Interim Report of the Working Group on Fisheries Acoustics, Science and Technology (WGFAST)

20-23 March 2018

Seattle, USA

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Contents

Executive summary

The ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST) is the major international forum where individuals working in fisheries acoustics network to discuss ongoing developments in the technique. As such, it is highly successful, attracting 91 participants from 18 countries to its meeting in Seattle, USA from 20-23 March 2018.

Highlights

The major themes addressed during the WGFAST meeting included:

- Behaviour;
- Acoustic properties of marine organisms;
- Emerging technologies, methodologies, and protocols;
- Applications of acoustic methods to characterize ecosystems.

A separate session was held for each theme, where the participants first presented the latest results of their work, followed by a discussion. The abstracts and discussion summaries are given in the report. The contributions highlighted the wide range of applications of acoustics for ecosystem characterization and monitoring, as well as for abundance surveys. Advancing acoustic technology and alternative sampling platforms (e.g. autonomous vehicles, ocean observatories) has led to increases in the volume of acoustic data, which has created challenges for data processing and storage. A discussion group was held in association with the WGFAST meeting to discuss development of Python-based and other automated processing and analysis tools.

Several presentations highlighted research and increasing applications of acoustic wideband technologies. WGFAST organized a second ICES Training Course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics' in December 2017. Wideband systems are expected to replace the current standard narrowband scientific echosounders, but there is a need for future quantitative assessment of the impact of this change on abundance surveys. WGFAST proposes a session on "Application of new technologies (e.g. wideband acoustics) for fisheries surveys and ecosystem investigation" for the 2019 ASC conference.

WGFAST provided a training course on 'Introduction to abundance estimation from fisheries acoustic surveys' in June 2017, and will co-chair theme session J at the 2018 ICES ASC meeting on "Survey data products for stock and ecosystem assessments: challenges and future directions".

A topic group on 'Collecting Quality Underwater Acoustic Data in Inclement Weather' (TG-QUAD) was held in conjunction with the 2018 WGFAST meeting.

1   Administrative details

Working Group name

The Working Group on Fisheries, Acoustics, Science and Technology (WGFAST)

Year of Appointment within the current three-year cycle

2018

Reporting year concluding the current three-year cycle

2

Chair(s)

Richard O'Driscoll, New Zealand

Meeting venue(s) and dates

Seattle, United States of America

20-23 March 2018

2   Terms of Reference a) – d)

ToR	Description	Background	Duration	Expected Deliverables
a	Collate information on acoustic related research and surveys by Country represented in WGFAST	a) Science Requirements b) Advisory Requirements	3	Filled in template for WGFAST report
b	Present recent work within the topics "Applications of acoustic methods to characterize ecosystems", "Acoustic properties of marine organisms", "Behaviour", and "Emerging technologies, methodologies, and protocols"	Create a venue for informing the group members on recent activities and seeking input to further development. An overview of the different contributions will be presented in the annual report	1, 2, 3	Report
c	Organize training session on use of acoustics for biomass estimation	Introductory course on use of acoustic for abundance estimation, including survey design and data analysis	1	ICES training course
d	Provide guidance for calibrating echosounders on fishing vessels (topic group)	Fishing vessels increasingly collect acoustic data. To allow quantitative use of these data, suitable calibration procedures for fishing conditions are needed	1 or 2	Report
e	Organize joint sessions at ICES ASC		2 or 3	Topic session at ICES ASC
f	Define a data format for omni fisheries sonars	Increasingly use of omni fisheries sonars in research requires a data format defined by the scientific community. Format definition will involve also software producers and equipment manufacturers.	1, 2	ICES CRR
g	Work towards developing and recommending procedures for collecting and processing quality acoustic data in inclement weather.	Acoustic data are collected from a variety of vessels that respond to inclement weather in di-	2, 3	Review paper(s) and/or CRR; updates of relevant SISP manuals (to

	verse ways. Procedures are needed to provide quality control for data collected in inclement weather to stock assessment	be produced in the first year of the next WG cycle)
Recommendation from WKQUAD	Compile information on transducer location and vessel trim, and collect vessel motion (pitch, roll, heave) data at a sampling rate of at least twice the frequency of the vessel motion (<1/2 the period), i.e. Nyquist sampling rate. A typical rate is 3 Hz	2017
Recommendation from WKQUAD	Collect meteorological data, e.g. windspeed and direction, swell, sea state, wave height during the surveys	2017
Recommendation from JFATB	JFATB recommends the development of terms of reference for a joint session of WGFAST and WGFTFB in April/May of 2020. The Terms of Reference are to be mutually decided by the Working Group Chairs and new joint session chairs. WGFAST proposes Stéphane Gauthier (Canada) and WGFTFB proposes Michael Pol (USA) as new chairs of JFATB. We recommend that WGFTFB investigate 'improved methods to refine survey gear, and quantify trawl selectivity across a broad range of species and sizes'. This may lead to improved survey estimates of species and size distributions, which is a key source of uncertainty in acoustic-trawl surveys. Survey groups WGIPS, WGBIFS, WGACEGG should be included in planning for this session as establishing survey trawl selectivity is important for these surveys. The joint session should review existing knowledge and recent developments in this area, with a focus on trawls used to sample pelagic organisms, and practical approaches to estimate trawl selectivity. A subset of WGFTFB and WGFAST members and members of survey groups (WGIPS, WGBIFS, WGACEGG) have expertise that is relevant in this area.	2017
Recommendation from WGIPS	Proposal to undertake a WK to coordinate the development of standardized protocols Aim: To coordinate the development of standardized protocols for the acoustic assessment of resources in the mesopelagic zone. Open ocean acoustic surveys frequently encounter significant biomass within the mesopelagic zone. This zone contains a complex mixture of organisms, visible from acoustic sensors as multispecies scattering layers, DSL (deep scattering layer), diel mixing layers and single species fish schools. Classification of biomass into useful biological groups is no doubt a complex processes, but is nonetheless necessary for reliable measurements.	2018

The complexities of such classification are recognized as are the limitations of vessel based acoustic measurements and the collection of biological samples using existing survey trawl designs.

Several international surveys coordinated by WGIPS (e.g. IBWSS, IESSNS and IESNS) cover areas where extensive mesopelagic layers are present, providing an opportunity for routine measurement. The recent WKMESO workshop (Workshop on monitoring technologies for the mesopelagic zone) discussed some of the limitations and opportunities afforded from utilizing existing survey programs for data collection and developments in wideband acoustics, biological and optical sampling technologies.

To improve the understanding within WGIPS it is proposed that a workshop is undertaken under guidance of WGFAST to bring together experts in the field on biology and acoustic properties of assemblages within the DSL. The ubiquitous nature of DSL and its understanding may appeal to the wider community.

3   Summary of Work plan

Year 1	Produce the annual overview of recent developments within the field; organize training session on use of acoustics for biomass estimation; provide guidance for calibrating echosounders on fishing vessels; provide guidance for calibrating echosounders on fishing vessels; collate information on acoustic related research and surveys by country to which WGFAST contributes.
Year 2	Produce the annual overview of recent developments within the field; provide guidance for calibrating echosounders on fishing vessels; collate information on acoustic related research and surveys by country to which WGFAST contributes
Year 3	Produce the annual overview of recent developments within the field; collate information on acoustic related research and surveys; collate information on acoustic related research and surveys by country to which WGFAST contributes

4   List of Outcomes and Achievements of the WG in this delivery period

Publications:

A full list of publications will be compiled at the end of the current 3-year cycle in 2019.

Data Portals:

- Processed acoustic and biotic data collected on acoustic trawl surveys in the Northeast Atlantic and Baltic Seas. http://www.ices.dk/marine-data/data-portals/Pages/acoustic.aspx;
- Raw acoustic data collected on fisheries and research surveys in waters throughout the U.S. and internationally are archived at the NOAA National Centers for Environmental Information. The main data contributor is the NOAA National Marine Fisheries Service. https://maps.ngdc.noaa.gov/viewers/water_column_sonar/.

Activities initiated by WGFAST:

- ICES Training course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics' (Bergen, Norway, December 2017). There were 20 participants from 13 countries. Due to high demand, another course is being considered for 2019;
- ICES Training course on 'Introduction to abundance estimation from fisheries acoustic surveys' (ICES Secretariat, Copenhagen, Denmark, June 2017). There were 25 participants from 14 countries;
- Topic group on 'Collecting Quality Underwater Acoustic Data in Inclement Weather' (TGQUAD) met in Seattle, USA, 17-19 March 2018. There were 16 participants from 9 countries. The group established a framework for developing metrics and indicators of degraded data quality due to inclement weather. This framework will help direct data investigations by focusing analyses on the effects of inclement weather on abundance estimates, and developing and testing metrics that indicate degraded data quality and ultimately increased bias in abundance estimates. The group will provide recommendations to other ICES expert groups and produce an ICES cooperative research report (CRR);
- ICES WGFAST Topic Group on 'Defining a data format for omni fisheries sonars' have prepared a Cooperative Research Report describing a netCDF4 file format which is in the ICES review process;
- A discussion on Open-Source Processing Tools was held on the evening of 21 March 2018 following the WGFAST sessions. Of the 91 WGFAST registered participants, 38 expressed interest in this group. The meeting discussed the communities' current work and needs for open-source tools to process acoustic data. There was interest in meeting again at WGFAST in 2019. Due to the mutual need for standardized data models, future discussions will be aided by work currently conducted by WGFAST members on metadata and data format standards, as well as increased collaboration between the NOAA and ICES data centres;
- A meeting of the TG-Meta group of 13 participants was held on 23 March immediately after the close of the WGFAST meeting chaired by Tim Ryan. This group has published and now maintains the ICES SISP publication "A metadata convention for processed acoustic data from active acoustic systems", current version is 1.10

http://www.ices.dk/sites/pub/Publication%20Reports/ICES%20Survey%20Protocols%20%28SISP%29/SISP-4%20A%20metadata%20convention%20for%20processed%20acoustic%20data%20from%20active%20acoustic%20systems.pdf;

- A notable feature of the WGFAST meeting was the growing number of endeavours where the TG-AcMeta convention has either been adopted or there are plans to do so. Another feature of WGFAST meeting was the expanding array of platforms including gliders, autonomous sailing vehicles, AUV's and moorings. The TG-Meta group noted that currently only attributes for vessel-based and moored acoustics are included in TG-AcMeta. Accordingly the WGFAST community is encouraged to propose attributes to the TG-Meta group for these emerging platforms to help ensure that appropriate metadata are being recorded. The TG-Meta group discussed ways to improve the publication of updates of the convention that is more agile and that can better facilitate group input. The current publication can be found at: TG-meta will advise WGFAST member of updates and of any changes to how and where the publication is accessed;
- The TG-Meta convention has been implemented in the ICES Acoustic trawl database(http://www.ices.dk/marine-data/data-portals/Pages/acoustic.aspx). There was discussion on the format of the TG-Meta convention and issues of implementation into a database framework. It was agreed that the existing 'flat-file' format of the TG-Meta convention be maintained but that an interchange format be developed to facilitate implementation of the metadata convention in other data storage frameworks such as relational databases. **WGFAST recommended acoustic survey groups adopt the ICES metadata convention for processed acoustic data and the ICES data portal for acoustic trawl surveys.**

5 Progress on ToRs and workplan

5.1 Progress and fulfillment by ToR

5.1.1 ToR a: Produce a list of papers originating from the community of the WGFAST working group

To be compiled for the 3-year term in year 3 (2019).

5.1.2 ToR b: Present recent work in fisheries acoustics

The meeting agenda for the 2018 WGFAST meeting is in Annex 3. Abstracts for all work presented in 2018 are found in Annex 4.

Behaviour

The behaviour theme session was composed of four presentations. The presentations were concerned with both, how surveying resources changes the behaviour of the resource as well as how the behaviour of resources and their environment influences our survey methodologies.

