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Report of the Workshop on Monitoring Technologies for the Mesopelagic Zone (WKMESO)

6-10 November 2017

Bergen, Norway

ICES International Council for the Exploration of the Sea

CIEM Conseil International pour l'Exploration de la Mer

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Executive summary

The Workshop on Monitoring Technologies for the Mesopelagic Zone (WKMESO), chaired by Dave Reid (Ireland) and Kristján Kristinsson (Iceland) met in, Bergen, Norway, 6-10 November 2017. There were 12 participants from five countries, Ireland, Iceland, Norway, Russia and Denmark.

The main aim of the meeting was to review the performance of the international deep pelagic surveys in the Norwegian Sea and the in the Irminger Sea, and to make recommendations for their future development, especially new technological developments. Also, the aim was to evaluate the survey potential for the wider mesopelagic community.

The meeting was set up to first examine the specific surveys and the possible new technological tools available for them through specific presentations. These are summarised in Chapter 2. The next step was a critical evaluation of the WGIDEEPS surveys. This was carried out using two SWOT (Strengths, Weakness, Opportunities and Threats) analyses. These looked at the current position, then repeated the SWOT on the basis of a number of recommendations for improvement. These are presented in Chapter 3. Finally, the meeting looked at the potential for these and other acoustic surveys in the NE Atlantic as platforms for providing quantitative data on the mesopelagic community, in terms of abundance, variability, biodiversity, and spatial distributions.

The SWOT analyses provide both a critical appraisal of the current surveys, and of ways of improving these. This was combined with recommendations on the use of a number of new or emerging technologies to improve the performance of the surveys for their core objective, redfish estimation, and in terms of the wider mesopelagic community. The technologies included:

- Multi-frequency, broadband sounders, mounted on vessels, as well as deep towed or drop type deployment systems;
- Optical technologies to quantify species going into trawl cod ends allowing a highly depth resolved picture of species in the water column;
- New net designs specific to mesopelagics, including both trawlnets, and large-scale plankton nets.

The acoustic, optical and net systems open the potential for these surveys to be used to quantify the mesopelagic community down to species and size. The potential for a number of other surveys to be developed in the same way was also evaluated. The surveys considered were the:

- Norwegian spring-spawning herring survey (IESNS).
- International blue whiting SSB survey (IBWSS).
- International ecosystem summer survey in the Nordic Seas (IESSNS).

All are coordinated under WGIPS.

In conclusion, the WK made a series of recommendations for the improvement of the redfish surveys and indicated the way in which new technologies could be incorporated into those and other acoustic surveys across the region.

1 Opening of the meeting

The Workshop on Monitoring Technologies for the Mesopelagic Zone (WKMESO), chaired by Dave Reid (Ireland) and Kristján Kristinsson (Iceland) met in, Bergen, Norway, 6-10 November 2017 to:

a) review and evaluate the strength and limitations of the approach currently used to monitor the abundance of commercial fish and other species in the mesopelagic zone of the Irminger and Norwegian Seas.

b) evaluate the potential of trawls, nets, acoustic, optical and other techniques to monitor the abundance of commercial fish and other species in the mesopelagic zone of the Irminger and Norwegian Seas.

c) recommend additions or modifications in the observation method used by the ongoing WGIDEEPS survey, within the 3y-term of the group.

d) recommend further developments in the observation method used by the WGIDEEPS survey, beyond the 3y-term of the group

2 Perspectives on the surveys, and technological advances

In pursuit of ToR a and b, WKMESO invited presentations on the WGIDEEPS surveys, and on the possible technological developments that could be used to improve these. Fuller survey reports can be found in ICES (2008, 2013). These presentations are summarised in this chapter.

2.1 Description of the current redfish survey in the Norwegian Sea

Historical development:

The beaked redfish survey in the Norwegian Sea is an acoustic-trawl survey. The survey started in 2008 as an international effort to map the distribution and abundance of redfish in the Norwegian Sea. The first survey was conducted by three vessels from Norway, Russia and the Faroes during August 2008 for a total of 39 days-at-sea. The survey was repeated in 2009, 2013 and 2016 by Norway only and the area covered was restricted to the Northern part of the Norwegian Sea. The survey was conducted on board fishing vessels except in 2016 when it was conducted aboard R/V Arni Fridriksson. The next survey is scheduled in 2019 by Norway and participation from other nations is not confirmed.

Methodological approach:

The survey is based on an acoustic transect design. Acoustic data has been acquired with an EK60 Hull mounted echosounder and the primary frequency used is 38kHz. This was complemented by 18, 120 and 200kHz in 2016. Trawling has been conducted with a Gloria 2048 (2008, 2009), Gloria Helix 2560 (2013) and Gloria 1024 (2016), all combined with a multi-sampler that allows sampling at three different depths within one haul. Because beaked redfish forms large layers rather than schools, trawling is not done on registration but in the steaming direction of the vessel on a grid of stations that cover almost regularly the geographical and depth range of the survey. There are no fixed stations during this survey but hydrographical measurements are collected at the time of trawling with CTD attached to trawl headline.

The biological analysis of trawl samples includes identification and weighing of all species present in the 3 cod-ends, length measurements for commercial species and dedicated biological sampling (weight, sex, maturity, age, genetics, morphometrics, and parasites) for redfish.

Acoustic-abundance estimates are done by echo-integration and energy allocation to individual species is derived from trawl composition. In addition, a swept volume estimate is calculated using trawl data only.

Limitations to the current approach

1. The major limitation of the current survey is its geographical coverage. The survey was designed for three vessels and is operated by one, thereby covering only one third of the assumed distribution area of the stock.
2. Because most redfish reside in the Deep Scattering Layer (DSL) and because small/fragile organisms in this layer are not quantitatively sampled by the Gloria trawls, the interpretation of the echograms in this layer is challenging. A workshop held in 2009 to evaluate echogram interpretation methods concluded that "*...differences in scrutinizing methods have a very large impact on the abundance esti-*

mate of redfish. They probably constitute the major source of uncertainty for any quantitative estimate" (Planque et al. 2009). It is also possible that echogram interpretation has changed over time.

3. Catchabilities of the Gloria trawls have been estimated from experiments conducted above the DSL. It is assumed that the catchability is identical within the DSL but this could not be verified with the current observation approach.
4. The Gloria trawls are not designed to collect small fragile organisms in the DSL. Very little information is collected on these species aside from occurrence and total acoustic energy (s_A) in the DSL.
5. The target strength equation for beaked redfish remains an issue. A workshop held in 2010 reviewed an ensemble of available studies and recommended the equation TS = 10.6 log(L) - 55.4 to be used (ICES, 2010). Today, two different equations are used in the Norwegian and Irminger Sea and these differ by 1.3dB (i.e. 35%).

