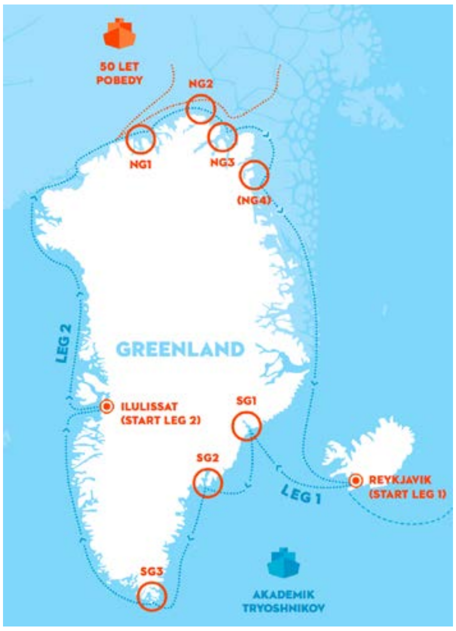

Figure 2.2.2.6.1. Route of the RV *Akademik Tryoshnikov* and locations of the sampling sites during the GLACE Expedition in August-September 2019.

2.2.2.6 Pacific Hake, Northeast Pacific

Pacific Hake is a transboundary migratory species found in the NE Pacific. The stock is monitored by a joint acoustic-trawl survey carried out by the USA and Canada. The survey occurs typically every 2-years, from June to September, while the fish are on their northward feeding migration along the continental shelf, starting in southern California through Canada and to the Alaska border (or beyond if fish migration extend further north). The survey consists of a series of East-West parallel transects with spacing of 10 or 20 nmi, and extend from the 50 m to the 1500 m isobath contours, covering areas with several mesopelagic scattering layers. The survey vessels employ multiple acoustic frequencies (with 38 and 120 kHz at a minimum), and midwater trawls (with 32 mm or 7 mm codends) are used to verify acoustic marks and collect biological samples. A number of other sampling tools (including Methot net, hydrobios midi multinet, and

MOCNESS) have been used during the surveys or during survey-related research to further sample and identify species within the mesopelagic scattering layers. With Pacific Hake feeding on mesopelagic organisms, and the desire to implement increased ecosystem considerations in future stock assessments, there is a growing interest in assessing and understanding the mesopelagic communities as part of these survey efforts.

2.2.2.7 Strait of Georgia pelagic ecosystem survey, Northeast Pacific

The Strait of Georgia is located between Vancouver Island and the British Columbia mainland in Canada, and is part of the larger Salish Sea. Although it is a relatively small and semi-enclosed body of water, depth can be in excess of 400 m and it harbours a diverse mesopelagic community. The Strait of Georgia pelagic ecosystem surveys are based on acoustic-trawl methodologies, where multi-frequency fisheries acoustics systems are used to monitor pelagic or semi-pelagic species along a series of parallel transects, and midwater trawls and other sampling nets are used to assess acoustic mark species composition and gather biological samples. The main focus of these surveys includes commercial species such as Pacific Hake and walleye pollock, as well as Pacific herring and forage species such as euphausiids. Recent surveys were carried out in 2011, 2012, 2014, and 2016, while another survey is planned for 2020.

2.3 Research findings

2.3.1 Ongoing research and publications

A bibliography provided by participants and material referenced in the report is provided in Section 2.8.

2.3.2 Dedicated mesopelagic projects

Recent, ongoing and upcoming dedicated mesopelagic projects are listed in Table 2.2.3.1.

Table 2.2.3.1 Summary table of dedicated mesopelagic projects.