Two studies focused on the behavioural responses of mesopelagic fish and zooplankton to artificial light from survey platforms, either towed (Geoffroy *et al.*) or vessel based (Geoffroy *et al.*, Pena). In both studies artificial light caused a vertical diving response and change in measured backscatter. Backscatter fluctuations were mainly attributed to changes in incident angle brought on by a sudden tilt change of observed animals and a lag recovery time to post exposure behaviour. Geoffroy *et al.* focused on measurements of zooplankton avoidance response during the northern polar night from vessel and alternative survey platforms (JetYak and Zodiac) through the introduction of artificial light. A response was evident down to depths of 80 m and often reached 100 m or more. In static observations made on mesopelagic species in surface water at night, Pena noted a defined diving response due to a combined effect of mechanical (thruster) noise from the vessels dynamic positioning system (DP) and light sources. During the discussion, it was agreed that light (and the presence of a vessel) affects animal behaviour and this has implications on our monitoring.

Topographic features and physical flow regimes around seamounts were shown to determine the site-specific productivity of two seamounts (MAD and Le Réousse) in the southern Indian Ocean by Annasawmy *et al.* A combination of CTD data, including chlorophyll measurements, satellite data and Bongo net samples were used as alternative and complementing sampling methods. In general terms, the 38 kHz echosounder data were stronger in cyclonic flow regimes, when compared to anticyclonic regimes. Internal waves were shown to occasionally cause local displacement.

The interaction of fish with an energy-harnessing device deployed in a high-flow tidal energy-testing site was discussed by Viehman *et al.* The study used a static instrument array deployed in close proximity to an energy-harnessing device. Data quality was an issue due to dynamic environment with entrained bubbles during flood tides and wind induced aeration leading to prolonged periods of data loss within the tidal cycle. Fish detections were made during all phases of the tidal range, including during peak flow. Diurnal vertical migration was observed and the altimetry of fish was observed to increase with increasing tidal race leading to greatest exposure of fish to the turbine itself at the highest flow rate. The difficulty of biological sampling of targets in high flow rates at the test site was discussed.

Acoustic properties of marine organisms

This session confirmed that echo classification and target strength (TS) estimation remain important research topics for the refinement of acoustic surveys and ecological investigations. Acoustic measurements were presented for *in situ* and *ex situ* experiments.

The effect of the large gonads present in spawning Atlantic herring can potentially distort the swimbladder and hence affect the mean target strength. New dorsal aspect target strength data has been collected in Norway by Kubilius and Ona to investigate this. No significant difference was found between the spawning target strength and the existing target strength used for survey analysis.

Chu and Bassett presented an acoustic scattering model of walleye pollock based on swimbladder and body shapes that were derived from X-ray images of a range of fish sizes. The model provided an estimate of how much energy came from the swimbladder compared to the fish body. Of interest is that it was considerably less than the commonly quoted 90% and was dependent on acoustic frequency.

Gastauer *et al.* presented initial results from a study of the effect of Antarctic krill behaviour on target strength. Several thousand krill were contained in an instrumented tank and the different behaviour of krill in response to the tank environment was reflected in the target strength distributions.

Kubilius *et al.* demonstrated the ability of high-resolution broadband signals to see different parts of artificial fish-like targets and thence to estimate the size. An assessment of the limitations with respect to object size was provided. Future work will include the use of fish rather than artificial targets and testing of a process to estimate fish size during routine fishing operations.

Chawarski *et al.* presented the use of support vector machine (SVM) techniques to automatically classify, from broadband frequency responses, single targets that were from Arctic cod in the Beaufort Sea.

Emerging Technologies, Methodologies, and Protocols

This session covered three main areas: Broadband and multibeam systems, alternative vehicles and platforms, and analytic tools and formats.

Broadband systems continue to be widely used and evaluated by user groups. Results from comparisons between EK60 and EK80 CW-mode were mixed - one suggested good agreement (Renfree *et al.*) and another suggesting a potential bias (up to ~ 10%) with EK80 producing lower backscatter with increasing depth (De Robertis *et al.*). The larger group agreed that their results have also been mixed. Although this was not the cause of the observed discrepancies in the EK60/EK80 comparisons, the EK80 may be more sensitive to noise (i.e. different SNR than EK60) and users should carry out a thorough evaluation of platform-associated noise. Broadband systems have potential to refine scattering model parameters (Abe *et al.*) and calculations of target strength to support biomass estimation and species identification. However, one demonstration indicated that for micronekton, the information contained in broadband did not confer a significant advantage over judicious selection of narrowband [multiple] frequencies (Wu-Jung *et al.*). Angular sensitivity from multibeam (ME70) systems, used to classify sediment type (Fezzani *et al.*), also measured an effect of fish in shallow waters diving in response to the passage of the vessel with a concomitant effect on measured backscatter (Berger *et al.*). This session also highlighted an increasing diversity of applications for broadband and multibeam systems, including deployment approximately

perpendicular to the surface for counting and sizing bluefin tuna (Melvin and Arriza-balaga).

Surface, diving, moored, and towed alternative and/or autonomous vehicles and platforms are being used in a range of applications (Hentati-Sundberg *et al.*; Pedersen & Camus). Unmanned platforms, equipped with a suite of sensors, are being used for a variety fish and zooplankton studies (Lemon *et al.*; Bristow *et al.*). Each platform has their strengths and limitations, with the latter potentially including power constraints, internal noise generation, robustness, biofouling, and low speed. Potential improvements for such limitations were discussed and may be resolved with modifications to the platforms. Calibration of a deep-deployed towed body suggested that in addition to on-axis gain, the equivalent beam angle (EBA) should be measured at a range of depths and environmental conditions, as they may be depth specific and differ from the manufacturer's values (Kunnath *et al.*). However, this requires known, accurate and independent positioning of the calibration sphere within the beam, which is not a trivial task. An industry-deployed, trawl-mounted echosounder and optical system was used to obtain target strength of orange roughy at depth in the Southern Indian Ocean (Scoulding and Kloser). While the system requires modification to improve data collection, preliminary data suggests this system has potential future application to stock assessment.

With increasing data volumes from broadband systems and autonomous vehicle/platform deployments, the need for rapid automatic [unsupervised] data processing is widely recognized. Discussed approaches included subsampling data (Levine and De Robertis), applying a "deep learning" approach (Handegard *et al.*), and using analytic tools such as wavelets and Extreme Value Analysis (Gonzalez and Horne). Open source data processing packages are being developed for acoustic users (ESP3, Ladroit et al) and general users (EchoTools, Horne and Hytnen), with the potential to provide processed data products and visualizations to data users from online data repositories (PyEcholab, Anderson *et al.*). ICES (Parner *et al.*) has started to make processed acoustic data publicly available and have developed a metadata repository (based on WGFAST-TGMeta). A standardized, flexible, open-source netCDF-4 data convention for multibeam sonar data has been developed by the WGFAST Topic Group on 'Defining a data format for omni fisheries sonars' (Macauley and Pena, and see Section 5.1.6). This has guidance for industry, software developers, data distributors/archivers, and end-users. Future developments can include other sonar types.

WGFAST recommended that an ASC session in 2019 considers application of new technologies (e.g. wideband acoustics) for fisheries surveys and ecosystem investigation.

Applications of acoustic methods to characterize ecosystems

A total of 15 talks were given in this session, covering a wide range of topics making it difficult to identify a central unifying theme. However, this displays the wide range of applications suitable for acoustic methods.

The spatial scale of the investigations presented was broad, ranging from large-scale studies to small-scale laboratory studies. Examples of large-scale studies included Fernandes *et al.* who characterized the deep scattering layers in the Southern Oceans during the Antarctic Circumnavigation Expedition, and Wall *et al.* who associated satellite observations with archived water column sonar data to characterize the distribution of marine organisms along the west coast of the US. Interesting small-scale presentations included Gorska *et al.* who conducted laboratory studies to assess the influence, and to

explain the mechanism, of microphytobenthos photosynthetic activity on acoustic backscatter from seafloor sediments. Ressler *et al.* presented results from shipboard laboratory experiments related to improve the estimate of krill in the Bering Sea and Gulf of Alaska, by determining material parameters of krill for target strength modelling. Ressler *et al.* also reported on the influence that artificial light had on krill capture by towed samplers.

Several studies displayed a move beyond simply counting or integrating fish to a more holistic approach, where biophysical factors were used to explain distribution and behaviour of marine organisms. McGowan *et al.* linked environmental covariates, including bathymetry and water properties, to explain capelin distribution in the Northeast Pacific. Receveur *et al.* utilized shipboard ADCP data to examine micronekton distribution around New-Caledonia, and linked the mean surface backscatter to a suite of oceanographic and geographic variables with statistical models. Demer *et al.* presented the acoustic-trawl method used by the Southwest Fisheries Science Center, which included novel protocols to constrain the sampling area by satellite-sensed potential habitat.

Our current understanding of Pacific hake distribution, behaviour, and ecology in the California Current Ecosystem was examined by several authors. Parker-Stetter *et al.* presented results from several acoustic-trawl cruises during the winter 2016/2017 seasons to try to locate and characterize the winter spawning habitat(s) of Pacific hake. Thomas *et al.* re-examined 15 years of hake acoustic-trawl survey data to determine whether generalized life-history strategies, which are often cited for Pacific coast hake, were clearly supported by the survey data. Guan *et al.* reported on pelagic ecosystem surveys conducted in the Strait of Georgia, by examining the distribution of Pacific hake, walleye pollock, Pacific herring and euphasiids separated by multifrequency analysis. They reported on possible resource partitioning by hake and Pollock in the Strait.

Several contributions highlighted novel means of data collection or the innovative use of sensors to characterize marine systems. Fredriksson *et al.* presented a clever analysis of EM2040 multibeam data, originally collected for seafloor mapping purposes of the southern zone of the Gotland shelf, to infer distribution of pelagic fish. O'Driscoll *et al.* collected acoustic and video data through the ice in the Ross Sea to improve understanding of the toothfish and silverfish life histories, and to improve target strength estimates of toothfish.

Other presentations included results based on fixed seafloor-mounted echosounders, or a combination of moored echosounders and vessel-based surveys. Rousseau *et al.* monitored Pacific juvenile salmon migration with a multi frequency approach to separate juvenile salmon from other species as well as to derive a relationship between juvenile salmon length and frequency (67-125 kHz) differences. Whitton *et al.* also collected multifrequency data with bottom-mounted echosounders and with ship-based surveys to characterize coastal tidal sites with regard to distributions of pelagic fish and crustaceans prior to installation of the tidal power infrastructure.

A large number of the presentations included broadband measurements (Simrad EK80), often in addition to traditional narrowband observations with Simrad EK60s. Blaunlet *et al.* presented a dedicated study utilizing broadband acoustics on sound-scattering layers in the Bay of Biscay, where they compared measured frequency responses with forward modelled spectra to net and *in situ* video observations.

5.1.3 ToR c: Organize training session on use of acoustics for biomass estimation

An ICES Training course on 'Introduction to abundance estimation from fisheries acoustic surveys' took place 12-16 June 2017 at ICES Secretariat, Copenhagen, Denmark, with course instructors John Horne and Paul Fernandes. A total of 25 participants attended from 14 countries (Australia, Cabo Verde, Canada, Denmark, France, Germany, Greece, Italy, Kenya, Latvia, Northern Ireland, Portugal, UK (Scotland), USA). The course consisted of 10 presentations, 4 practical sessions and discussion sessions. The presentations covered a range of theoretical and logistical concerns relating to conducting and analysing an acoustic survey. Presentations included: underwater sound; sound as a sensor; fish and zooplankton as targets; survey design; geostatistics; the sonar equation; acoustic data processing; target classification; calibration; and abundance estimation. The practical sessions consisted of problems sets, a paper based survey design exercise, a session on basic post-processing in Echoview (run, with thanks, by Briony Hutton) and a computer based practical on abundance estimation using code written in the statistical programming language, R.