Use of the survey data in assessment

The pelagic survey data has not yet been used in the beaked redfish analytical assessment. Because of the limitations listed above, it is not believed that the abundance estimates derived from the survey are reliable. The sharp decline observed in 2016 (Figure 2.1.1) is worrying but, because the survey coverage is insufficient, it is not possible to assign this to a decline in population abundance. The next survey is scheduled for 2019 and unless the major limitations are addressed, it is unlikely to provide a clearer picture of the stock dynamics. Survey information on population age-structure will be reviewed for inclusion in the assessment at the forthcoming benchmark assessment workshop in 2018.

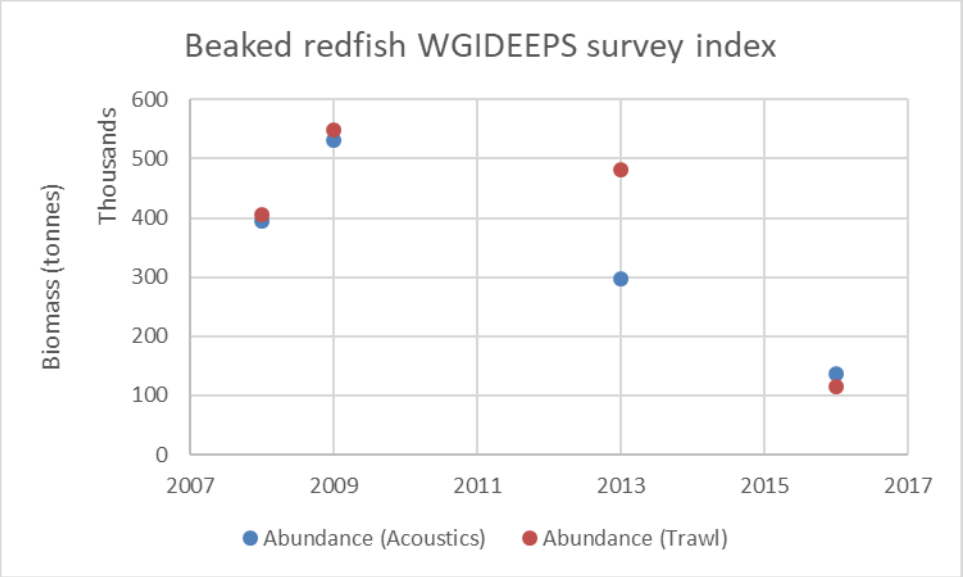

Figure 2.1.1. Abundance estimates derived from acoustics and trawls for the WGIDEEPS survey in the northern Norwegian Sea in 2008 (Norway only), 2009, 2013 and 2016.

Conclusion

The Strength, Weaknesses, Opportunities and Threats for the current WGIDEEPS survey are summarised in section 3.3. There is a clear need to improve the design and observational approach in this survey to resolve many of the issues listed above and to provide robust and informative data that can serve redfish assessment and forthcoming observational needs for mesopelagic species in the deep scattering layer of the Norwegian Sea.

2.2 International redfish survey in the Irminger Sea and adjacent waters.

History

Surveys on pelagic beaked redfish (*Sebastes mentella*) have been conducted since 1982 in the Irminger Sea. These surveys have been conducted by individual nations or in collaboration between two or more nations. The area coverage and methodology have varied and often the area coverage was limited, especially in earlier years. The surveys are mainly hydroacoustic surveys, but since 1999, pelagic trawling has also been used to estimate biomass of pelagic beaked redfish when acoustic estimates are not possible because of the deep scattering layer (DSL). Over time, both the horizontal (area covered 350,000-400,000 nmi^2, Figure 2.2.1) and vertical coverage (0-900 m) have increased, as earlier survey coverage was not considered sufficient for stock assessment purposes. The survey in 1999-2015 has been conducted biennially by Germany, Iceland and Russia (with Norway participating in 2001) using two to five vessels with shipping time between 45-70 days. Only the deep pelagic stock was surveyed in 2015 with two vessels.

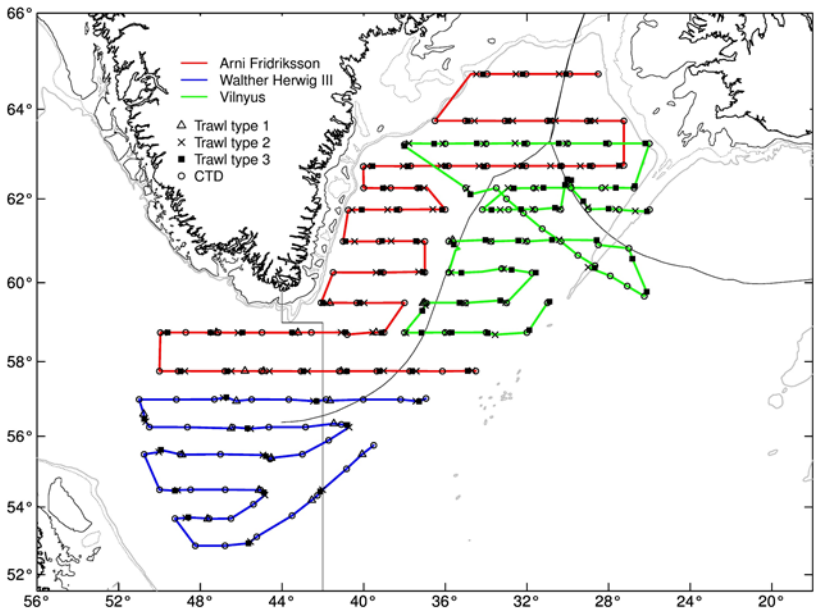

Figure 2.2.1. Cruise tracks, trawls and CTD stations taken in the joint international redfish survey in June/July 2013 in the Irminger Sea and adjacent waters.

Objectives

6. To provide survey biomass indices for the North Western Working Group (NWWG) to support advice on pelagic beaked redfish stocks in the Irminger Sea and adjacent water;

7. To estimate the geographical and depth distribution and relative abundance of pelagic beaked redfish stocks;
8. To monitor changes in the stocks of pelagic beaked redfish independently of commercial fisheries data;
9. To collect data for the determination of biological parameters for beaked redfish stocks;
10. To collect hydrographical and environmental information;
11. To collect additional observations relevant to integrated ecosystem assessment in the area.

Method

The survey is based on acoustic transects. Acoustic data are collected with hull mounted echosounder (EK60 being the latest version on all vessels). The primary frequency is 38 kHz, but 18 kHz, 120 kHz and 200 kHz are also stored by Iceland and Germany in latest surveys. The trawl used are Gloria 1024 (Germany, Iceland) and Russian pelagic trawl (Russia). Both trawls are with 50x50 m opening. The trawls used by Germany and Iceland use multisampler that allows sampling in three different depth layers. The trawling is done on a grid of stations on the transects (45-60 NM between stations) in three different depth layers: 0-ca. 350 m where redfish can be acoustically identified; ca. 300-500 m within the DSL layer; and 550-900 m within and below the DSL.