Project title	Acronym	Start	End	Country/ region	Project web link
Mesopelagic Southern Ocean Prey and Predators	MESSOP	May 2016	May 2019	Southern Ocean	http://www.mesopp.eu/
Sustainable Management of Mesopelagic Resources	SUMMER	Sept 2019	Sept 2022	Global context	http://iocag.ulpgc.es/home
Ecologically and economically sustainable mesopelagic fisheries	MESSO	Sept 2019	Sept 2023	Global context	not yet available
Mesopelagic fish: Biology, Ecological role and distribution	MesoBED	Oct 2018	Mar 2021	Greece	http://mesobed.hcmr.gr/?page_id=116&lang=en
Real-time information about catch composition	FishScanner	2018	2021	Iceland	
Deep-See and Ocean Twilight Zone	Deep-See; OTZ	Aug 2018	Dec 2024	USA	https://twilightzone.whoi.edu/ https://twilightzone.whoi.edu/deep-see/
Deep Pelagic Dynamics of the Gulf of Mexico	DEEPEND	May 2015		USA/Gulf of Mexico	http://www.deependconsortium.org/

2.3.2.1 MesoBED Project, Greece

Contact person: Konstantinos Tsagarakis, kontsag@hcmr.gr
Project duration: 30 months (Oct 2018 – Mar 2021)
Budget: 155,000 €
website: http://mesobed.hcmr.gr/?page_id=116&lang=en

MesoBED is a research project aiming to explore the distribution, biological aspects and the ecological role of mesopelagic fish in the Greek seas. The project includes the application of the acoustic methodology during research cruises in selected study areas of the Aegean and Ionian Seas aiming to shed light on the properties and species composition of the deep scattering layer (DSL), to study the horizontal and vertical distribution of mesopelagic fish in relation to environmental factors and to derive density estimates of the DSL. In addition, the project will study the biology of mesopelagic fish populations, including aspects of reproductive strategies (e.g., sex ratio, maturity, fecundity), length-weight relationships, age and growth. Finally, their feeding habits will be studied and along with (i) a review of their use as a prey by predators, (ii) the biomass estimates and (iii) biological parameters, will be used to parameterize an ecosystem model in order to explore the ecological role of mesopelagic. Overall, MesoBED aims to advance knowledge on mesopelagic fish and the pelagic environment in general, to advance the application of Ecosystem Approach to Fisheries in the Mediterranean Sea as well as to set the basis for future research on this topic.

2.3.2.2 FishScanner, Iceland

Contact person: Haraldur A. Einarsson, haraldur.arnar.einarsson@hafogvatn.is

Project ongoing over the years 2018 – 2021

This project started in 2018 in cooperation with sensor specialist StarOddi and gear manufacturer Hampiðjan. The objective of the project is to develop a lightweight and user-friendly device that provides real-time information on the catch composition. Optical technology will be used to scan the fish before it enters the codend and the data immediately processed. The information is then relayed to the ship by DynIce data-cable (or by transducer). This promises a major improvement in the analysis of catches in trawls. Today only the catch sensor gives a rough indication of catch levels.

This technology is very likely to have a significant impact on the commercial fishing fleet. The Fishscanner gives fishermen real-time information about catch composition both for species and average sizes. This, in turn, will help to maximize the value of catches through better organization and utilization of the fishing effort.

This can as well have an impact to sampling technology where it gives the real-time possibility to divide sampling between layers with controlling collecting of the catch in multi codends behind the system (not a part of this project). As well give information's about catch composition collected in different trawling depths.

The project is still in the design stage and limited progress has been made in 2018.

2.3.2.3 MESSOP (Mesopelagic Southern Ocean Prey and Predators)

This was an EU International Collaboration project enhancing and focusing research and innovation cooperation with Australia. The project was led by Patrick Lehodey, France. Other EU partner countries were Norway (IMR) and UK (St Andrews; BAS). Partners in Australia were CSIRO and UTas. The headline objective was to develop standardised methods and datasets for assimilating acoustic biomass estimates of micronekton organisms into ocean ecosystem models

2.3.2.4 SUMMER (Sustainable management of mesopelagic resources)

SUMMER (Sustainable management of mesopelagic resources) is a new EU BG3 project that will start in September 2019 and run for 3 years. It is led by AZTI, Spain, and has 22 partners. The project abstract is as follows:

The mesopelagic layer is one of the least understood ecosystems on Earth. Recent research suggests that the fish biomass in the mesopelagic ecosystem might be 10 times higher than previously thought, and therefore represent 90 % of the fish biomass of the planet. However, this estimate is subject to a high degree of uncertainty in the fraction of the community that is fish. The potential high biomass has raised interest in its exploitation, mainly as a fish meal, but other potential exploitation pathways for high value compounds, such as nutraceuticals and pharmaceuticals, are possible. Nevertheless, if the biomass is as high as estimated, mesopelagic fish may play a key role in ecosystem services, such as sustaining other commercially relevant species and carbon sequestration. SUMMER will establish a protocol to accurately estimate mesopelagic fish biomass, quantify the ecosystem services provided by the mesopelagic community (food, climate regulation and potential for bioactive compounds) and develop a decision support tool to measure the trade-offs between the different services. Combining eDNA with in situ acoustics and trawls SUMMER will obtain an accurate assessment of the composition and biomass of the mesopelagic community. Gut content analysis, molecular markers and stable isotopes will allow quantification of the vertically integrated trophic network, linking to commercial and charismatic species. Models will be used to estimate the impact of fishing scenarios on trophic network stability and carbon sequestration. Mesopelagic organisms will be tested for their potential as fish meal, nutra and pharmaceuticals. The project will develop a decision support tool to enable accounting for trade-offs between services in when considering sustainable use of mesopelagic resources. Finally, a range of interactions with stakeholders, policy makers and public will ensure that any strategy to exploit the mesopelagic ecosystem takes account of all the consequences.

2.3.2.5 MEESO (Ecologically and economically sustainable mesopelagic fisheries)

Contact person: Webjørn Melle, webjoern.melle@hi.no

Project operational from 2019 – 2023

MEESO (Ecologically and economically sustainable mesopelagic fisheries) is a EU-funded research project to quantify the spatio-temporal distributions of biomass, production, and ecosystem role of mesopelagic resources and to assess options to sustainably manage and govern their exploitation. MEESO will create new knowledge and data on the mesopelagic community, its biodiversity, drivers of its biomass, its role in carbon sequestration, its role in the oceanic ecosystem and its interactions with the epipelagic community which includes several important commercial fish stocks. Besides applying state of the art experimental and quantitative methods, MEESO will develop and implement new acoustic and trawling technologies necessary for the knowledge and data generation in relation to this largely unknown and remote part of marine ecosystems. MEESO includes a significant amount of in-kind financing for technology development and scientific surveys.

2.4 Opportunities and limitations

Measurements of the abundance of mesopelagic fishes are an important requirement for adequate understanding and management of mesopelagic fisheries. The opportunity offered by adapting existing acoustic surveys that are carried out in areas of mesopelagic interest must be tempered by the limitations that the primary survey objectives places on vessel operations and facilities.

Precise and spatially extensive absolute estimates of mesopelagic fishes appear to not be feasible as a secondary objective of existing routine acoustic fish surveys. The additional effort required to adequately sample mesopelagic layers compromises on survey design, and the difficulty in detecting some mesopelagic organisms with acoustics preclude precise biomass estimates. However, there is much useful information that can be derived without absolute biomass estimates. This includes presence and distribution, relative indices of abundance, dynamics and behavior, spatial and temporal variability, and ecosystem functioning. It was noted that many existing datasets have not been analysed with mesopelagic fishes in mind, and re-analysis of these may lead to useful information, especially for designing and carrying out mesopelagic surveys in the future. In addition, adding mesopelagic objectives to an existing survey is likely to increase the value of such surveys.

A useful characteristic of some mesopelagic organisms is their tendency to resonate at particular acoustic frequencies – for the depths and species of interest, this occurs at relatively low frequencies allowing for long-range use from ship-mounted echosounders (as opposed to the higher frequencies that cannot propagate to the depths at which mesopelagic organisms are often found).

Limitations in using acoustic techniques to quantify mesopelagic species from existing acoustic surveys include the lack of acoustic target strength knowledge, the lack of operational range for the higher acoustic frequencies when operated from a surface vessel and obtaining adequate ground-truth information on the species-composition of the observed backscatter. A reluctance to modify the procedures of existing acoustic surveys is also a limitation, based mainly on the desire to maintain comparability in existing survey time series.