On the basis of the 17 evaluation forms that were completed, the course was generally well received. Participants were neutral about the balance of theory and practical work, with one suggesting that the course was "…a bit too advanced" and another that it was "too short". Most participants would have preferred more practical sessions, which is in keeping with the general student learning experience and preference for more active learning. Participants agreed that the instructors were helpful and approachable, and the quality of teaching was rated in the top two categories (of 5). Overall, 12 participants rated the training course highly and 4 were neutral; none were dissatisfied. Final comments reiterated the preference for practical work and many were pleased to have received computer code to analyse data which they thought they could use in future. The instructors experience was also positive and it was taken on board that fewer lectures may be appropriate if this were to be repeated, with the possibility of considering a basic and advanced course.

Participants and instructors on ICES Training course on 'Introduction to abundance estimation from fisheries acoustic surveys' 'held from 12-16 June at ICES Secretariat, Copenhagen, Denmark.

5.1.4 ToR d: Provide guidance for calibrating echosounders on fishing vessels

ICES Cooperative Research Report No. 326 by Demer *et al.* (2015) on 'Calibration of acoustic instruments' provides guidance on calibration of a range of acoustic instruments currently used in fisheries research, including some systems (e.g. Simrad ES60 and ES70) used on fishing vessels. Section 4.1.7 of CRR 326 provides a 'quick-start' guide to calibrating Simrad EK60, ES60, and ES70 echosounders, which was intended to be of use to the wider community.

The South Pacific Regional Fishery Management Organisation (SPRFMO) created a task group on 'Fishing Vessels as Scientific Platforms'. At its meeting in Lima, Peru in September 2015, this group carried out a 3-day workshop considering the 'Calibration procedure for acoustic devices aboard fishing vessels'. The report of this website, including Annex 2 which defines a calibration protocol for fishing vessels is available publically on the SPRFMO website: http://www.sprfmo.int/assets/Meetings/Meetings-2013-plus/SC-Meetings/3rd-SC-Meeting-2015/Papers/SC-03-11a-Acoustic-Task-group-1st-workshop-report.pdf

WGFAST reviewed the SPRFMO calibration protocol. While recognizing the need for sets of instructions for specific calibration situations, it was unclear whom the SPRFMO protocols were written for (acoustics scientists, fisheries biologists, technicians, or commercial fishers). The SPRFMO protocols also contain simplifications that might not be appropriate in all situations. WGFAST noted that individual experts within the group could be invited by SPRFMO to provide specific guidance.

5.1.5 ToR e: Organize joint sessions at ICES ASC

WGFAST will jointly chair ASC session J in 2018 to consider 'Survey data products for stock and ecosystem assessments: Challenges and future directions". This session will be convened by Verena Trenkel (France) in conjunction with Sven Kupschuss (UK) and Stan Kotwicki (USA).

WGFAST recommended an ASC session in 2019 to consider 'application of new technologies (e.g. wideband acoustics) for fisheries surveys and ecosystem investigation'. A proposal will be developed David Demer (USA) and Nils Olav Handegard (Norway).

5.1.6 ToR f: Define a data format for omni fisheries sonars

A convention for the storage of omni-sonar data in netCDF4-formatted computer files has been produced by the WG-FAST Topic Group for Defining a data format for omnidirectional fisheries sonar. The convention specification has been submitted to ICES for publication as a CRR and is currently under revision following reviewers comments. The name of the convention is SONAR-netCDF4.

5.1.7 ToR g: Work towards developing and recommending procedures for collecting and processing quality acoustic data in inclement weather

The Topic Group on Collecting Quality Underwater Acoustic Data in Inclement Weather (TGQUAD) met in Seattle, USA from 17-19 March 2018. TGQUAD was created following a Workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD) held from 31 March – 2 April 2017 in Nelson, New Zealand. WKQUAD was in response to Workshop on Scrutinisation Procedures for Pelagic Ecosystem Surveys (WKSCRUT).

Sixteen representatives from 9 countries participated in the first of three TGQUAD meetings. The participants addressed the terms of reference with a review of results

from WKQUAD and the historical literature, outlined a cooperative research report that will be one output of the group, began investigating standard procedures and methods for identifying unsuitable survey conditions, proposing methods for dealing with degraded data, and comparing procedures and methods on selected datasets. A goal is to develop diagnostics and metrics that are independent of a specific vessel, i.e. based on effects on the acoustic data. Each vessel responds differently to wind and sea state, so it will be quite difficult to derive absolute criteria that can be applied to every vessel, but the group will develop general criteria that can be applied broadly, in relative terms. Their priority is data that are used in stock assessment. The group will focus on single-beam narrow bandwidth echosounders operating at 18, 38, 70, 120, and 200 kHz on vessels with the transducers mounted on the hull or in a retractable keel. The group recognizes that broadbandwidth echosounders will soon replace narrow bandwidth systems, and that effects of inclement weather will need to be addressed for these systems. The group does not intend to address multibeam water column systems or multibeam bathymetric systems, because they are not currently used for abundance estimates.

The group established a framework for developing metrics and indicators of degraded data quality due to inclement weather. This framework will help direct data investigations by focusing analyses on the effects of inclement weather on abundance estimates (the primary response variable), and developing and testing metrics that indicate degraded data quality and ultimately increased bias in abundance estimates. For example, ping dropouts (transmit and received signal attenuated to levels below the analysis threshold) appear to be a diagnostic that is indicative of degraded data quality, but the algorithms for detecting ping dropouts need to tested and refined.

Output from TGQUAD comprise recommendations to other ICES expert groups, and an ICES cooperative research report (CRR). The group crafted a preliminary outline of the CRR based on the overall framework of developing metrics and indicators to quantify effects of inclement weather on acoustic data that provide abundance estimates for stock assessment. The CRR is structured with a literature review that transitions to data needs and case studies highlighting effects of weather on data quality, and ending with diagnostics, criteria, and recommendations for evaluating data quality.

TGQUAD will meet again in 2019 associated with the WGFAST meeting in Galway, Ireland.

5.1.8   Other ToRs

Recommendations from WKQUAD

- Compile information on transducer location and vessel trim, and collect vessel motion (pitch, roll, heave) data at a sampling rate of at least twice the frequency of the vessel motion (<1/2 the period), i.e. Nyquist sampling rate. A typical rate is 3 Hz.
- Collect meteorological data, e.g. windspeed and direction, swell, sea state, wave height during the surveys

Both the recommendations were passed onto members of WGFAST.

Recommendation from JFATB

- JFATB recommends the development of terms of reference for a joint session of WGFAST and WGFTFB in April/May of 2020.

WGFAST supports the development of terms of reference for a joint session in 2020.

Recommendation from WGIPS

- Proposal to undertake a WK to coordinate the development of standardized protocols for the acoustic assessment of resources in the mesopelagic zone.

WGFAST supports the proposed workshop on the development of protocols for the acoustic assessment of resources in the mesopelagic zone. **We recommend the development of terms of reference for a workshop to be held in association with the WGFAST meeting in Galway, Ireland in April 2019**. The workshop should review existing knowledge and recent developments in this area, bringing together experts in biology and acoustic properties of assemblages within the deep scattering layers. WGFAST nominated Ciaran O'Donnell (Ireland) and Gavin Macaulay (Norway) as co-chairs of the joint session.

5.2   Changes/Edits/Additions to ToR

Not required.

5.3   Cooperation with other WGs

The Topic Group on Collecting Quality Underwater Acoustic Data in Inclement Weather (TGQUAD) met in Seattle, USA from 17-19 March 2018 (see Section 5.1.7). TGQUAD was created following a Workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD) held from 31 March – 2 April 2017 in Nelson, New Zealand. WKQUAD was in response to Workshop on Scrutinisation Procedures for Pelagic Ecosystem Surveys (WKSCRUT).

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, including 4 members of WGFAST. 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 (including acoustics).

5.4   Cooperation with Advisory structures

The TG-Meta convention has been implemented in the ICES Acoustic trawl database (http://www.ices.dk/marine-data/data-portals/Pages/acoustic.aspx)

5.5   Cooperation with other IGOs

Several WGFAST members are also members of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) Subgroup on Acoustic Survey and Analysis Methods (SG-ASAM). SG-ASAM will next meet in Puenta Arenas, Chile from 30 April – 4 May 2018. WGFAST requested that its Members engaged in the work of SG-ASAM provide an update to WGFAST in 2019.

As described in Section 5.1.4, WGFAST reviewed the South Pacific Regional Fishery Management Organization (SPRFMO) calibration protocol to assess its consistency with ICES CRR 326.

WGFAST members from CSIRO (Australia) have been engaged with the South Indian Ocean Fisheries Agreement (SIOFA) to determine whether unsupervised industry collected, acoustic data on orange roughy can be used for stock assessment and target

strength purposes. The findings were summarized in a report, which is being considered by the SIOFA scientific committee.

5.6   Science Highlights

ICES Training course on 'Introduction to abundance estimation from fisheries acoustic surveys'

See Section 5.1.3.

ICES Training course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics'

This course was held on RV G.O. Sars, Bergen, Norway in December 2017. There were 20 participants from 13 countries. Topics covered included:

1. Theory on broadband technologies

    a) Background on narrowband and broadband signals

    b) Understanding the temporal, spatial, and spectral aspects of the complex broadband signals

2. Overview of the specifications and data flow of commercially available and most commonly used broadband systems – Simrad EK80

3. Knowledge on EK80 system operation and hands-on experiences

    a) System configuration

    b) Calibration procedures

    c) Data collection and preliminary processing

4. Data Processing

    a) Calibration quantities as a function of frequency

    b) TS(f) of tracked individual targets

    c) Sv(f) of a scattering layer

    d) Cross-channel talk

In 2018 Institute of Marine Research will organize a similar training class, with mostly internal applicants and limited external participants. Another ICES-sponsored course is being considered for 2019.

Participants and instructors on ICES Training course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics', RV G.O. Sars, Bergen, Norway, December 2017.

6 Revisions to the work plan and justification

Not required.

7   Next meetings

WGFAST proposes that its 2019 meeting will be in Galway Ireland from 29 April – 3 May 2019.

Annex 1: List of participants

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Participants in WGFAST meeting in Seattle, USA, March 2018

Annex 2: Recommendations

Recommendation	Adressed to
1. WGFAST recommends that acoustic survey groups adopt the ICES metadata convention for processed acoustic data and the ICES data portal for acoustic trawl surveys.	WGIPS, WGBIFS, ACEGG
2. WGFAST recommended an ASC session in 2019 to consider 'application of new technologies (e.g. wideband acoustics) for fisheries surveys and ecosystem investigation'. A proposal will be developed David Demer (USA) and Nils Olav Handegard (Norway).	SCICOM

Annex 3: Meeting Agenda

	TUESDAY March 20 2018	Session
8:45-9:00	House keeping	
9:00-9:20	WGFAST opening ***John Horne and Richard O'Driscoll***	
9:20-10:00	Introduction slides	
10:00-10:30	**COFFEE BREAK**	
10:30-10:50	Welcome to ICES ***ICES Secretariat (presented by Richard O'Driscoll)***	*WGFAST business* *Chair: Richard ODriscoll*
10:50-11:10	Why we are here - update on WGFAST TORs ***Richard O'Driscoll***	
11:10-11:20	Training course on Introduction to abundance estimation from fisheries acoustic surveys ***Paul Fernandes and John Horne***	
11:20-11:30	Training course on Principles and methods of broadband/wideband technologies: application to fisheries acoustics ***Dezhang Chu and Gavin Macaulay***	
11:30-11:50	Mesopelagic fish avoidance of vessel noise ***Marian Peña***	*Behaviour* *Chair: Ciaran ODonnell*
11:50-13:40	**LUNCH BREAK** **Simrad Update starting 11:50** *Lars Andersen*	
13:40-14:00	Dynamics of micronekton on seamounts in South West Indian Ocean ***Pavanee Annasawmy Jean-François Ternon, Pascal Cotel, Anne Lebourges-Dhaussy, Gildas Roudaut, Steven Herbette, Yves Cherel, Evgeny Romanov, Francis Marsac***	
14:00-14:20	Hydroacoustic studies reveal the impact of artificial light from research vessels on the distribution and abundance of marine organisms under low solar irradiance ***Maxime Geoffroy, Jørgen Berge, Jonathan H. Cohen, Martin Ludvigsen, Finlo Cottier, Kim Last, Pedro R. De La Torre, Stein M. Nornes, Asgeir J. Sørensen, Malin Daase, Philip Anderson, and Geir Johnsen***	
14:20-14:40	Relating fish density with hydrodynamics at a tidal energy site ***Haley Viehman, Tyler Boucher, and Anna Redden***	
14:40-15:00	Discussion	
15:00-15:30	**COFFEE BREAK**	
15:30-15:50	Target strength of spawning herring ***Egil Ona and Rokas Kubilius***	*Acoustic properties of marine organisms* *Chair: Marian Pena*
15:50-16:10	Characterization of backscattering by walleye Pollock ***Dezhang Chu and Christopher Bassett***	
16:10-16:30	Simultaneous optical and broadband acoustic recordings of free swimming krill in a large tank ***Sven Gastauer Dezhang Chu, Rob King, So Kawaguchi, Martin Cox***	
16:30-16:50	Broadband backscattering from artificial fish-like targets ***Rokas Kubilius, Egil Ona, Gavin Macaulay and Atle Totland***	
16:50-17:10	In situ acoustic frequency response of Arctic cod in the Beaufort Sea ***Julek Chawarski, Maxime Geoffroy, Andrew Majewski, Stéphane Gauthier, and Jim Reist***	
17:10-17:30	Discussion	
18:00-	**Welcome Reception in lobby of the UW School of Aquatic and Fishery Sciences**	