Hydrographical measurements are done at each trawl stations and at the corners of each transects using CTD probes down to 1000 m.

Catch weight and number of all species is recorded for each haul. If possible, squids should be divided by species and/or size. The weight of jellyfish is recorded. Shrimps are reported in one group, but krill is reported in a separate category. For redfish weight, sex, and maturity is measured and otolith sampling (for aging), parasite and pigmentation observation, and stomach analysis are also conducted. For other fish species, length measurements are done for at least 20 individuals per species per trawl type.

Limitations

- Acoustic estimates of redfish are not possible in the deep scattering layer as it is currently not possible to separate the redfish from small organisms in the layer.
- Scrutinizing of the acoustic data are not cross-validated between partners.
- The trawls are not designed to collect small organisms in the DSL (mesh size in the codend 16 and 22 mm). Very little information is collected on these species aside from occurrence and length measurement of fish species, and total acoustic energy (sA) of the DSL.
- Different trawls are used by different partners (Gloria pelagic trawl and Russian pelagic trawl). Catchabilities of these trawls have been estimated from experiments conducted above the DSL. It is assumed that the catchability is the same within the DSL which cannot be verified.

Use of data in assessment

The abundance estimates derived from the survey has been used as a basis for the advice for both stocks, but no analytical assessment conducted until 2016. In 2016, analytical assessment (Gadget model) was approved for the deep beaked pelagic stock and

reference points defined. This model utilizes age and length information from the fishery in addition to the biomass index and lengths from the trawl–acoustic survey.

Both stocks have declined sharply over the past two decades (Figure 2.2.2). The shallow stock size is now estimated to be 5% of what it was in the early 1990s. The deep stock size is estimated to be around 20% of what it was in 2001.

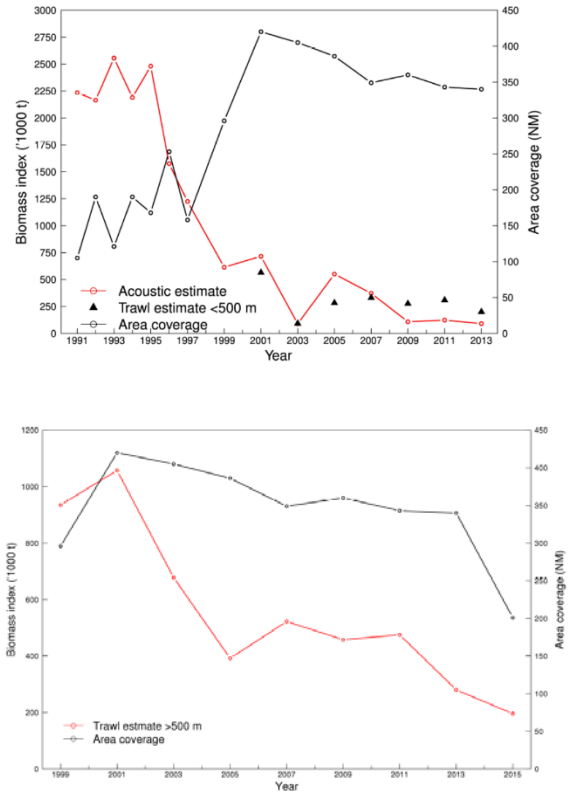

Figure 2.2.2. Right: Overview of acoustic survey indices (thousand tonnes) of the shallow pelagic stock from above scattering layer (red open circles, line), trawl estimates within the scattering layer and shallower than 500 m (black triangle), and aerial coverage (nautical miles squared, black open circle) in the Irminger Sea and adjacent waters 1991– 2013. Right: Overview of trawl survey indices (thousand tonnes) of the deep pelagic stock deeper than 500 m ((red open circles, line) and aerial coverage (nautical miles squared, black open circle) in the Irminger Sea and adjacent waters 1999–2015.

2.3 Deep Vision

The Deep Vision in-trawl camera system can be used to identify and measure fish inside a trawl (Fig 2.3.1.). Although initially designed for medium-sized commercial fish species (small pelagics to large gadoids), recent work has demonstrated the system may be well suited to surveys of mesopelagic species (Fig 2.3.2.). All organisms passing through the trawl are guided into the field of view of a stereo camera system which collects 5-10 full-colour image pairs per second. The accompanying analysis software is used to identify and measure fish, with results output in .csv format. Work is underway to automate species identification and selection of start and end points for length measurement. Time- and depth-referenced Deep Vision images can be imported directly into the LSSS software system for post-processing acoustic data, providing improved information for species discrimination.

Figure 2.3.1. Deep Vision system deployed in a pelagic trawl

Figure 2.3.2 Mesopelagic fish identified in Deep Vision system

2.4 Acoustics

IMR have developed and used a multi-frequency, broadband acoustic probing system for measuring density and target strength at depth, mainly for the use on commercially important fish, but methods have been developed for of the use of this system in stationary and profiling modes on mesopelagic fish. The methods are important for removing two potentially huge error sources in acoustic estimates of mesopelagic fish; resonance and the presence of alternative gas bearing organisms like siphonopores, but also for new estimates of the real catch efficiency of different trawl sampling gears historically and currently used on mesopelagic fish.

The IMR "TS-probe" have been extensively been used on experimental research surveys and occasionally on routine surveys since 2005. The main task for the probe have been to measure mean target strength of important fishes at their normal depths and densities, carefully lowered close to or into the layer of interest, resolving the densities into single targets and measuring their mean target strength over typically one to two hours. In recent years, the probe has also been used in profiling mode, where the transducer platform has been mounted in lateral viewing mode and the probe lowered like a CTD from surface to the bottom at a speed of 0.5 to 1 ms-1. The major use of the probe

has been detailed mean dorsal target-strength measurements to supply the fisheries acoustic surveys in Norway as herring, blue whiting, capelin and sand eel, but also target strength for horizontally observing sonar aspect measurements on herring, mackerel and capelin.

The 400 mm inner diameter central pressure cylinder (www.imenco.no) simultaneously holds 4 echosounders, either 4 Simrad EK60 split-beam systems, or from 2009; 4 Simrad EK80 wideband transceivers, (WBT), split-beam echosounders, all driven on linear power supplies (CALEX 32012D) from inside the can. The split-beam transducers are mounted in a maximum packing (Korneliussen et al., 2008) on a transducer plate, which in turn is mounted in a compass suspension system, which can be controlled by two subsea motors. The transducer platform orientation is monitored by an accurate tilt/roll sensor (EZ-Compass 3; Advanced Orientation Inc.), alternatively a NS-15/P2 dual-axis inclinometer, (HL-Planartechnik GmbH) for higher accuracy. The tilt/roll sensor unit contain a ScanSense PS-30 Series Pressure/Temperature transmitter.