2.5 Potential to develop methods

2.5.1.1 Classification of target schools and aggregations

During the IBWSS survey, aggregations of mesopelagic fish are most frequently observed as distinct schools and aggregations occurring from 50-300 m during daylight hours (Figure 5.5.1). Directed trawling on schools within this depth region has showed schools to be composed of a low number of species and dominated by *Maurolicus muelleri* and *Benthosema glaciale.* Schools within this depth region are readily identified given they most frequently occur above the deep scattering layer (DSL) and below the near surface phytoplankton layer (0-50 m). Approaching sunset, schools migrate to surface waters and are joined by other migrants from the DSL as part of the diel vertical migration (DVM) cycle. During the hours of darkness, target discrimination is not possible due to the dispersion of targets and vertical containment within the surface blind zone.

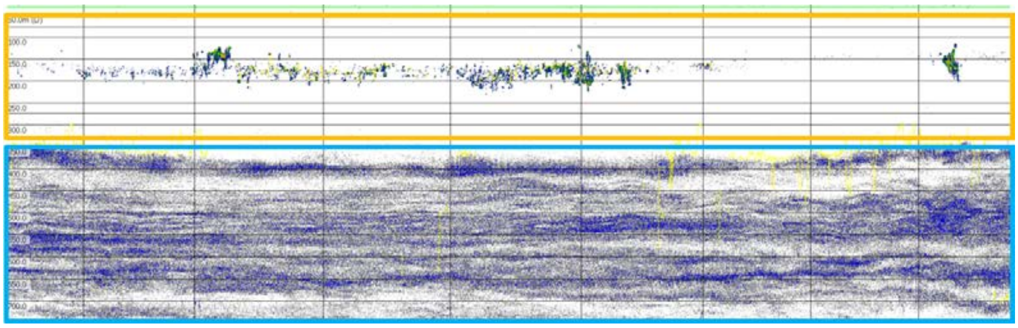

Figure 2.5.1.1.1 Typical 38 kHz echogram showing daylight aggregations of mesopelagic fish (orange box) distinct from the deep scattering layer (blue box) during the IBWSS survey. Vertical lines represent 1 nmi and 50m vertical depth channels.

2.5.1.1 Acoustic data acquisition

During the IBWSS survey, hull mounted echosounders routinely collected acoustic data to depths of 750 m using a ping rate of 1 ping per sec-1. Data collection down to 1,000 m is achievable with minimal or no modification of the existing ping rate when using the Simrad EK60. For EK80 broadband systems testing is required to determine the most effective configuration. Multifrequency data (18, 38 and 70 kHz), where feasible, have the capacity to resolve targets within this depth range and can be used in combination to aid species discrimination to characterize species backscatter for hull mounted systems. Currently, no towed systems are employed during the IBWSS survey. Using a towed system would enhance the capacity to collect multifrequency by eliminating range effects associated with higher frequencies such as 120 and 200 kHz.

2.5.1.3 Biological sampling

Directed sampling of insonified schools and aggregations is a requirement to determine species composition for robust abundance estimation. Effective sampling is the ability to provide a representative sample of the animals contained within a school or aggregation to aid species composition for echo integration purposes and to determine biological metrics such as age, length, sex and maturity of target animals. Active sampling gears in use in the wider community during dedicated surveys include; single mesopelagic-midwater trawls, rectangular frame trawl (RFT) and multi-net systems of various sizes, each with their own limitations. Regardless of gear type, animal avoidance to the sampling gear and the bias associated biological sampling methods remains an issue. During the IBWSS survey, the use of large geometry pelagic mid-water trawls for sampling mesopelagic fish has had limited success. The addition of small mesh liners into trawl codends has proved ineffective as a means of increasing bulk landings. Trawls used during the IBWSS survey are scaled down versions of commercial trawls designed to target mature blue whiting and thus are ineffective at sampling much smaller fish such as *Maurolicus muelleri* and *Benthosema glaciale*. Details of trawl types currently used during the IBWSS survey are provided in Section 2.2.2.1, Table 2.2.2.2.

To begin the process of meaningful sampling of mesopelagic fishes during WGIPS survey a dedicated trawl or sampling gear is required. A dedicated sampling gear is required to reduce the effects of sampling bias observed with the current trawls employed and also to ensure the quality of individual specimens for further analysis. In an ideal situation, a multi-vessel survey effort would see each vessel using the same sampling trawl as observed during the IESSNS. A component of the MESSO project (see Section 2.3.2.5) is the development of a dedicated mesopelagic midwater trawl. Details of trawls and net plans currently utilized within the community have been collected on the WK share point.