	WEDNESDAY March 21 2018	Session
8:45-9:00	House keeping	
9:00-9:20	Comparison of EK60 and EK80 data collected during Acoustic-Trawl Surveys *Josiah S. Renfree, David A. Demer, Juan P. Zwolinski, Kevin L. Stierhoff, Danial Palance, Scott Mau, David Murfin, and Steve Sessions*	
9:20-9:40	Using EK80 echosounders in narrowband mode: does $S_{v,EK80} = S_{v,EK60}$? *Alex De Robertis, Chris Bassett, and Scott Furnish*	
9:40-10:00	Discussion	
10:00-10:30	**COFFEE BREAK**	
10:30-10:50	New methodology for mapping seabed habitats using calibrated backscatter: A case study for the multi-year EVHOE bottom-trawl survey using Simrad ME70 multibeam echosounder *Ridha Fezzani, Laurent Berger, Naig Le Bouffant and Xavier Lurton*	
10:50-11:10	Deep-water calibration of echosounders used for biomass surveys and species identification *Haris Kunnath, Rudy J. Kloser, Tim E. Ryan, and Jacques Malan*	
11:10-11:30	Exploring model sensitivity in Bayesian inversion of zooplankton sonar echoes *Wu-Jung Lee, Dezhang Chu, and Stan Dosso*	
11:30-11:50	ICES Acoustic Trawl Survey Database *Hjalte Parner, Mehdi Abbasi, Anna Osypchuk, and Neil Holdsworth*	
11:50-13:40	**LUNCH BREAK** **Echoview Update starting 11:50** *Briony Hutton*	
13:40-14:00	Hydro-acoustic data collection trials in the Baltic Sea using a 5 m unmanned surface vessel *Jonas Hentati-Sundberg, Joakim Hjelm, Olof Olsson*	
14:00-14:20	Ocean Glider Mounted Echo Sounders for Monitoring Fish and Zooplankton Populations *David Lemon, Jan Buermans, Chris Taylor, Chad Lembke, Chris DeCollibus, Toby Jarvis*	
14:20-14:40	Coastal and oceanic ecosystem monitoring with autonomous vehicles equipped with active and passive acoustic sensors *Geir Pedersen and Lionel Camus*	
14:40-15:00	Don't work so hard: efficient analysis of large acoustic datasets *Mike Levine and Alex De Robertis*	
15:00-15:30	**COFFEE BREAK**	
15:30-15:50	Analytic tools for acoustic monitoring in aquatic ecosystems *Silvana González and John K. Horne*	
15:50-16:10	Drowning in data: Can deep learning approaches be the solution? *Nils Olav Handegard, Vaneeda Allken, Ketil Malde*	
16:10-16:30	Latest developments in open-source software for fisheries acoustics ESP3 *Yoann Ladroit, Pablo Escobar, Alexandre C. G. Schimel and Richard O'Driscoll*	
16:30-16:50	An open and extensible netCDF4-based file format for sonar data *Gavin J Macaulay, Héctor Peña*	
16:50-17:10	Active acoustic monitoring of aquatic ecosystems *John K. Horne and Ross Hytnen*	
17:10-17:30	PyEcholab: A Python toolkit for water-column echosounder data analysis *Charles Anderson, Rick Towler, Pamme Crandall, Randy Cutter, Michael Jech, Carrie Wall*	
18:00-	**Python Users Group meeting** *Carrie Wall*	

Session column (spanning): **Emerging technologies, methodologies and protocols** — Chair: Paul Fernandes

THURSDAY March 22 2018		
8:45-9:00	House keeping	
9:00-9:20	A plan of in-situ broadband measurements of Antarctic krill in 2018/19 field season *Koki Abe, Kazuo Amakasu, and Hiroto Murase*	Emerging technologies, methodologies and protocols Chair: Paul Fernandes
9:20-9:40	Abundance estimation of pelagic fish using multifrequency and multibeam echosounders: A case study for the multi-year PELGAS acoustic survey using Simrad EK60 and ME70 echosounders *Laurent Berger, Mathieu Doray and Naig Le Bouffant*	
9:40-10:00	Marine ecosystem assessment in a patchy world: are autonomous technologies the solution to quantify zooplankton? *Martina Bristow, Karen Heywood, Bastien Queste, Sophie Fielding and Jeroen Van Der Kooij*	
10:00-10:30	COFFEE BREAK	
10:30-10:50	Enumeration of juvenile bluefin tuna (*Thunnus thynnus*) in the Bay of Biscay: A multi-beam sonar approach *Gary D. Melvin, Urang J, Arrizabalaga H.*	
10:50-11:10	Use of active-acoustics in the high seas: the case of orange roughy (*Hoplostethus atlanticus*) *Ben Scoulding and Rudy Kloser*	
11:10-11:30	**Discussion**	
11:30-11:50	Evaluating winter distribution and biology of Pacific hake along the U.S. west coast *Sandra Parker-Stetter, Rebecca Thomas, and Dezhang Chu*	Applications to characterize ecosystems Chair: Chris Wilson
11:50-12:10	Observing behaviour of pelagic fauna at a coastal tidal kite development site using bottom mounted and ship based echosounders *Timothy Whitton, Jan G. Hiddink, Luis Gimenez, Suzanna Jackson, David Bowers, David Lemon, Ben Scoulding*	
12:10-13:40	LUNCH BREAK **Lunchtime excursions**	
13:40-14:00	Characterization of sound-scattering layers in the Bay of Biscay using broadband acoustics, nets and video *Arthur Blanluet, Mathieu Doray, Laurent Berger, Naig Le Bouffant, Sigrid Lehuta, Jean-Baptiste Romagnan, Pierre Petitgas*	
14:00-14:20	Acoustic-Trawl Surveys of Forage Fishes in the California Current Ecosystem *David A. Demer, Juan P. Zwolinski, Kevin L. Stierhoff, Josiah S. Renfree, Danial Palance, Scott Mau, David Murfin, and Steve Sessions*	
14:20-14:40	A circumnavigation of the Southern Ocean to study the deep scattering layer and krill *Paul G. Fernandes, Inigo Everson, Roland Proud, Camille Le Guen, Matteo Bernasconi, Joshua Lawrence, Linsey Mortimer, Katie MacDonald, and Andrew S. Brierley*	
14:40-15:00	Distribution of pelagic fish in the Hoburgs bank *Ronny Fredriksson, Olavi Kaljuste, Ulf Bergström*	
15:00-15:30	COFFEE BREAK	
15:30-15:50	Impact of the microphytobenthos photosynthesis on the Baltic sandy sediment backscattering properties *Natalia Gorska, Adam Latała, Filip Pniewski, Ewa Kowalska-Duda*	
15:50-16:10	Acoustically derived indicators of demersal and forage species productivity in the Strait of Georgia (British Columbia, Canada): 2010-2016 *Lu Guan, Chelsea Stanley, and Stéphane Gauthier*	
16:10-16:30	Influence of environmental factors on distributions of capelin in the Gulf of Alaska *David W. McGowan, John K. Horne, Sandra L. Parker-Stetter, James T. Thorson, and Mark Zimmermann*	
16:30-16:50	Sea-ice deployments reveal silverfish and toothfish under the ice in the Ross Sea, Antarctica *Richard L. O'Driscoll, Yoann Ladroit, Steven J. Parker, Marino Vacchi, Simonepietro Canese, Laura Ghigliotti, and Sophie Mormede*	

16:50-17:00	Report from Topic Group on Acoustic Meta Data (TG-Meta) *Tim Ryan*	**WGFAST business** Chair: Richard ODriscoll
17:00-17:20	Report from Workshop on Collecting Quality Under-water Acoustic Data in Inclement Weather (TGQUAD) *Mike Jech*	
17:20-17:30	Report on topic group for defining data format for sonar *Gavin Macaulay*	
17:45	**Meet buses at SAFS for transport for conference dinner at Living Computer Museum**	

	FRIDAY March 23 2018	Session
8:45-9:00	House keeping	
9:00-9:20	SPRFMO protocols on calibrating echosounders on fishing vessels *Richard O'Driscoll*	**WGFAST** Chair: Richard ODriscoll
9:20-9:40	Self-evaluation of WGFAST, new ToRs, next meeting, ...	
9:40-10:00	Other initiatives and business	
10:00-10:30	**COFFEE BREAK**	
10:30-10:50	Blending satellite observations with water-column sonar data from a national archive to characterize the distribution of marine life *Carrie C Wall, Charles Anderson, and Kristopher Karnauskas*	**Applications to characterize ecosystems** Chair: Chris Wilson
10:50-11:10	Acoustic characterization of micronekton distribution in the surface layer related to the environment across the New Caledonia economic zone (south-west Pacific). *Aurore Receveur, Christophe Menkes, Elodie Kestenare, Valerie Allain, Sophie Cravatte, Anne Lebourges Dhaussy, Gildas Roudaut, Morgan Mangeas, Neville Smith, Marie-Hélène Radencac, Fréderic Menard*	
11:10-11:30	How many krill are there in the eastern Bering Sea and Gulf of Alaska? *Patrick H. Ressler, Joseph D. Warren, Brandyn M. Lucca, H. Rodger Harvey, Georgina A. Gibson*	
11:30-11:50	Use of inverted echo-sounders to monitor Pacific juvenile salmon in the Discovery Islands, British Columbia *Shani Rousseau and Stephane Gauthier*	
11:50-12:10	What the hake? Re-examining common models for distribution of Pacific hake *Rebecca Thomas, Julia Getsiv-Clemons, Larry Hufnagle, and Stéphane Gauthier*	
12:10-13:40	**LUNCH BREAK** **Lunchtime Excursions**	
13:40-14:20	**Discussion**	
14:20-15:00	*Meeting close-up*	
15:00-17:00	**Topic Group on Acoustic Meta Data (TG-Meta)** *Tim Ryan*	

Annex 4: Abstract of contributions

WGFAST 1. Applications of acoustic methods to characterize ecosystems

Characterization of sound scattering layers in the Bay of Biscay using broadband acoustics, nets and video

Arthur Blanluet, Mathieu Doray, Laurent Berger, Naig Le Bouffant, Sigrid Lehuta, Jean-Baptiste Romagnan, Pierre Petitgas (arthur.blanluet@ifremer.fr)

Sound scattering layers (SSLs) are observed over a broad range of spatio-temporal scales and geographical areas. Yet, the SSLs taxonomic composition remains largely unknown. To improve our comprehension of SSLs, a dedicated study was conducted in Northern Bay of Biscay (France) using broadband acoustic. Four broadband EK80 (i.e. 70, 120, 200 and 333 kHz nominal frequencies) and two narrowband EK60 (i.e. 18 and 38 kHz) echosounders were used to obtain the frequency spectra of SSLs in two contrasted zones. Ground-truthing data were collected by deploying plankton and micronekton nets and in situ video in the SSLs. Measured frequency spectra were compared to forward modelled spectra derived from ground-truthing data to identify organisms contributing to the observed SSLs. The results showed that SSLs were dominated by resonant Gas Bearing organisms, siphonophores and juvenile fish, especially in the lower range of frequencies (< 90 kHz). Copepods, pteropods and euphausiids contributed to the response at higher frequencies. The usefulness of broadband acoustics to characterize resonant backscatterers and mixed mesozooplankton assemblages is further discussed.