The resolution capability of the new broadband echosounders allows the system to measure not only mean TS at the centre frequency, but the TS(f), the target strength spectrum of the individual target echo. Averaged over more than 1000 tracks with 20 – 30 measurements in each track, the mean spectrum response can be well described. Broadband target-strength measurements of the lantern fish *Bentosema glaciale* in Osterfjord at 300 meters depth have also been obtained.

Over the last 5 years, the probe has also been used as a profiling instrument, where the transducers are side-mounted and the probe is lowered at constant speed from surface to the bottom, while measuring marine organisms in the water column at relatively short range, and subsequently at high ping rate. In these profiles, the different layers are measured with multi-frequency acoustics, or recently with broadband acoustics, where standard tools for automatic or semi-automatic species identification for single targets is conceivable. With the high-resolution capability using standard narrow beam, 7^{o}, transducers and short pulse duration, the deep layers are in most cases resolved into single target conditions, where only one animal is measured in the pulse resolution volume. Since both the nominator and the denominator in the echo integrator equation is measured directly within the same volume, absolute density estimates are achievable. Studies have been carried out down to 440 m in a Norwegian fjord with abundant mesopelagic fish, dominated by two species, pearlside (*Maurolicus muelleri*) and Glacier lantern fish lanternfish (*Bentosema glaciale*).

2.5 Commercial gears and exploitation surveys

Mapping the potential for commercial exploitation of mesopelagic fish in the area NEAFC RA 1 (XXR Reykjanes Ridge). Industrial research project (2016-2020):

Three cruises have been carried out on board the commercial fishing vessel "Birkeland" (62m LOA) in the periods 27 June - 29 July 2017; 15 April – 6 May 2017; and 15 July – 04 August 2017. The area covered was NEAFC RA 1 (XXR Reykjanes Ridge) (Figure 2.5.1). Vertical distribution of fish was monitored using FURUNO echosounders (38kHz and 60kHz and 120kHz) and net sounder (200kHz). Experimental fishing was carried out with full-scale prototypes of mesopelagic trawls. In 2016, we used a 1200m HEX laksesildtrål (Egersund Trawl AS) which in operation was approx. 100m wide and 65m high. To this trawl we attached an extension part with a series of small-meshed inner nets (pampers), providing an effective fishing area of approx. $160m^2$. The rear most part of the 70m-codend had 8mm mesh size. In 2017, the 1200m Hex laksesildtrål was modified and additional small-meshed inner nets (pampers) off different

mesh sized (50mm to 16mm) were added to the body of the trawl, providing an effective fishing area of approx. 960m^2 in operation. In addition, a new 800m Lysprikkfisktrål (Egersund Trål AS) entirely built with small-mesh inner nets and that in operation was 45m high and 45 m wide was tested. Catches rates varied from few kg to approx. 4000kg per hour. 1-2kg samples were taken from each trawl station and the main species were identified and length measured. Chemical characterization of the biomass was also carried out in each fishing station, including thermic separation and hydrolysis.

Shortly, the first two years in this industrial project has provided valuable information on:

- Fish behaviour in respect to trawl (i.e. herding and filtering in different parts of the trawl and different mesh sizes). This have been done by using underwater cameras attached to the trawl (using red light and infrared lights) and by mounting small-mesh collecting bags on the outside of the trawl to quantify escaping fish.
- Towing resistance, net geometry, and water flow has constantly been measured in all tows.
- Experiments in pilot- and laboratory scale on processing of mesopelagic raw material are carried out on board such: as hydrolysis and thermal processing/separation and production of silage.
- Chemical characterization of the raw material representing each fishing station is carried out. The composition of proteins, fats, ash and water is determined. Lipid acid composition is measured as well as lipid class analysis and determination of mineral content and soluble low molecular components and larger molecular components in the solid phase.
- Samples, both from 2016 and 2017, were sent to AZTI for age determination.
- Representative samples have also been analysed for content and unwanted substances such as dioxins, PCBs, PAH, pesticides, and heavy metals.

This project will continue to 2020 and at least two cruises (with a total of 45 cruise days) will be carried out annually in the coming three years. The main area will continue to be NEAFC RA 1(XXR Reykjanes Ridge).

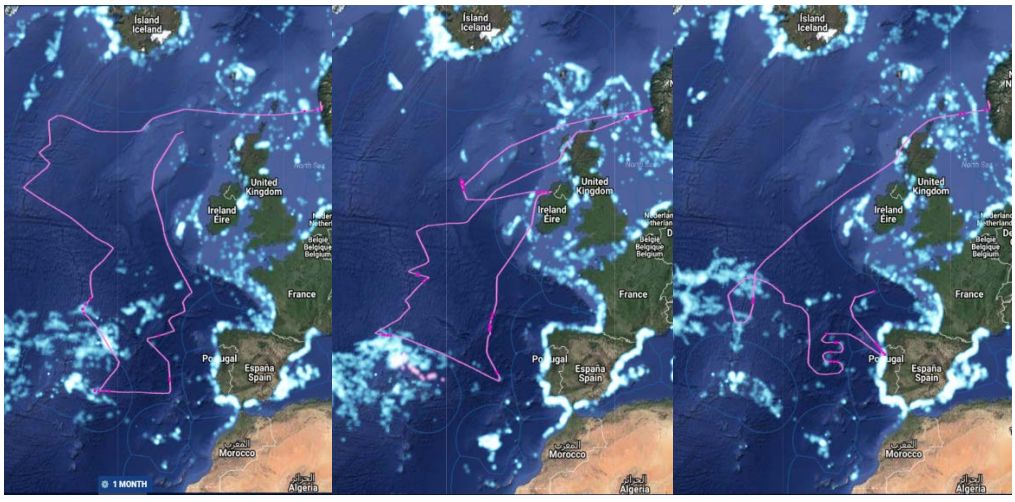

Figure 2.5.1: Area cover by MS Birkeland in June-July 2016 (left), April-May 2017 (centre) and July 2017 (right) in the area NEAFC RA 1 (XXR Reykjanes Ridge).

Figure 2.5.2: Clean catch of *Maurilocus muelleri*

Figure 2.5.3: Mixed catch of diverse mesopelagic fish and krill.

Figure 2.5.4: Mixed catch of *Maurolicus muelleri* and krill.

2.6 Some aspects of trawl work in the Irminger Sea redfish surveys

A trawl with opening 50m is currently used by all vessels participated in IDEEP survey in the Irminger Sea. Trawls with opening 100, 120, 150 m are used in the redfish fishery in this area. It is known that fish react on capture by the trawl. Fish inside a large trawl will start to react much later than inside a small one and then cannot leave the trawl because of the large distance between the beginning of trawl and the point where they start to show a reaction. Fish inside a small trawl will reacts to the trawl earlier and will have a better opportunity to escape the trawl due to the short distance needed.