2.5.1.4 Echogram scrutinisation protocol

To ensure harmonization of echo integration procedures across surveys requires agreement from survey group members. It is recommended that time is allocated during the WGIPS meetings in 2020-2021 to develop a joint protocol.

Suggested baseline scrutinisation criteria when allocating to mesopelagic fish during the IBWSS are suggested below:

- Daylight only allocation- excluding dawn and dusk periods when active vertical migration is underway
- Depth restricted from 50 to 300 m, below the surface plankton layer and above the DSL.
- Restricted to clear and distinct schools and aggregations occurring in open ocean
- Shelf break regions are complex in terms of species mixing; where high density blue whiting schools are most frequently encountered and where mesopelagic fish are sometimes observed to 'wash over' onto the shallower shelf sea.

2.5.1.5 Calculation of relative abundance and biomass

Within WGIPS, analysis procedures are in place for the calculation of biomass and abundance during acoustic trawl surveys using the StoX software package (ICES, 2015). Existing data repositories (PGNAPES and ICES trawl acoustic databases) for WGIPS surveys can be readily adapted for the inclusion of mesopelagic fish abundance for future use.

2.5.1.6 Supplementary data

Supplementary data sources can be broken into three categories; enhancement of existing data, developing new data sources and the re-analysis of historic data.

As time is typically limited during routine survey for additional work on non-target species, optimizing existing data collection procedures to enhance survey output, without impacting core work programs, is more feasible. By increasing the depth at which acoustic data is collected (into the DSL) can provide new sources of data for future research with minimal or no time and financial penalty to routine operations.

By utilising current sampling activities to provide additional data sources such as optical/acoustic systems on CTD rosettes and trawls can provide in-situ measurements during existing survey operations. Such additional data sources can be used to aid the identification and acoustic characteristics of layers within the DSL.

Given additional time and resources more structured work programs can be implemented into existing surveys.

The re-analysis of existing times series data has the capacity to provide information on acoustic density and distribution of mesopelagic fish where no information currently exists. The development of echogram scrutinisation protocols for use in future WGIPS as discussed could be used applied to re-analyze the IBWSS survey time series as far back as 2004.

2.6 Minimum requirements

2.6.1.1 Resources

To develop a robust index of relative abundance using a dedicated mesopelagic acoustic survey data requires adequate time and resources to complete the intended area coverage and allow for sufficient biological sampling to groundtruth insonified targets and provide supporting biological information. Careful consideration must be given to the survey aims and what is feasible given the complexity involved.

To undertake mesopelagic monitoring as part of an existing survey program, such as the IBWSS, an additional work package would require careful planning to determine the time and resources required.

Research surveys are carefully planned and designed to provide a high quality data product and to maximize sampling potential of allotted shiptime. By adding a new work package to an existing survey program requires careful planning to determine the additional time required to achieve the aims of the program without compromising the integrity of the core work program. To successfully achieve this requires input from those who regularly lead the surveys at sea and who are best placed to identify potential opportunities and limitations.

2.6.1.2 Acoustic data acquisition

Calibrated echosounder data is the minimum requirement for quantitative measurements of acoustic density. The depth ranges of species of interest described here (section 2.1.1.1) are within the range of the lower frequencies typically found on survey ships (18, 38 and 70 kHz), but excludes the typical higher frequencies (120 and 200 kHz) due to their operational range. For ship based systems a minimum requirement would be to have at least two of the lower frequencies to for acoustic species discrimination.

2.6.1.3 Biological sampling

Trawl sampling is a requirement to groundtruth insonified targets and to provide biological data on target species for abundance calculation. Representative sampling of targets to determine species composition and biological data including length, age and maturity within schools or aggregations is important. In order to sample effectively it is important to have gear designed with the target species in mind and to reduce the effects of gear avoidance as far as possible.

The design and development of a dedicated trawl for sampling mesopelagic fish is currently underway through the MEESO project (Section 2.3.2.5).