Acoustic-Trawl Surveys of Forage Fishes in the California Current Ecosystem

David A. Demer, Juan P. Zwolinski, Kevin L. Stierhoff, Josiah S. Renfree, Danial Palance, Scott Mau, David Murfin, and Steve Sessions (david.demer@noaa.gov)

In the California Current, multiple coastal pelagic fish species (CPS; i.e. Pacific sardine *Sardinops sagax*, northern anchovy *Engraulis mordax*, jack mackerel *Trachurus symmetricus*, Pacific mackerel *Scomber japonicus*, and Pacific herring *Clupea pallasii*) comprise the bulk of the forage fish assemblage. These species can attain large biomasses during short periods, comprise prey to marine mammals, birds, and large migratory fish, and are targets of commercial fisheries. We present the acoustic-trawl method (ATM) as currently used by the Southwest Fisheries Science Center to survey CPS, and example results. Described are some non-standard ATM protocols, e.g. constraining the sampling area by satellite-sensed potential habitat, daytime acoustic sampling with nighttime trawl sampling, industry-collaborative nearshore sampling, post-sampling stratification, and automated data analysis and reporting.

A circumnavigation of the Southern Ocean to study the deep scattering layer and krill

Paul G. Fernandes, Inigo Everson, Roland Proud, Camille Le Guen, Matteo Bernasconi, Joshua Lawrence, Linsey Mortimer, Katie MacDonald, and Andrew S. Brierley (Fernandespg@abdn.ac.uk)

Within the mesopelagic zone of the oceans, deep scattering layers (DSLs) of small fish, zooplankton and squids aggregate in distinct layers stretching tens to thousands of kilometers horizontally and tens to hundreds of meters vertically. In the Southern Ocean (SO), DSLs contain prey for apex predators, such as king penguins, and may

provide an alternative prey source to krill predators when krill biomass is low, but studies of DSLs in this region are limited. Acoustic data from around the entire SO were collected on the Antarctic Circumnavigation Expedition in the austral summer of 2017. A Simrad EK80 12.5 kHz broadband scientific echosounder linked to the ships own transducer was used to study the circumpolar distribution of DSLs, and an EK60 200 kHz for krill distributions. DSL density varied significantly across the survey; density was lowest at high latitudes and increased across the frontal zones, peaking around the island of Tasmania. Krill was distributed as expected, with much higher densities around South Georgia. This study forms part of an international interdisciplinary effort, and ongoing work will link these data to simultaneous oceanographic and atmospheric measurements, providing new information to understand the SO marine ecosystem and the effects of climate change.

Distribution of pelagic fish in the Hoburgs bank

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In the autumn of 2016, a cooperation project was initiated between Geological Survey of Sweden (SGU), the Department of Aquatic Resources at the Swedish University of Agricultural Sciences (SLU Aqua) and Aquabiota AB, with the intention of carrying out a comprehensive marine mapping of Hoburgs bank (Hoburg Shoal), a shoal located in the Baltic Sea, in the southern zone of the Gotland shelf. The mapping covered bathymetry, geology, oceanography and biology. This study presents the results of the hydroacoustic data analyses. The data for the analysis were collected in August and September 2016. The acoustic measurements were performed by SGU aboard their survey vessel Ocean Surveyor with a Kongsberg EM2040 multibeam echosounder. The purpose of the acoustic investigation was to map the bottom topography, but within the framework of this study, these data are also used for mapping of pelagic fish. These analyses have been performed by SLU Aqua and an important part of the study was to evaluate the possibility of collecting information about pelagic fish in the water column with SGU's equipment while collecting bathymetric information.

Impact of the microphytobenthos photosynthesis on the Baltic sandy sediment backscattering properties

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The understanding of the microphytobenthos photosynthesis influence on the characteristics of the signals backscattered by the sea floor, is crucial in the development of the hydroacoustic benthic habitat classification techniques. Previous studies, demonstrating the photosynthesis effect on the backscattering sediment properties, were conducted in warm and salty Atlantic hydrological conditions. To account for the Baltic Sea hydrology specifics (brackish water, lower typical temperature), it is important to understand the microphytobenthos photosynthesis impact on the acoustic wave interaction with the seabed in this area. This was the main motivation of our study.

Five multiday laboratory experiments, different in hydrophysical or biological conditions, were conducted. During each measurement series, the "day" (illumination) and "night" (darkness) conditions (L:D cycle) were simulated. Hydroacoustical data were collected under controlled constant light, temperature and salinity conditions. Simultaneously, the oxygen content was monitored. The influence of the microphytobenthos

photosynthesis on the characteristics of the signals backscattered by sandy sediments is discussed. The study clarifies the impact of the abiotic (illumination level) and biotic (benthic microalgal biomass and macrozoobenthos bioturbation) factors on the diel variation of the backscattering caused by the benthic microalgal photosynthetic activity.

Acoustically derived indicators of demersal and forage species productivity in the Strait of Georgia (British Columbia, Canada): 2010-2016

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Pelagic ecosystem surveys have been conducted in the Strait of Georgia (SoG, British Columbia, Canada) in 2010, 2011, 2014 and 2016. Multifrequency acoustic data (EK60) have been collected along series of parallel transects in conjunction with mark-identification trawling. Acoustic signals were further partitioned and classified to discriminate dominant fish species (Pacific Hake, walleye Pollock, and Pacific herring) and euphausiid based on their frequency-dependent backscattering strength, which yielded consistent results due to differences in size and characteristics. Acoustic data were converted into biomass estimates to develop time series along with historical data Biomass of Pacific Hake was at an historical low level of approximately 6,117 mt in 2010, but rose up to over ~ 20,000 mt and ~40,000 mt in 2014 and 2016, respectively. The biomass of walleye pollock fluctuated between the highest biomass in 2016 (27,457 mt) and lowest biomass in 2010 (17,750 mt). Pacific Hake aggregations were mainly distributed in the central-northern SoG, while walleye pollock were more spread out, with relatively higher biomass in the southern SoG, suggesting space partitioning between these two species. The estimated biomass of dominant species will be investigated for potential links to marine survival of juvenile salmon in this ecosystem.

Influence of environmental factors on distributions of capelin in the Gulf of Alaska

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Capelin (*Mallotus villosus*) are an important mid-trophic link within marine foodwebs, yet there is limited information describing fluctuations in their distributions in the Northeast Pacific. Multifrequency (38, 120 kHz) acoustic data were collected during a fisheries-oceanographic survey over the Gulf of Alaska shelf in summer 2013. The influence of environmental factors on the occurrence and density of capelin were quantified at two spatial resolutions associated with sampling at discrete stations and continuously along-transects. At the station resolution (37 km), capelin occurrence probabilities increased with warmer bottom temperatures and higher chlorophyll concentrations, with densities increasing in closer proximity to the edges of submarine banks (< 100 m) and in waters with reduced thermal stratification. At the transect resolution (0.5 km), increases in capelin density were associated with increases in age-0 walleye pollock (competitor) densities over banks and with increases in macrozooplankton (prey) and semi-demersal groundfish (predator) densities in troughs (100-300 m). We infer that age-1 capelin concentrate over shallow banks in well-mixed, productive waters to feed on abundant copepods, whereas age-2+ capelin primarily occupy deeper waters in troughs where they consume larger euphausiid and amphipod prey.

Sea-ice deployments reveal silverfish and toothfish under the ice in the Ross Sea, Antarctica

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Antarctic toothfish (*Dissostichus mawsoni*) and Antarctic silverfish (*Pleuragramma antarctica*) are nototheniid fish endemic in Antarctic waters. Toothfish are a top predator, and an important commercially fished species. Silverfish are a keystone forage species. Data were collected by deploying acoustic equipment through the sea-ice in conjunction with vertical line fishing and baited underwater video (BUV) observations in the Ross Sea. We present the first estimates of target strength (TS) for Antarctic toothfish. Estimated mean TS from 250 tracked single targets detected in Terra Nova Bay was -37.8 dB. Estimates of toothfish length from BUV images of 42 individuals ranged from 92 to 201 cm total length (TL) with mean 134 cm. Estimates from 15 toothfish (104–153 cm TL, mean 131 cm) captured using vertical lines in McMurdo Sound gave a lower mean TS of -40.2 dB, but estimates from hooked fish have a number of potential biases. Adult silverfish were also detected through the ice in McMurdo Sound, and juvenile silverfish, but not adults, were observed in Terra Nova Bay. This paper provides a proof of concept, showing that innovative use of acoustics may help fill important observation gaps in the life history of Antarctic fish.

Evaluating winter distribution and biology of Pacific hake along the U.S. west coast

Sandra Parker-Stetter, Rebecca Thomas, and Dezhang Chu (sandy.parker-stetter@noaa.gov)

Current understanding of Pacific hake (*Merluccius productus*) distribution, behavior, and ecology in the California Current Ecosystem has come primarily from biennial summer assessment surveys along the west coasts of the U.S. and Canada. What Pacific hake do and/or where they are during winter has largely been assumed from hypotheses developed from limited egg and/or larval surveys. Concomitantly, these hypotheses have shaped ecosystem models and management approaches. Acoustic-trawl research cruises were conducted off Oregon and California in January-February of 2016 and 2017 with the goals of (1) characterizing winter distribution and ecology of Pacific hake, and (2) evaluating feasibility of a winter biomass survey. The acoustic and biological characterizations of hake differed between winters 2016 and 2017, and the two winters did not fully reflect expectations from previous hypotheses/assumptions. Comparisons between winter cruises in 2016 and 2017 and summer surveys in 2015 and 2017 suggest that hake biomass estimates, biomass distribution, vertical and horizontal distributions by age classes, and spatial overlap with other species were dissimilar between the seasons. This research challenges previous assumptions about Pacific hake life history and hake's larger seasonal role in the ecosystem.

Acoustic characterization of micronekton distribution in the surface layer related to the environment across the New Caledonia economic zone (south-west Pacific).

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Acoustic data are an inestimable data source to characterize mid-trophic level organisms' distribution and abundance that play a pivotal role in the ecosystem as prey of

top predators and as predators of low-trophic level organisms. This study uses 19 years (1999 - 2017) of acoustic recording from shipboard ADCP in New-Caledonia oceanic subtropical domain to examine the micronekton distribution dynamic. Two statistical models are used to link the mean surface scattering layer value (20–100 meters) to a suite of oceanographic and geographical variables. We show that the dominant signal in this surface layer is the diel vertical migration. Organisms are mostly influenced by the sea surface temperature. The micronekton abundance is higher during the austral summer (January, February and March) and concentrated in the northern part of New Caledonia, while it is lower during the austral winter (June, July and August) and more in the southern part. We also compare our predictions with micronekton biomass simulations of the Seapodym ecosystemic model. The seasonal cycle given by S-ADCP data lags the Seapodym seasonal cycle by around 3 months. This study improves our knowledge about micronekton dynamic, needed for ecosystem-based management and represents an opportunity to validate models such as Seapodym.

How many krill are there in the eastern Bering Sea and Gulf of Alaska?