It could be assumed that the difference in the catches of trawls between those with 50 and 100 m opening would a factor of 2. But actually the difference will likely be more than 2 times (up to several times) for the reasons described above. Both issues are explained in Korotkov (1998).

Fishers use additional nets on the lower panel of trawl. These are called “pampers” and made from lightweight material. This net is used to prevent diving redfish avoiding or escaping trawl capture. The fishery practice showed that the redfish escape through the bottom panel of the trawl. Using a small mesh inner net in the cod end will result in a poor water filtration through this small mesh and the zone at the beginning of inner net with water back pressure which prevents for normal inflow of fish into the cod end. Fishers use a pump system in the krill fishery which provides suction of water from the cod end to the vessel deck. The pump is installed in the tip of the cod end and has a long hose up to the vessel. So there is no influence from this inner net on the krill fishery. The described issue is presented for instance and confirms that the problem with inner net is existed. When using a small mesh inner net in the cod end, survey vessels should consider carrying out a trawl calibration with and without inner net to evaluate the influence on redfish catch.

All described issues have been derived from fishery practice and represent the potential ways to improve redfish biomass estimates based on trawl catch data obtained in

the mesopelagic zone. Before considering of appliance, these ways should be confirmed in surveys or during ad hoc investigations.

2.7 Estimation of Trawl/Deep Vision catchability/observability

Catchability of individual species caught in the Deep Vision can be derived from the following equation:

$$(1)\ N_i = \sum_{sp} \frac{1}{q_{sp}} C_{sp,i}$$

Where N_i is the absolute number of individual targets in a given volume of water. $C_{sp,}$i is the observed number of individuals of species *sp* by Deep Vision in the same volume of water and q_{sp} is the catchability of species *sp*. Assuming no observation error, it is possible to estimate directly and precisely all catchabilities (*q*'s) if the number of samples is equal or greater to the number of species.

Given that there are observation uncertainties, more samples are required and the *q*'s will be estimated with some level of uncertainty.

If WBAT can provide absolute numbers by acoustic categories that can be linked to species groups (e.g. shrimps, jellies, etc.) then the problem can be simplified by estimating the catchabilities within each acoustic category. In this case N_i is the absolute number of individual targets in a given acoustic category and the sum on the right side of the equation is calculated over the species that belong to this acoustic category only.

The above method relies on the following key assumptions:

- the bodies of water explored by WBAT and Deep Vision are comparable (same species composition and abundance),
- all targets counted by WBAT can be seen by Deep Vision and vice versa (as a whole, of by 'acoustic category').
- individual *q*'s are constant (i.e. they don't vary with species composition or abundance),
- samples compositions are linearly independent (different samples don't have the same proportions of species),
- WBAT estimates are absolute (at least for the acoustic categories of interest).

3 Appraisal and proposals for the redfish surveys

3.1 SWOT analyses and proposals for revision for the Norwegian and Irminger Sea surveys

WKMESO carried out two SWOT (Strengths, Weakness, Opportunities and Threats) analyses for the redfish surveys in the Norwegian and Irminger Seas. The SWOTS are presented below. The first row presents the organisation of the current survey in the main left-hand box, and the proposed changes in the right-hand box. The subsequent boxes in the column headed for the "Current survey" provides the SWOT information on the basis of the survey as it stands. The second column "Proposed revision" indicates the SWOT IF the proposed changes were made.

3.2 Proposed revised Norwegian Sea survey

The newly proposed Norwegian Sea survey attempts to resolve many of the observational issues that currently exist for the assessment of redfish abundance and distribution while contributing to a whole-ecosystem survey that covers many animal groups, commercial and non-commercial, in the epipelagic and mesopelagic zones. The survey is conceived in coordination with the international observation efforts conducted by WGIPS, in particular the international July survey (*IESSNS*), which has mackerel as the primary target.

Changes in the survey design are summarised in the SWOT table. These include in particular: a larger geographical coverage, a station-based design with use of WBAT and DeepVision as the primary observation tools, and the coordination with the IESSNS survey for acoustic transect data. The latter doesn't require changes in the design of the IESSNS survey, except for the hydroacoustic data which would need to be registered down to 800m instead of the 500m depth limit currently in use.

The combined use of multi-frequency acoustics from the IESSNS survey, WBAT, DeepVision and trawl samples at different depth with the multi-sampler would constitute the observation basis for the first integrated pelagic ecosystem survey in the Norwegian Sea, from surface down to 800m depth. In this way, the distribution and abundance of commercial species (mackerel, blue whiting, redfish, herring) as well as non-commercial (or not-yet commercial) species (gonatus, ribbon barracudina, maurolicus, benthosema, krill, jellies) can be jointly assessed. The survey(s) would expand the nature and quantity of data provided to the ICES Working Group in the integrated ecosystem assessment of the Norwegian Sea (WGINOR).

3.3 SWOT for the Norwegian Sea survey

	Current survey	***Proposed revision***
Description	Frequency: every 3rd year	Frequency: every year
	Duration: 3-4 weeks	Duration: 5-6 weeks
	Acoustics: hull mounted 38kHz (+18kHz)	Acoustics: hull mounted 38kHz+18kHz
	Trawl: Gloria spp + multi-sampler	Trawl: Gloria spp + multi-sampler + DeepVision
	No fixed stations	Stations: CTD+WBAT every 2500-3500NM^2
	Area: ~69,000NM^2	Area: ~300,000NM^2
	Survey design: acoustic transect/zigzag combined with trawl samples	

		Survey design: trawl/station-based combined with multi-frequency acoustics collected during the mackerel (IESSNS) survey
Strength	Max 1.5 week ship time/year Results comparable with earlier years (Norway only) and with Irminger Sea to a large extent. Provides unique biological data on age/sex/maturity of redfish in the Norwegian Sea. Only survey to monitor waters deeper than 500m in the Norwegian Sea.	*Covers the entire distribution area of beaked redfish,* *Interpretation of echograms is qualified,* *information about other species in the DSL at the scale of the Norwegian Sea (species, frequency),* *Provides unique biological data on age/sex/maturity of redfish in the Norwegian Sea,* *Information every year,* *Catchability in and out of the DSL can be estimated,* *Becomes a potential test platform for novel observation equipment.*
Weaknesses	Does not cover the entire distribution area of beaked redfish (survey designed for 3 vessels but conducted by one), Provides information only every 3rd year, Trawl and vessel have changed over time, Quality control on the hydroacoustics scrutiny is poor (lack of information on other species, + inconsistent in time), Trawl catchability estimates in and out of the DSL are assumed identical, but this needs verifying Little biological information about other species in the DSL (occurrence only)	*More ship time required.* *Requires more equipment, more staff, more training, data analysis method developments and post-cruise data processing*
Opportunities	Because it is focused on water layers between 200 and 800m, this survey has the opportunity to provide unique deep pelagic ecosystem monitoring that is currently lacking in the Norwegian Sea.	*Provides a platform for the first integrated pelagic ecosystem survey in the Norwegian Sea, from surface to 800m.* *Possibility to use the platform for new observations of the mesopelagic zone (e.g. deep towed acoustics using WBAT and Flexus)*
Threats	There is a risk that the survey be dismissed because of insufficient data quality. Because of its low prioritisation there is a recurrent risk of change in survey timing, reduction in ship time and difficulty to find appropriate vessels. This is reinforced	*Many vessels required at the same time (most for the mackerel survey), so finding a vessel for this component can be challenging.*