2.7 Discussion

In a global context, monitoring of mesopelagic resources by way of research surveys has been ongoing in some areas for over 27 years (New Zealand). In total, 15 survey programs currently report acoustic density of fish in the mesopelagic zone, with nine more reporting the capacity to do so in the future. Research by means of peer reviewed publications is ongoing as summarised here. Five multi-disciplinary international/national research projects are currently underway focusing on the animals, ecosystem interactions, potential resources and drivers associated with mesopelagic zone in the global oceans.

The ability of existing survey programs to provide additional data sources to feed into this process over time scales exceeding the longevity of these projects was considered. Given the time, equipment and resources required for robust abundance estimation, such surveys have the capacity to undertake monitoring and measuring of mesopelagic fish resources thus adding value to the existing core work program. Research findings from multi-disciplinary projects can be applied during future survey operations to further enhance the quality of data provided.

The complexities of collecting acoustic and biological data within the mesopelagic zone were discussed. The limitations associated with ship based acoustics for species discrimination and identification is restrictive for all but the few species occupying the upper mesopelagic zone. In the case of the IBWSS survey this relates particularly to *Maurolicus muelleri* and *Benthosema glaciale*. The use of current midwater trawl gears for sampling mesopelagic fish were not considered viable in terms of representative sampling or specimen collection.

Developing protocols for the classification of mesopelagic fish, as observed during the IBWSS survey, through WGIPS, will allow for the standardisation of submissions to the survey database going forward and can be applied to other surveys within the group. Given agreement from participant countries this protocol could then be used for the re-analysis of existing survey time series. Where appropriate, this has the capacity to provide data on acoustic density and distribution of mesopelagic fish where none currently exists.

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3 Cooperation

- WGFAST- The workshop was planned to coincide with the annual WGFAST meeting to facilitate participation and input from members of the WGFAST community.
- FTFB- in terms of input and advice on biological sampling gear designs best suited for sampling in the mesopelagic zone. Development on gear design expertise as part of the triennial joint session between WGFAST and FTFB.
- WGIPS- on going process to integrate the monitoring and measuring on mesopelagic fish during routine surveys.
- WGDEEPs- exchange of ideas between survey coordination groups as established during WKMESO on the development of common monitoring methods for routine survey operations

Annex 1: List of Participants

Name	Institute	Country	Email
Andy Brierley	University of St Andrews	UK	asb4@st-andrews.ac.uk
Anibal Aliaga	Pesquera Diamante	Peru	aaliaga@diamante.com.pe
Aquiles Sepulveda	INSTITUTO DE INVESTIGACION PESQUERA	Chile	asepulveda@inpesca.cl
Ben Scoulding	CSIRO Marine and Atmospheric Research	Australia	ben.scoulding@csiro.au
Bram Couperus	Wageningen Marine Research	Netherlands	bram.couperus@wur.nl
Castillo Valderrama	Instituto del Mar del Peru	Peru	ramirocasti@gmail.com
Chris Taylor	NOAA Ocean Services	USA	chris.taylor@noaa.gov
Ciaran O'Donnell	FEAS	Ireland	Ciaran.ODonnell@Marine.ie
David Demer	Southwest Fisheries Science Center	USA	david.demer@noaa.gov
Erin LaBrecque	Duke University Marine Lab	USA	erinlab@gmail.com
François Gerlotto	L'Institut de Recherche pour le Développement (IRD)	France	francois.gerlotto@ird.fr
Gavin Macaulay	Institute of Marine Research	Norway	gavin.macaulay@hi.no
Geir Pedersen	Institute of Marine Research	Norway	geir.pedersen@cmr.no
Guillermo Boyra	AZTI-Tecnalia	Spain	gboyra@azti.es
Haraldur Einarsson	Marine and Freshwater Research Institute	Iceland	haraldur.arnar.einarsson@hafogvatn.is
J. Michael Jech	Northeast Fisheries Science Center	USA	michael.jech@noaa.gov
Jan Arge Jacobsen	Faroe Marine Research Institute	Faroe Islands	janarge@hav.fo
Jeroen Van der Kooij	Lowestoft Laboratory	UK	jeroen.vanderkooij@cefas.co.uk
Jhon Robles	Pesquera EXALMAR S.A.A.	Peru	jrobles@exalmar.com.pe
John Horne	University of Washington	USA	jhorne@u.washington.edu