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Euphausiids ('krill') are a globally important group of zooplankton and key prey for commercially important fish. Data collected during acoustic-trawl surveys of walleye pollock (*Gadus chalcogrammus*) can also be used to estimate krill (*Thysanoessa* spp.) abundance and distribution. Net capture and acoustic-trawl estimates of krill abundance differ widely, and the true abundance in this system remains uncertain. We hypothesized that this difference was due to krill avoidance of towed samplers and uncertainty or negative bias in krill target strength (TS, dB re 1 m^2) estimated by scattering models. To evaluate these hypotheses, we conducted paired trawl experiments with and without flashing strobe lights to assess the magnitude of net avoidance, parameterized, modelled, and measured the TS of live krill aboard ship, and analysed intact lipid content and distribution of the same specimens. Preliminary results show that krill catches in trawls (g/m^3) with strobe lights averaged 2x (night) to 4x higher (day), consistent with the effects of net avoidance. TS was variable among individuals, with model estimates comparing well with measured TS at some frequencies but falling substantially lower at others including 120 kHz. Total lipid content (mg/g) varied among krill individuals, but lipid class content showed less variation.

Use of inverted echo-sounders to monitor Pacific juvenile salmon in the Discovery Islands, British Columbia

Shani Rousseau and Stephane Gauthier (shani.rousseau@dfo-mpo.gc.ca)

Several autonomous, multifrequency echo-sounders (AZFP) were deployed in the Discovery Islands and in Johnstone Strait, British Columbia, from May to September of 2015, 2016 and 2017 to study the abundance, distribution and migration timing of Pacific juvenile salmon. A combination of multifrequency analysis and schools characteristics was used to separate juvenile salmon from other species. Species classification was validated with purse-seine samples above the echo-sounders location. An automation approach using random forests was tested to separate juvenile salmon aggregations from other schools. Juvenile salmon migration timing observed acoustically was in good agreement with data obtained from net samples. The migration period was longer in 2015 and in 2017, when chum and sockeye dominated the juvenile

salmon population, in comparison to 2016, a year dominated by sockeye. Vertical distribution showed that juvenile salmon were mainly found in the upper 20 m of the water column. A logarithmic relationship between juvenile salmon length and $\Delta MVBS_{67-125kHz}$ was derived from empirical acoustic and fish net data. This study shows that inverted echo-sounders provide a cost-effective, non-intrusive option for long-term monitoring of juvenile salmon populations in the area.

What the hake? Re-examining common models for distribution of Pacific hake

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Pacific hake (*Merluccius productus*) have been surveyed in the California Current Ecosystem since the 1970's, with the current stock assessment model using acoustic survey data since 1995. There are a number of generally acknowledged paradigms for distribution of Pacific hake, including models that hake go deeper as they get older, that older hake go further north, and that age-1 hake segregate vertically from older fish. Survey data spanning about 15 years are used to re-examine these models. Results demonstrate that these models are both true in the generality but not necessarily true in the specifics. Hake depth varies with age, but not necessarily in the way that we expect. Older hake go further north, but some lag behind. Adult and age-1 hake segregate, except when they don't. This research provides useful information for understanding the complex dynamics of Pacific hake distribution.

Blending satellite observations with water-column sonar data from a national archive to characterize the distribution of marine life

Carrie C Wall, Charles Anderson, and Kristopher Karnauskas (carrie.bell@colorado.edu)

The National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Information (NCEI) has developed an archive for the long-term stewardship of active acoustic data. Water-column sonar data have been collected for fisheries research and habitat characterization over large spatial and temporal scales around the world, and these data have been archived at NCEI since 2013. With over 50 TB of data freely available to the world, the ability to use these data to answer new scientific questions is easier than ever. Here we provide an example of such an endeavour. Using a novel combination of multiple NASA satellite products and EK60 data, we examined the linkages between the surface expression and vertical structure of ocean productivity and biomass in the California Current System (CCS). The interannual variability of the spatial distribution of satellite-derived surface chlorophyll concentration and temperature estimates were compared to variations in the subsurface nautical area scattering coefficient. The results illustrated a correlation between the parameters for upwelling regions of the CCS. The ability to determine the extent to which satellite measurements can predict the subsurface distribution of marine biogeography will be discussed.

Observing behaviour of pelagic fauna at a coastal tidal kite development site using bottom mounted and ship based echosounders

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There has been a fast increase in the use of tidal marine renewable energy devices (MREDs), but our understanding of interactions between MREDs and fish and their predators (e.g. diving seabirds and cetaceans) is very limited, a present an obstacle for the assessment and mitigation of the impacts of this industry. A first step toward this assessment is understanding the use of the pelagic habitat by biota. Here we investigate the depth distribution of pelagic fish and crustacea in an 85 m deep tidal kite development site off Wales. Ship-based (Simrad EK60, 38 and 120 kHz) and bottom-mounted (ASL AZFP, 38, 67, 125 and 200 kHz) echosounders, a mid-water trawl and physical oceanographic sampling were used to quantify fish school depths and variables such as irradiance depth and suspended particulate matter. We observed strong diel migratory behaviour in small pelagic fish schools with clear variation in school characteristics over lunar cycles, with mean daily school depths varying from 2 to 50 m. Trawl catches indicate that several shrimp and amphipod species migrate upwards during the night. These observations of vertical migration patterns can inform predictions of top predator feeding opportunities and possible MRED-ecosystem interactions with fauna in the water column.

WGFAST 2. Acoustic properties of marine organisms

In situ acoustic frequency response of Arctic cod in the Beaufort Sea

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The development of broadband echosounders has long been an anticipated step toward better identification of sound scattering organisms in marine ecosystems. Using Simrad EK80 data collected in of 2017, echotraces from the epipelagic layer to within 5 m of the seafloor have been identified and analysed for frequency response. We present preliminary results of species-specific identification criteria across the 34-45 kHz frequency range. The location and depth of echotraces correspond to bottom and midwater trawl catches with >95% Arctic cod (*Boreogadus saida*). Through further development of broadband echo characterization of forage fish, we aim to improve discrimination between boreal and Arctic species.

Characterization of backscattering by walleye Pollock

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It is well known that for swimbladdered fish the resonance scattering by the swimbladder dominates at lower frequencies while the scattering by fish body (flesh and bone) dominates at higher frequencies. In this study, systematic and quantitative numerical simulations were performed to study the age-dependent frequency response of walleye pollock (*Gadus chalcogrammus).* Digital X-Ray images of walleye pollock from age0 (young-of-the-year) to age 4+ were taken processed to obtain morphological information about the swimbladders and bodies. For the scattering model, backscattering by swimbladders of equal-volume prolate spheroids is based on the resonance scattering model combined with a directivity function due to the elongation of the swimbladders. The backscattering by weakly scattering fish body of equal-volume ellipsoids is based on the Distorted Wave Born Approximation. The total backscattering is the incoherent

average of the contributions both swimbladders and fish body averaged over length and angle of fish orientation. The transition frequency from the resonance scattering by swimbladder to weakly scattering by fluid-like fish flesh is age-dependent. The quantitative information on this transition frequency may be useful for fish species identification and/or classification based on spectral analysis.

Simultaneous optical and broadband acoustic recordings of free swimming krill in a large tank

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The target strength of Antarctic krill strongly depends on frequency, size, orientation, body flexing as well as density and sound speed contrasts of krill. The use of broadband acoustics in combination with optical stereo recordings and a modelling approach can provide new insights into the relationship between behaviour and acoustic scattering properties of marine organisms. Here, we used a large (10,000 l) tank to obtain combined acoustic and optical recordings of krill (~8,000 individuals). With the current setup, we were able to withhold krill for a prolonged period of time. Acoustic recordings were done with a calibrated Simrad EK80 echosounder, operated over a bandwidth of 90-170 kHz with fast ramping. Stereo video recordings in combination with a modelling approach (DWBA) were used to validate acoustic findings. These experiments represent first simultaneous optical and acoustic recordings of such a large amount of free swimming krill in a controlled environment. Differences in behaviour and TS for experiments with a high (thousands) and a low (120) number of free swimming individuals and the influence of orientation and body flexing on TS are discussed.

Broadband backscattering from artificial fish-like targets

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Due to size-dependent pricing and regulations, pre-catch sizing of pelagic fish is desirable in a range of fisheries. High-resolution broadband echosounders are potentially capable of direct remote fish sizing in relatively dense concentrations, as typically found during purse seining. The increased spatial resolution of pulse compressed broadband echoes and narrow beamwidth transducers provide the ability to resolve not only the target strength and echo spectrum, but also scattering from different parts of the fish body and hence measure the body size. As a first step, we measured broadband scattering from artificial, fish-flesh-like targets of varying sizes as a function of orientation angle. Two sets of prolate spheroids, made of polyvinyl-alcohol-cryogel (PVA), with a length range of 10-45cm have been measured. One set consisted of solid PVA, while a second set contained internal air-filled prolate spheroids that simulate a swimbladder. A motorized apparatus was used to suspend the targets in the acoustic beam of two laterally oriented transducers (45-90 kHz, 160-260 kHz, 13 m range), with precise control of rotation angle. Under these controlled conditions the fish-like PVA targets could be directly sized. Measurements using fish will be carried out in 2018.

Target strength of spawning herring

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Norwegian spring-spawning (NSS) herring is the most abundant and commercially important subpopulation of herring in Northeast Atlantic. Acoustic target strength (TS) of this fish has been previously measured and reported from both in situ and ex situ investigations and partially incorporated in the stock assessment for this fish. Surveys on the spawning grounds are now important for the stock assessment and subsequent management. The main question investigated here is whether the mean target strength of herring with a gonadosomatic index of 30% is different from the mean target strength of herring without gonads. The gonads can alter both swimbladder shape and volume as the room in the body cavity is restricted. The buoyancy of the fish may also be affected. Here we report initial results of in situ herring TS measurements obtained on the spawning grounds. TS was measured both from vessel based echosounders and by an autonomous echosounder deployed inside herring layers at depth. Several TS datasets were obtained, both in shallow water (10-40m) and at depths up to 250m. Narrowband TS was measured at 18, 38, 70, 120 and 200kHz, and broadband TS measurements (35-45kHz, 55-90kHz, 160-260kHz) were obtained on both young (4 years) and adult (13 years) spawners.

WGFAST 3. Behaviour

Dynamics of micronekton on seamounts in South West Indian Ocean

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Seamounts are ubiquitous topographic features across all ocean basins. Depending on their size, shape and summit depths, seamounts have an impact on the physical flow regimes. They may promote the aggregation of zooplankton, micronekton, and top predators above or in the immediate vicinity of their summits. The dynamics of micronekton was investigated as part of a multidisciplinary research project carried out at two shallow seamounts of the South West Indian Ocean: La Perouse (19°40'S, 54°09'E, summit depth 55m) and "MAD-Ridge" (27°25'S, 46°15'E, summit depth 200m). Physical parameters (nutrient, chlorophyll *a* and temperature) were sampled and measured using a CTD Rosette system. Micronekton were sampled using an International Young Gadoid Pelagic Trawl, towed for 30 min-1 hour at a speed of 3-4 knots. Acoustic data were collected continuously during the day and night at 4 frequencies: 38, 70, 120 and 200 kHz. Preliminary results demonstrate the influence of mesoscale eddies in concentrating micronekton above 200 m during daytime, and the influence of seamounts, aggregating specific communities of fishes (responding equally to the 38 and 70 kHz frequencies) at their summits,. A greater micronekton acoustic density was recorded at MAD-Ridge compared to La Perouse, owing to the differing environmental characteristics of these two seamount ecosystems.

Hydroacoustic studies reveal the impact of artificial light from research vessels on the distribution and abundance of marine organisms under low solar irradiance

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Active acoustics is widely used to document the distribution and abundance of marine organisms, and most surveys are conducted continuously during both daytime and

night-time. When it is dark, light is generally considered as pollution, with increasing appreciation of its negative ecological effects. Using an automated vehicle fitted with an Acoustic Zooplankton and Fish Profiler (AZFP) and a hyperspectral irradiance sensor, we quantified the behavior of marine organisms in an unpolluted light environment in the high Arctic polar night and compared the results with that from a light-polluted environment close to our research vessel. The vast majority of the pelagic community exhibited a strong light-escape response in the presence of artificial light, observed down to 100m. Avoidance of the light beam and changes in orientation of the organisms resulted in inaccurate vertical distribution measurements and in a reduction in volume backscattering strength values that could reach 4dB. We conclude that artificial light from traditional sampling platforms affects pelagic communities to a degree where it is impossible to accurately estimate its abundance and natural rhythms within the upper 100m. This study underscores the need to adjust sampling platforms, particularly in dim-light conditions, to capture relevant physical and biological data for ecological studies.