	by the lack of international participation in recent years which is likely to persist if the survey remains unchanged.	*Communication of hydroacoustic data and post-cruise scrutinizing can be difficult issues.* *Dependent on the maintenance of the mackerel survey.* *If other nations join the survey, they will need to adjust to the technological approach chosen (not really a threat but worth noting).*

3.4 SWOT for the Irminger Sea survey

	Current survey	***Proposed revision***
Description	Frequency: every 2nd year 1999-2015, but changed to every 3rd year. Duration: 3-4 weeks Acoustics: hull mounted 38kHz Trawl: Gloria 1024 + multi-sampler and Russian pelagic trawl No fixed stations Area: ~400,000NM^2 Hydrography: CTD stations down to 1000 m at each trawl stations and at corner of each transects Survey design: acoustic transect combined with trawl samples	Acoustics: hull mounted 38kHz+18kHz Trawl: Gloria spp + multi-sampler + DeepVision Stations: CTD+WBAT at each CTD cast.
Strength	The survey covers the whole distribution area of adult pelagic beaked redfish, both vertically and horizontally. Various biological information compiled on pelagic beaked redfish. Survey designed adaptable to redfish abundance distribution. Comparable between years. Hydrography information collected with over 140 CTD stations deployed. One permanent hydrographic section (10 stations). Data collected on pelagic beaked redfish used as basis for advice for the stocks and in analytical assessment.	

	The only survey in the area that goes below 350 m. Used for other research (whale sighting, oceanographic sampling). Long time-series. Hydroacoustic survey started in 1991 and in 1999-2015 biennial trawl-acoustic survey.	
Weaknesses	Scrutinizing of the acoustic data are not cross-validated between partners. Different trawls used although the net opening is similar. Catchability is different between trawls. Catchability assumed to be the same in different layers and between gear. Inter-transect spacing has not been analytically determined. Basis for stratification is not known. Little biological information about other species in the DSL (occurrence only). The survey was in 1999-2015 conducted every second year but since then the plan is to conduct it every third year.	*Interpretation of echograms is qualified,* *information about other species in the DSL at the scale of the Irminger Sea (species, frequency),* *Provides unique biological data on age/sex/maturity of redfish in the Irminger Sea* *Catchability in and out of the DSL can be estimated* *Becomes a potential test platform for novel observation equipment*
Opportunities	Opportunities of ecosystem monitoring e.g.: Platform for whale observation. Plankton sampling. Research on mesopelagic diversity and abundance. Incorporation of new technologies: Deep Vision WBAT attached to the CTD	*Provides a platform for the first integrated pelagic ecosystem survey in the Irminger Sea, from surface to 900 m.* *Possibility to use the platform for new observations of the mesopelagic zone (e.g. deep towed acoustics using WBAT and Flexus)*
Threats	Many vessels are needed to cover the areas. Where to find vessels to do the research? At least three vessels are needed with combined ship time of 60-70 days. Stocks are declining to economically less viable. Priority on pelagic redfish research not high.	

	Not many nations interested in the research (cost, priority).

4 Acoustic Trawl surveys to quantify abundance in the mesopelagic zone

In this chapter, we look at the scope for developing some existing surveys to collect data and information for the quantification of the mesopelagic communities. The surveys considered were:

- International blue whiting spawning stock survey (IBWSS).
- International Ecosystem Survey in Nordic Sea (IESNS).
- International ecosystem summer survey in the Nordic Seas (IESSNS)

These surveys are fully reported in ICES (2017).

4.1 Scope for expanding existing surveys for mesopelagic estimation

Based on the information presented at the meeting and summarised in Chapter 2, the WK concluded that there was considerable scope to expand the existing surveys to encompass the acoustic estimation of the mesopelagic biota community, and of the deep scattering layer. All, or some of these systems may have potential to be deployed on the surveys to expand their data collection and monitoring capabilities in the context of the mesopelagic community. It should be recognised that this would normally be feasible only if it did not compromise the current purpose of these surveys. The key tools that are coming available now are:

- Simrad EK80 Scientific wideband echosounder can operate across a large number of frequencies simultaneously ranging from 10 to 500 kHz. With a wideband frequency sweep ("chirp") in combination with advanced signal processing it provides a good signal to noise ratio and range resolution. It also allows multi frequency application for species identification.
- Simrad WBT Mini Miniature wideband transceiver, WBT Tube Subsea wideband transceiver, which can allow the system to be used in AUVs etc., as well as deep towed systems, bringing the transducers closer to the mesopelagic community.
- MacArtney FLEXUS, a versatile vehicle for working off survey vessels and has an operational envelope of 0-200 metres and is able to operate at a tow speed of up to 10 knots making it capable of going into deeper water appropriate for mesopelagics estimation.
- Deep Vision – See Chapter 2.3.
- Adapted pelagic trawls targeting mesopelagics – See Chapter 2.5.
- Large-scale plankton nets with large openings e.g. 20 x 20m, and small mesh (3mm) cod ends, specifically designed for mesopelagic organisms. Currently under development at IMR.

4.2 International blue whiting spawning stock survey (IBWSS)

Background

The IBWSS survey was established in 2004 and is carried out annually in March/April over a three week period by vessels from Ireland, Norway, Faroes and the Netherlands. The survey reports the distribution and age stratified abundance of the Northeast Atlantic blue whiting stock during the spawning season to the west of Ireland and Britain covering an area of over 135,000 nmi². Survey results are submitted annually to WGWIDE and survey data are submitted to the PGNAPES online database. Coordination and planning is undertaken during a post-cruise meeting (April) and reported to WGIPS in January of the following year.

The IBWSS survey coordinator is rotated on a four year cycle and is currently held by Faroes until 2018 when it will rotate to Norway.

Survey design

The overall design uses stratified transects with a random start (random latitude) to ensure transect coverage is not replicated but randomized between years. Survey stratification is based on (acoustic) sampling effort determined by individual vessel coverage determined during planning. The survey design follows a variable transect spacing, ranging from 30 nm in areas historically containing low abundance, to 7.5 nm in the core area. Survey design, data analysis and biological sampling are carried out as detailed in the WGIPS survey manual (SISP #9).