Joe Freijer		Netherlands	joefreijser@gmail.com
Jose Rojas	Austral Group S.A.A. Peru	Peru	jrojas@austral.com.pe
Kevin M. Boswell	Florida International University	USA	kevin.boswell@fiu.edu
Marian Peña	Centro Oceanográfico de Baleares	Spain	marian.pena@ieo.es
Mariano Gutierrez Torero	Humboldt Universität zu Berlin	Peru	msgutierrezt@gmail.com
Martin Santivañez Yuffra	Copeinca (CFG)	Peru	msantivanez@copeinca.com.pe
Maxime Geoffroy	Memorial University of Newfoundland	Canada	Maxime.Geoffroy@mi.mun.ca
Pablo Carrera	Centro Oceanográfico de Vigo	Spain	pablo.carrera@ieo.es
Pablo Escobar-Flores	NIWA Wellington	New Zealand	pablo.escobar-flores@niwa.co.nz
Rebecca Thomas	Northwest Fisheries Science Center	United States	rebecca.thomas@noaa.gov
Richard O'Driscoll	NIWA Wellington	New Zealand	richard.odriscoll@niwa.co.nz
Roudaut Gildas	L'Institut de Recherche pour le Développement (IRD)	France	gildas.roudaut@ird.fr
Rudy Kloser	CSIRO Marine and Atmospheric Research	Australia	rudy.kloser@csiro.au
Stephane Gauthier	Institute of Ocean Sciences	Canada	stephane.gauthier@dfo-mpo.gc.ca
Sven Gastauer	Center for Marine Science & Technology	Australia	sven.gastauer@postgrad.curtin.edu.au
Tomas Didrikas	Marine and Freshwater Research Institute	Iceland	tomas.didrikas@hafogvatn.is
Zacharias Kapelonis	Institute of Marine Biological Resources	Greece	zkapelonis@hcmr.gr

Annex 2: Copy of Working Group Self-Evaluation

1. WKMESOMeth
2. 2018 (Single year only)
3. Ciaran O'Donnell, Gavin Macaulay
4. Galway, 27-28 April, 2018, 37 participants attended

WG Evaluation

5. Mesopelagic resources represent a major untapped food resource. There is considerable interest in commercial exploitation. But, little is known about the species present in the mesopelagic zone, their abundance distribution, food web linkages and biodiversity. The workshop gathered together experts within the field to provide information of large scale research projects currently underway and individual research effort. This expertise was used to evaluate the potential to develop methods for undertaking monitoring surveys in the mesopelagic zone and identify current limitations in terms of knowledge and sampling equipment. Together the group evaluated the opportunities of establishing resource monitoring as part of existing surveys and the resources required to do so. The workshop worked towards developing methods to address the need identified by the Working Group on International Pelagic Surveys (WGIPS) concerning data quality insurance and expansion from individual species towards ecosystem oriented surveys. Provision of reliable data to for the development of a monitoring index and to support ecosystem integrated assessment that are considered to have a very high priority. Science plan code 3.2

6. First evaluation- single year workshop.
   - Catalogue of current global surveys that undertake, or have the capacity to undertake, acoustic measurements and biological sampling of animals within the mesopelagic zone. (Science plan code 3.2)
   - Review on example data and research findings and multi-agency research projects (Science plan codes 3.3, 3.4)
   - Report on the opportunities and limitations associated with measurements of abundance including acoustic detection criteria, species discrimination and biological sampling, in the context of existing routine acoustic surveys. (Science plan code 2.3)
   - Report on the potential to develop methods to establish abundance monitoring of mesopelagic fishes during open ocean surveys within ICES coordinated surveys, including, WGIPS and WGMEGS (Science plan code 4.1)
   - Determine the minimum requirements in terms of resources, hardware and sampling equipment required for meaningful abundance measurements (Science plan codes 5.2, 6.6)
7. No
8. Not applicable
9. Due to the level of interest within the community the WK was well attended and the work schedule was achieved as planned.