Mesopelagic fish avoidance of vessel noise.

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This study analyses the mesopelagic fishes behaviour influenced by the presence of a research vessel. Acoustic data recorded on board the RV Ángeles Alvariño during the RAPROCAN 2017 survey showed a clear pattern of mesopelagic fishes migrating deeper down in the water column at night when the DP system was connected. Details on how the scatterers changed their trajectory when migrating to the surface at night and the progressive increase in avoidance depth when dawn approached is shown. An experiment was carried out to discern fish reaction to vessel lights and to the DP system. Both vessel noise and light modified the mesopelagic fish behaviour, which needs to be accounted for when studying mesopelagic layers close to the surface. Similar reactions were recorded weeks later on board RV Sarmiento de Gamboa.

Relating fish density with hydrodynamics at a tidal energy site

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The interactions of fish with hydrodynamics in the high-flow conditions of tidal energy sites are not well understood, which makes it difficult to predict fish interactions with tidal energy devices. This assessment examines the relationship between fish density and current velocity at the FORCE tidal energy site in the upper Bay of Fundy, Canada. Concurrent information on current velocity and volume backscatter were collected from a stationary, bottom-mounted sensor platform deployed at the FORCE site from 15 September to 12 October 2017. Data were collected by an upward-facing Nortek Signature 500 ADCP and a 120 kHz Simrad WBAT for 5 minutes every half-hour. The ADCP returned current speed and direction measurements for 1-m bins of the water column, and volume backscatter data from the WBAT were echo-integrated in corresponding 1-m bins. The correlation between current speed and fish density are examined for relationships with environmental factors, including tidal stage, water column depth, and diel stage. As more data are collected, this study will seek to better understand how fish density relates to hydrodynamic conditions at high-flow sites to inform predictions of fish encounters with MHK devices.

WGFAST 4. Emerging technologies, methodologies, and protocols

A plan of in-situ broadband measurements of Antarctic krill in 2018/19 field season

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A dedicated krill survey for CCAMLR Division 58.4.1 (Indian sector of Antarctic) during 2018/19 season is planned by Fisheries Agency, Japan. EK80 with operating frequencies of 38, 70, 120 and 200 kHz installed on RV Kaiyo-maru. Biomass of krill will be estimated based on CCAMLR-2000 protocol using narrowband (CW) data. CW data will be collected along the predetermined tracklines and the vessel will turn around and go back once a target swarm is detected to conduct net sampling by RMT1+8. The broadband (FM) data will be collected during the net sampling to compare the length frequencies of net samples and acoustic estimation. Following settings will be applied to EK80 during FM data collection: (1) bandwidth "full range" (30-45 kHz, 45-95 kHz, 96-160 kHz, 160-260 kHz), (2) pulse duration = 8.192 ms, (3) ramping "fast", (4) ping interval "sequential pinging". Because FM has rarely applied to Antarctic krill in field, we would like to invite comments from FAST members so that we can improve our survey methods.

PyEcholab: A Python toolkit for water-column echosounder data analysis

Charles Anderson, Rick Towler[3], Pamme Crandall, Randy Cutter, Michael Jech[5], Carrie Wall (charles.d.anderson@colorado.edu)

Water-column echosounder data are becoming increasingly available and are used for a diversity of research objectives. However, these data are voluminous, complex, and recorded in instrument-specific binary file formats. Tools to process these data are limited to a few commercial applications, or custom programs developed by researchers. These limited options leave potential users without sufficient financial resources or programming knowledge unable to use these data. To address this problem, NOAA Fisheries, University of Colorado Cooperative Institute for Research in Environmental Sciences, and NOAA National Centers for Environmental Information (NCEI) personnel are developing PyEcholab. PyEcholab is an open-source, python-based system for reading, processing, and visualizing water-column echosounder files. Currently, the system is being developed to meet existing NCEI processing and visualization needs, but PyEcholab's base classes and open architecture provide a framework for developing new file readers, processing algorithms and visualization techniques that can be modularized into the system. The long-term vision is to engage the community in an open-source effort that continually grows PyEcholab's capabilities and expands the use of water-column echosounder data.

Abundance estimation of pelagic fish using multifrequency and multibeam echosounders: A case study for the multi-year PELGAS acoustic survey using Simrad EK60 and ME70 echosounders

Laurent Berger, Mathieu Doray and Naig Le Bouffant (laurent.berger@ifremer.fr)

Ten years of data acquisition using a standardized protocol for EK60 and ME70 echosounders during PELGAS acoustic survey has enabled to build a ground-truth database of frequency and angular volume backscatter response for the two main species, anchovy and sardine. Influence of the combined echosounder and fish directivity is

modelled using a realistic simulation scheme and used to explain the observed measurements. Consequences on species identification and abundance estimates of these two species are discussed.

Marine ecosystem assessment in a patchy world: are autonomous technologies the solution to quantify zooplankton?

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Zooplankton are important indicators of marine ecosystem health. However, deriving reliable abundance estimates from commonly used acoustic techniques can be complicated by difficulties in target identification (particularly within mixed species layers) and the dynamic, patchy distributions of zooplankton. Furthermore, traditional ship-based methods to quantitatively assess abundance are costly and thus ship-time is often limited. Recent developments in autonomous technologies offer novel cost-effective ways to sample the ocean environment and study zooplankton patchiness at high spatial and temporal resolutions. In my PhD, I explore the capacity for non-traditional acoustic platforms, such as autonomous surface vehicles, profiling gliders and moorings, to contribute towards ecosystem assessments. Acoustically sampling zooplankton using autonomous wideband echosounders whilst simultaneously collecting in-situ environmental data will enable me to explore relationships between hypothesised physical and biogeochemical drivers of patchiness and actual observed distributions. I will discuss preliminary findings from data collected by a Simrad Wideband Autonomous Transceiver mounted on a mooring deployed in the Scotia Sea, Southern Ocean, for two weeks in 2016. I will also present plans for future field campaigns during 2018, including deployments of a WBT-mini wideband echosounder on a *WaveGlider* autonomous surface vehicle in the North Sea as part of the *AlterEco* project.

Comparison of EK60 and EK80 data collected during Acoustic-Trawl Surveys

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Simrad EK80 echosounders have superseded Simrad EK60 echosounders, used to conduct fisheries surveys around the world. To ensure the continuation of accurate and precise measures, we quantitatively compared the performances of these systems using data from two surveys of small pelagic fishes off the U.S. west coast, in 2017, aboard NOAA FSV *Reuben Lasker*. Using a custom multiplexer and six transducers mounted in the ship's centreboard, EK60 and EK80 systems alternately transmitted CW pulses throughout the surveys. We present the results of the comparison.

Using EK80 echosounders in narrowband mode: does $Sv_{,EK80} = Sv_{,EK60}$?

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The new EK80 echosounder can be configured to operate in a narrowband mode, which is designed to produce results equivalent to those of the EK60, the instrument with which many existing acoustic-trawl survey time series are based. To examine whether EK80 echosounders configured for narrowband operation can be substituted for EK60 echosounders without making adjustments to abundance time series, we are conducting a field evaluation of narrowband echo integration measurements made

with a 5-frequency EK60/EK80 system during three acoustic-trawl surveys of walleye pollock in winter/spring 2018. The EK60 and EK80 systems were configured to alternate transmissions from the same set of transducers using a triggering system and a multiplexer. These paired transmissions were collected over a broad range of conditions, and have been post-processed the same way using echoview software. Four sphere calibrations of the echosounders have been conducted to date in order to estimate the gain of these systems and the uncertainty attributable to calibration. This work is ongoing, and this presentation will present some preliminary results comparing echo integration measurements from the two instruments.

New methodology for mapping seabed habitats using calibrated backscatter: A case study for the multi-year EVHOE bottom-trawl survey using Simrad ME70 multibeam echosounder

Ridha Fezzani, Laurent Berger, Naig Le Bouffant and Xavier Lurton (laurent.berger@ifremer.fr)

An automated signal-based method was developed in order to analyse semi-automatically the seafloor backscatter data logged by the Simrad ME70 calibrated multibeam echosounder. The dataset was acquired using a standardized protocol in order to map the area covered by the trawl during 8 years (2008-2016) of the annual EVHOE bottom-trawl survey in the Bay of Biscay, France and Celtic Sea, Ireland. The processing consists first in the clustering of each trawling area into a small number (2 or 3) of homogeneous sediment types, based on the backscatter average level at one or several incidence angles. Second, it uses their local average angular response to extract discriminant descriptors, obtained by fitting the field data to the Generic Seafloor Acoustic Backscatter parametric model (Lamarche *et al.* 2010). Third, these descriptors are used for seafloor type classification. The method was applied for seafloor-type classification into 12 classes, to a dataset of 158 spots surveyed for demersal and benthic fauna study and monitoring. Qualitative analyses and classified clusters using extracted parameters show a good discriminatory potential, indicating the robustness of this approach. The study resulted in a large-scale mapping of the seafloor areas surveyed by the EVHOE cruises.

Analytic tools for acoustic monitoring in aquatic ecosystems

Silvana González, and John K. Horne (silgonz@uw.edu)

An increasing number of research projects and industrial applications use active acoustic technologies to monitor biomass in the water column. Common objectives among applications include: characterizing variability in biomass, detecting biological change and/or environmental impacts, and identifying extreme events. Analytic tools that satisfy these objectives over diverse environments and variable conditions are needed to establish best practices for monitoring and to allow comparisons among studies and sites. Wavelets are used to identify scales of variation in time series and to characterize and compare patterns in biomass distributions over time (e.g. before and after an intervention) or between sites (e.g. control vs. treatment sites). Extreme events are rare but potentially important or even catastrophic. Extreme value analysis provides objective techniques to determine thresholds of extreme events, model tails of outcome distributions, and to estimate probabilities and periodicities of extreme events. We illustrate the utility of these approaches by characterizing and comparing temporal varia-

bility and extreme values in pelagic fish and zooplankton biomass distributions at Marine Renewable Energy tidal sites in Admiralty Inlet (WA, US) and the Fall of Warness (Scotland, UK), and a wave energy test site (OR, US).

Drowning in data: Can deep learning approaches be the solution?

Nils Olav Handegard, Vaneeda Allken, Ketil Malde (nilsolav@hi.no)

Oceanography and fisheries science depend heavily on data collection programs, and new platforms and sensors have the potential to increase the data volumes at moderate costs. Analysing the data often require expert knowledge that needs time consuming manual curation, which is hard to code explicitly in automated systems. In this presentation we briefly review the recent development using deep learning algorithms to implicitly code the tacit knowledge from expert system. We introduce the methods, the different frameworks that can be used, and a few cases where we successfully have used the methods. Challenges include insufficient amount of training data and weak data organization, whereas the advantage is rapid code development and deployment. We present how we have approached these challenges at IMR.

Hydro-acoustic data collection trials in the Baltic Sea using a 5 m unmanned surface vessel

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Autonomous surface vessels (USVs) are increasingly available for marine ecosystem research. In June 2017 we deployed a 5 m wave-powered USV, "Autonaut", equipped with a Simrad WBT Mini echo-sounder and a dual frequency transducer (38 and 200 kHz). The survey took part for 10 days in the Baltic Sea in the vicinity of the largest seabird colony in the Baltic Sea, hosting up to 80 000 individuals of seabirds. The data indicate high presence of pelagic fish in the area, probably a mix of sprat *Sprattus sprattus*, and Atlantic herring *Clupea harengus*. We also repeatedly observed diving birds on the echograms, which suggests that the vessel had a minimal disturbance on the foraging birds. We discuss pros and cons with different autonomous platforms currently available on the market for hydro-acoustic surveys, and the various applications of this technology as a complement to ship-based surveys.