Mesopelagic observations - current status within IBWSS

Directed pelagic trawls targeting blue whiting often contain mesopelagic fish species as an incidental bycatch. This occurs as the trawl passes through the upper mesopelagic zone (100-350m) to and from the target trawling depth (250-600m) for blue whiting. Bycatch species are recorded as components of the catch and usually reported in the national cruise reports. Ad hoc trawl sampling within the mesopelagic zone is carried out but not as part of routine operations. Such trawls are mostly for trace recognition purposes and/or to collect biological samples for independent studies.

Echograms are scrutinised at a national level to include a generic 'mesopelagic' category relating specifically to fish species aggregations. However, no agreed protocol exists for the definition of what constitutes allocations to this category and is therefore highly subjective. Deil migration, position in the water column and acoustic density of schools and scattering layers are the most obvious characteristics used to define this layer. Currently the lower limit of data acquisition is set at 750m, deemed as the lower limit of blue whiting vertical distribution.

Processed acoustic (38 kHz) and biological data from the IBWSS surveys (2004-present) are stored in an online database (PGNAPES) hosted by the Faroes. Acoustic data by category (including 'mesopelagics') are submitted in depth defined bins (50m) using a 1 or 5nmi ESDU (elementary sampling distance unit).

Future opportunities within IBWSS

The IBWSS survey is an established and coordinated multi-vessel survey program providing up to 50 days of ship time annually over four vessels with a spatial coverage of over 135,000 nmi^2.

Currently the IBWSS survey collects multi-frequency data down to 750m as standard and could be easily modified to collect deeper without changing established sampling rates or methods. However, vessel mounted acoustics are considered as limited for quantitative observations of this highly complex multi-species zone. Structured biological sampling of the mesopelagic zone could be undertaken using a suitable trawl design. Given this and the allocation of extra time and resources the survey has the capacity to record standard metrics to species level and to store biological samples for more detailed analysis ashore should it be required.

The acquisition of quantitative acoustic data from stationary or towed submersible platforms could be achievable given the time and resources to do so. A high speed towed submersible would be required so as to not impact on standard survey cruise speeds. Stationary observations could be carried out during routine hydrographic sampling stations.

This survey program provides an opportunity to acoustically and biologically sample the mesopelagic zone for species identification and quantification given the resources and support to do so. Expansion of the existing IBWSS survey to include mesopelagic zone observations as routine would further enhance this survey into the future.

4.3 International Ecosystem Survey in Nordic Sea (IESNS)

Background

The International Ecosystem Survey in Nordic Sea (IESNS) was established in 1995 and is carried out annually in 40 days starting around 1 May by vessels from Ireland, Norway, Faroes and Russia. Since 1997 EU have participated (except for 2002 and 2003). The aim of the survey is to cover the whole distribution area of the Norwegian Spring-spawning herring with the objective of estimating the total biomass of the herring stock, in addition to collect data on plankton abundance and hydrographical conditions in the area. In addition, acoustics and directed trawl sampling of blue whiting is performed. Survey results are submitted annually to WGWIDE and survey data are submitted to the WGNAPES online database. Coordination and planning is undertaken during a post-cruise meeting (June) and reported to WGIPS in January of the following year.

Survey design

The overall design uses stratified transects with a random start (random latitude) to ensure transect coverage is not replicated but randomized between years. The planed survey coverage in 2017 is shown in figure 4.3.1.

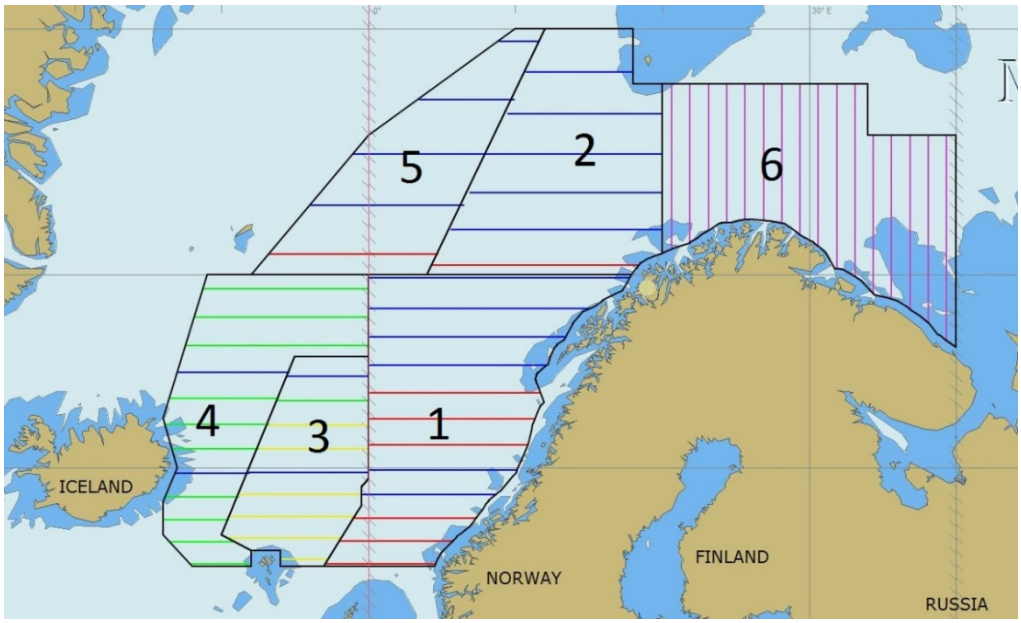

Figure 4.3.1.The pre-planned strata and transects for the IESNS survey in 2017 (red: EU, dark blue: Norway, yellow: Faroes Islands, violet: Russia, green: Iceland).

During the acoustic transects targeted fishery for herring and blue whiting is conducted. Acoustic data are collected down to 500m and acoustic data are scrutinized to herring and blue whiting. Salinity and temperature are measured by CTD casts down to 1000 meters at fixed station approx. by every 60 NM. In connection to CTD stations plankton is collected down to 200 m by WP2-nets.

Survey design, data analysis and biological sampling are carried out as detailed in the WGIPS survey manual (SISP 9 – IPS).

Mesopelagic observations- current status within IESNS

Directed pelagic trawls targeting herring and blue whiting often contain mesopelagic fish species as an incidental bycatch. This occurs as the trawl passes through the upper mesopelagic zone (100-350m) for herring and from the target trawling depth (250-500m) for blue whiting. Bycatch species are recorded as components of the catch and usually reported into the PGNASPES database. Ad hoc trawl sampling within the mesopelagic zone is carried out but not as part of routine operations. Such trawls are mostly for trace recognition purposes and/or to collect biological samples.