Future plans

10. Not at this time
11. No
12. Not applicable
13. One of the aims of the WK was to determine the feasibility of developing methods for measuring and monitoring in the mesopelagic zone during existing routine surveys. The WK found that certain existing surveys do have the capacity to begin reporting on mesopelagics given the additional resource, in terms of time and equipment and willingness to do so. Staring this process will provide an index of a currently unreported mesopelagic fish abundance during routine surveys and move such programs towards ecosystem oriented surveys.

Annex 3: Tables

Table 1. Current acoustic trawl surveys reporting acoustic density for mesopelagic fish.

Nation	Cruise	Platform type	Area	Date	Occurrence	Time series	Mesopelagic fish abundance
New Zealand	Chatham Rise	RV	Chatham Rise, New Zealand	Jan	Biennial	1992-present	yes - acoustic density
New Zealand	Fisheries Oceanography	RV	Chatham Rise, New Zealand	Various	Occasional	2008, 2011, 2015	yes - acoustic density
New Zealand	Sub-Antarctic	RV	Campbell Plateau, New Zealand	Nov-Dec	Biennial	1991-present	yes - acoustic density
New Zealand	Ross Sea	RV	Southern Ocean, Ross Sea	Jan-Mar	Biennial?	2008, 2010, 2015, 2018, 2019	yes - acoustic density
New Zealand	Toothfish FV	Multiple FV	Southern Ocean, Ross Sea	Nov-Marc	Annual	2001-present	yes - acoustic density
USA	AMAPPS	RV	NW Atlantic	Various	Biennial	2009-2016	yes - acoustic and trawl
USA	Deep-See	RV, Deep-see	NW Atlantic	July-August 2019	Occasional	2018-present	Yes – acoustic and trawl
Greece	MEDIAS (Greece)	RV	Mediterranean Sea	May-Jul, Sep	Annual	1997-present with gaps	Yes – acoustic density
Greece	MESOBED	RV	Eastern Mediterranean Sea	Winter/Spring/Summer/Fall	Occasional (3 years)	2017 – 2019	Yes – acoustic density
Canada	ArcticNet/ISECOLD	RV	Labrador Sea	June/July	Occasional (2 years)	2018-2019	Yes – acoustic density
Norway	UiT/UNIS	RV	Arctic Ocean (Svalbard)	January and August	Occasional (2 years)	2016-2017	Yes – acoustic density
Spain	JUVENA	Double RV	Bay of Biscay	Autumn	Annual	2013-present	Yes – acoustic and trawl
USA	DEEPEND	RV	Gulf of Mexico	Spring/Summer	Annual	2015-2018	Yes – acoustic density
USA	ONSAP	Multiple RV	Gulf of Mexico	Winter/Spring/Summer	Quarterly	2010-2011	Yes – acoustic density
Peru	IMARPE's Acoustic Assessment Prog	Multiple RV	Northern Humboldt sys	Summer, winter and spring	Seasonal	1999-present	Yes – acoustic density

Table 2. Current acoustic trawl surveys with the potential to report acoustic density for mesopelagic fish in the future.

Nation	Cruise	Platform type	Area	Date	Occurrence	Time series
IRL/NO/NL/FO	IBWSS	RV/FV Multi-vessel	NE Atlantic	Mar-April	Annual	2004-present
USA	CalCOFI	RV	South and Central California	Winter/Spring/Summer/Fall		2009-2016
USA	CPS	RV	NE Pacific	Spring	Annual	2006-2017
USA	CPS	RV	NE Pacific	Summer	Annual	2008-2018
Swiss/CAN/UK	GLACE	RV	Greenland Circumnavigation	July-September	Occasional (1 year)	2019
CAN+US	Pacific Hake	RV	NE Pacific	Late Summer	Annual/Biennial	1995-present
Canada	Strait of Georgia pelagic ecosystem	RV	Strait of Georgia	Summer	Biennial?	2011-present
DK, FO, IC, NO, RU	IESNS	RV/FV Multi-vessel	Norwegain Sea/Barents Sea	Summer	Annual	1995-present
DK, FO, IC, NO, GL	IESSNS	RV/FV Multi-vessel	Norwegain Sea	Summer	Annual	2007-present