Echograms are scrutinised at a national level to herring and blue whiting and the reporting to the database do only include these two species. No agreed protocol exists for the definition of what constitutes allocations to other species as mesopelagics and is therefore somewhat subjective. Deil migration, position in the water column and acoustic density of schools and scattering layers are the most obvious characteristics used to define this layer. Currently the lower limit of data acquisition is set at 500m as the lower limit of herring.

Processed acoustic (38 kHz) and biological data from the IESNS surveys (2004-present) are stored in an online database (PGNAPES) hosted by the Faroes. Acoustic data by category herring or blue whiting are submitted in depth defined bins using a 1 nmi ESDU (elementary sampling distance unit).

Future opportunities within IBWSS

The IBWSS survey is an established and coordinated multi-vessel survey program providing up to 40 days of ship time annually over four vessels with a spatial coverage as shown in the text figure above.

Currently the IESNS survey collects acoustic data down to 500m as standard and could be easily modified to collect deeper without changing established sampling rates or methods. However, vessel mounted acoustics are considered as limited for quantitative observations of this complex multi-species zone. Structured biological sampling of the mesopelagic zone could be undertaken using a suitable trawl design. Given this and the allocation of extra time and resources the survey has the capacity to record standard metrics to species level and to store biological samples for more detailed analysis ashore should it be required.

The acquisition of quantitative acoustic data from stationary or towed submersible platforms could be achievable given the time and resources to do so. A high speed towed submersible would be required so as to not impact on standard survey cruise speeds. Stationary observations could be carried out during routine hydrographic sampling stations.

This survey program provides an opportunity to acoustically and biologically sample the mesopelagic zone for species identification and quantification given the resources and support to do so.

4.4 International ecosystem summer survey in the Nordic Seas (IESSNS)

The International Ecosystem Summer Survey in the Nordic Seas (IESSNS) is carried out every year generally for around four weeks in July. In 2017 it used five vessels from Norway (2), Iceland (1), Faroe Islands (1) and Greenland (1). The main objective is to provide annual age-disaggregated abundance index, with an uncertainty estimate, for

the NEA mackerel (*Scomber scombrus*). The survey is also used as a platform for the acoustic estimation of blue whiting (*Micromesistius poutassou*) and for Norwegian spring-spawning (NSS) herring (*Clupea harengus*). These are obtained using standardized acoustic methods to estimate their abundance in combination with biological trawling on acoustic registrations.

WKMESO noted that this survey covers much of the Nordic Seas, and is already carrying out acoustic monitoring for blue whiting and herring, in addition to the core purpose of estimating mackerel abundance. WKMESO considered this survey as having considerable potential to include acoustic monitoring and estimation of the mesopelagic community with very minor modifications. The main change would be to record acoustic data down to 800m to 1000m. This would entail the need to lengthen the ping interval on the sounders from around 1 second, to 1.5 seconds. This would allow collection of the full acoustic data needed to examine the mesopelagic community, although WKMESO does not propose at this time to suggest any specific sampling with additional nets, or other systems. This change would also allow the survey to be used to provide a basis for redfish estimation in the Norwegian Sea. The current Norwegian Sea redfish survey is also carried out at this time of year. The vessel allocated to this survey could then concentrate on biological sampling with the acoustic monitoring done by the IESSNS.

5 References

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Annex 1: List of participants

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Annex 2: Agenda

Monday 6th November 10:00

1000 Opening and Welcome, administrative details, and individual intro-ductions

1030 rest of day – presentations from participants on work relevant to the ToRs. This will be an open format session, where all participants will be able to present and discuss any relevant work as they request. Presentations should be 20-20 minutes. Presenters will also be asked to provide a short abstract of their material.

This will be continued until completed, we will plan for this to take up most of the first day.

Tuesday 7th November

Start 0900

0900-1300 Open discussion on ToR a. This could be done as a Strengths, weaknesses, opportunities and threats analysis, if participants agree.

1400-1730 Open discussion on ToR b. We should have information on a range of possible approaches (trawls, nets, acoustic, optical etc.). This ses-sion should aim to provide information on each approach, and the state-of-the-art , plus what still needs to be done.

Wednesday 8th November

0900-1300 Open discussion on ToR c. What can or should be added to the existing survey design. This should include a cost benefit analysis, descrip-tion of what any new data streams would be used for, and what would be needed to make these operational.

1400-1730 Open discussion on ToR d. This will probably largely follow on from the session on ToR c. It should focus on methods and techniques that may not be fully ready to be used, but which have potential for these sur-veys. Ideally, this should prioritise the methods chosen, and detail the work required to bring these to an operational level.

Thursday 9th November

All day

The session will focus on the upcoming H2020 calls for firstly:

- LC-BG-03-2018: Sustainable harvesting of marine biological re-sources. Specific Challenge: a large unexploited biomass in the mes-opelagic zone!!

A consortium and proposal is underway for this call. Much of the method-ology and techniques link very strongly with WKMESO ToR a and b. The aim would be to integrate the information on existing or potentially opera-tional tools, and what would need to be done, as well as the research pro-gramme. The consortium would be led by Webjorn Melle (IMR), and hope-fully we can start from the basis of a presentation from Webjorn

And secondly

- BG-07-2019-2020: The Future of Seas and Oceans Flagship Initiative, and specifically:
  - [B] 2018-2019- Assessing the status of Atlantic marine ecosys-tems.

This is a wider call than the BG3 one, but may potentially include many of the WKMESO participants. Mike St John (DTU-Aqua) is coordinating one response to this call, and is strongly linked to another (led by Xabier Irigoien – AZTI). Again, hopefully, we can start from the basis of a presentation from Mike, on the state of play for these proposals.

Friday 10th November

0900 -1300 Assignment of any writing tasks, and planning for a way for-ward. This could include the need to have a follow up workshop.

1400 Close. The chairs anticipate that many delegates will plan to leave Bergen on Friday, so no formal activities are planned beyond this, but the time is available for text drafting and further discussion.

Annex 3: Recommendations

Recommendation	Adressed to
1. WKMESO requests WGIPS to carry out exploration of data within the PGNAPES database relating to time-series of acoustic allocations to meso-pelagics from the IBWSS.	WGIPS
2. WKMESO requests WGIPS to summarise the availability of raw acoustic data for future analysis in the context of the mesopelagics and the deep scattering layer	WGIPS
3. WKMESO requests WGIPS to collate information on characteristics at national level that define any current allocation to 'mesopelagics'. Determination of an agreed standard within the IBWSS group of the definitions and characteristics of mesopelagic allocations and application definitions going forward are requested	WGIPS
4. WKMESO request WGIPS to consider the acquisition of hydroacoustic data down to a maximum depth of 800m, instead of the current 500m limit, for future analysis of the deep scattering layer in the mesopelagic zone.	WGIPS