Active acoustic monitoring of aquatic ecosystems

John K. Horne and Ross Hytnen (jhorne@uw.edu)

A second-generation, Python software architecture has been developed to provide a monitoring and data management system that can be expanded from a single instrument to multiple sensor packages. This system is designed to 1) monitor movements of marine animals, 2) process raw data and calculate characterization metrics, 3) detect and record events above thresholds, and 4) store data products, visualizations, and generate reports. Live output or recorded data are converted to a common format and processed in real time or can be used to process or reprocess files in batch. By integrating data acquisition, processing, visualization, and data product output, this system can: detect and track single or groups of animals, increase monitoring capacity by adding sensors and/or computing power without redesigning architecture, and automate event or impact detection through threshold detection, triggering, and reporting. We

believe that COTS remote sensors can be integrated with custom software to provide cost-effective, environmental monitoring solutions.

Deep-water calibration of echosounders used for biomass surveys and species identification

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Acoustic quantification of aquatic biomass using echosounders requires accurate calibration. With the advancing applications of deep-water echosounders involving moored, towed, profiling and autonomous instruments, calibration of transducers at the operating depth is needed to ensure unbiased estimates of biomass and species identification. In this context, we used the Deepwater Calibration Acoustic Facility (DeCAF) to examine the depth-dependent variations in on-axis gain (G_0) and equivalent two-way beam angle (Ψ) of three different transducers, operating at 38 (Simard ES38-DD and MSI-38) and 120 kHz (Simard ES120-7CD) used for biomass surveys and species identification. The analyses carried out using the sphere calibration method reveal significant variations in calibrated G_0 and Ψ that in combination could result in substantial systemic biases in quantitative biomass estimation and species identification. The depth-dependent G_0 variations derived using the DeCAF system are in accordance with available deep-water calibration results, demonstrating reasonable repeatability of target strength (TS) measurements (±0.6 dB) over the calibration deployments. Importantly, Ψ of the transducers was calculated to be consistently lower than the values specified by the manufacturer, and for one transducer would result in 18% change in the estimated biomass. These results highlight the potential for bias if the Ψ of transducers is not independently calculated using the actual survey echosounder.

Latest developments in open-source software for fisheries acoustics ESP3

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ESP3 is an open-source software package for visualizing and processing fisheries acoustics data, under active development at NIWA. It focuses on allowing the processing of acoustic data in a consistent and efficient manner, with attention on reproducibility of results. ESP3 was first released last year, and has been evolving very quickly since then. New features include (1) the concurrent display and integration of multifrequency data, new algorithms than can be applied to all, or parts of an echogram, (3) new methods of bottom definition/edition, etc. It has also been optimized to work with large datasets and large files such as those produced by EK80 when recording complex samples in CW or FM mode. A scripting module allows the user to define parameters to process an entire dataset, then vary parameters and reprocess, without the need for any additional manual processing after the data has been scrutinized once. ESP3 has been used at NIWA to produce inputs for biomass estimations, spatial distribution of water-column backscatter, seafloor backscatter analysis, target-strength measurement analysis, data processing for long-term mooring deployments, and work on frequency responses of mesopelagic organisms.

Exploring model sensitivity in Bayesian inversion of zooplankton sonar echoes

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The recent availability of commercial broadband echosounders has elicited wide interests in their potentials for enhancing the effectiveness, efficiency, and accuracy of acoustic sensing capability during surveys. However, despite the significantly improved temporal and spatial resolutions, it remains unclear how the additional spectral information can be used to achieve these goals. To address these needs we developed a Bayesian inversion framework to estimate model parameters of biological scatterers. In this study, we evaluate the uncertainty associated with model parameters and the amount of information embedded in the additional bandwidth provided by broadband echosounders. We employ the Markov Chain Monte-Carlo (MCMC) sampling technique to construct the posterior probability density (PPD) of a full suite of biological model parameters given simulated zooplankton echo data in the form of volume backscattering strength (Sv) at multiple frequencies. The model parameters include length, width, tilt angle, and the density and sound speed contrasts (*g* and *h*, respectively) of the simulated zooplankton aggregation. We investigate the changes in PPD in response to variations in the echo spectral information, with specific emphasis on the correlation structure among model parameters. [Work supported by NMFS Office of Science and Technology Advanced Sampling Technology Working Group].

Ocean Glider Mounted Echo Sounders for Monitoring Fish and Zooplankton Populations

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Ocean gliders are growing in importance as components of ocean observing systems. Echosounders are now available with sufficiently small size and low power consumption that they can be installed in gliders, providing the means to simultaneously measure biological metrics through the water column over extended areas and linking physical properties and primary productivity to higher trophic levels such as zooplankton and fish. We have recently installed single-beam echosounders with up to four acoustic frequencies in gliders. In the initial case, a 200 kHz, single-beam echosounder was integrated and calibrated in a Slocum Webb electric ocean glider. Trial missions in the eastern Gulf of Mexico traveled over a submerged pipeline and a rocky reef. Acoustic backscatter signals attributed to mid-water plankton layers were co-located with oceanographic features and peaks in chlorophyll. Schools of pelagic and demersal fishes were detected and mapped over charted seafloor features. Preliminary results from some gliders with multifrequency echosounders will also be discussed.

Don't work so hard: efficient analysis of large acoustic datasets

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Echo integration data collected from fishing vessels, autonomous surface vehicles, and other emerging platforms is increasingly available. However, post-processing these data can be prohibitively time-consuming. Automated processing methods exist; as compared to traditional post-processing by trained analysts, these methods often cannot extend as closely to the sea floor and can increase uncertainty in partitioning acoustic backscatter to species. We developed an alternative approach based on processing subsampled data, which takes advantage of the spatial correlation common in many

fish populations. We sequentially removed 50-ping segments from an Eastern Bering Sea walleye pollock acoustic-trawl survey and compared estimates of backscatter attributed to pollock from these subsamples to those from the full survey. On a survey-wide scale, subsamples of <5% of the data resulted in backscatter estimates within 5% of those from the full survey. We applied this approach to data from two commercial fishing vessels covering over 6000 nautical mile of trackline. Two discrete datasets, each comprising 5% of the total data, were post-processed by an analyst using standard methods. Estimates of pollock backscatter from the two datasets agreed within ~5%. At large scales (e.g. those of a survey), precise echo integration estimates can be obtained with minimal effort.

An open and extensible netCDF4-based file format for sonar data

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A convention has been developed for the storage of sonar data in netCDF4-formatted computer files, with an initial focus on omni-sonars. The convention can accommodate backscatter data from multiple sonar manufacturers and is easily read by analysis tools. The aim is to facilitate the use of sonar data by providing a standardized netCDF4 convention for archiving, analysis, distribution, and exchange of data. The name of this convention is SONAR-netCDF4. The convention is sufficiently generic and flexible to contain all foreseeable fisheries sonar data, along with necessary meta-data. It also serves as a statement of the minimum set of data and meta-data required to use omni-sonar data in a quantitative manner. The intention is to facilitate the creation and use of data from multiple sonar manufacturers. The convention will be presented and examples of its use shown. A long-term vision for standardized file formats and conventions in fisheries acoustics will also be introduced, of which SONAR-netCDF4 is an initial step. This convention was developed by the WG-FAST Topic Group: *Defining a data format for omnidirectional fisheries sonar* and is currently under review by ICES for publication as a Cooperative Research Report.

Enumeration of juvenile bluefin tuna (*Thunnus thynnus*) in the Bay of Biscay: A multi-beam sonar approach.

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Each spring juvenile Atlantic Bluefin tuna from the Mediterranean Sea enter the Bay of Biscay to feed. From April through September schools of age 2-5 tuna can be found throughout the Bay. Traditionally a standardized age aggregated CPUE index of abundance was derived from the bait boat fishery for use in the eastern bluefin tuna stock assessment. Unfortunately, changes in the behaviour of the fleet prevented the continuation of the index beyond 2011. In search of a new index we explored the potential of using a multi-beam sonar to quantifying schools of bluefin tuna. Mean number of targets estimated for selected time intervals, after removal of noise, are used to quantify the observations. The results indicate that individual bluefin can be detected and counted in schools of up 300 fish. In addition, estimates of fish size were made with the sonar and compared with biological samples collected during fishing. Our observations indicate that the high resolution sonar can be used to enumerate/quantify juvenile bluefin tuna within the systems swathe at ranges in excess of 100m without the need to collaborate the system.

ICES Acoustic Trawl Survey Database

Hjalte Parner, Mehdi Abbasi, Anna Osypchuk, and Neil Holdsworth (hjalte.parner@ices.dk)

The ICES Data Centre has led the development of a new Acoustic Trawl Survey Database and Portal http://acoustic.ices.dk to host data collected from ICES coordinated pelagic/acoustic surveys. The database consists of two parts – an Acoustic and a Biotic part. The acoustic part is based on the SISP 4 – A metadata convention for processed acoustic data from active acoustic systems developed by the ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST), while the biotic part is based on the ICES Database of Trawl Surveys (DATRAS). Both the acoustic and the biotic parts contain fields that rely on controlled vocabularies accessible via the ICES vocabulary server http://vocab.ices.dk. In the submission process, a submitted XML file will be validated directly against the XML schema and schematron rules, while a submitted CSV file will be converted on the fly into the XML format to allow validation. The new system was developed in close cooperation with relevant working groups and funded through the AtlantOS project.

Coastal and oceanic ecosystem monitoring with autonomous vehicles equipped with active and passive acoustic sensors

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The advancement of low-power autonomous and remotely operated platforms is enabling sustained observations of costal and oceanic ecosystems. Combined with low-power sensors and enhancements in on-board data processing and near real-time data transmission, the value of such systems extends beyond research and traditional surveying to operational monitoring with relevance to multiple oceanic industries. Near real-time data from such systems are also valuable for data assimilation in meteorology and oceanography. Within the "GLIDER" project three mature platforms are used; Wave Glider (Liquid Robotics, operated by Maritime Robotics), Seaglider (Kongsberg Maritime), and Sailbuoy (Offshore Sensing). A range of sensors, including active and passive acoustics, is integrated on the platforms. The Wave Glider and Sailbuoy are currently equipped with Simrad WBT minis operating at 70 and 333 kHz (Wave Glider) and 333 kHz (Sailbuoy). The systems were tested during a one-month deployment August 2017. Early March 2018 the systems were deployed for a six-month duration mission, aimed at multi-trophic monitoring off the coast of Northern Norway. The integration and testing of the acoustic systems are discussed, as well as the preliminary results, operational use and future plans.

Use of active-acoustics in the high seas: the case of orange roughy (*Hoplostethus atlanticus*)

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High seas lie beyond any national jurisdiction and comprise of open ocean deep-water habitats. Fisheries management in these regions rely on international agreements. As an example, the South Indian Ocean Fisheries Agreement (SIOFA) came in to effect in 2012 with the aim of ensuring the long-term conservation and sustainable use of the fishery resources in the area. One fishery is orange roughy, a long-lived species found

at depths >500 m. Unsupervised industry acoustic surveys of orange roughy have been undertaken in the SIOFA area since 2004. These surveys are associated with issues including data quality and range dependent factors of absorption, near-seabed sampling and species identification. Here, we assess whether industry collected acoustic data can be used to inform stock assessments of orange roughy. Simrad ES60 38 kHz echosounder data were analysed to provide estimates of orange roughy biomass accounting for a range of uncertainties. Data were also collected from an Acoustical Optical System (AOS) to assess species identification and measure the *TS* of orange roughy *in situ* at 38 and 120 kHz. The vessel and AOS results demonstrate that these data can be used to provide meaningful inputs to assessment frameworks in high seas situations.

Development of open-source (e.g. Python) processing tools

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Our goal is to create software tools that are open-source, useful, and robust for processing and visualizing large volumes of water-column sonar data. NOAA Fisheries-funded work is supporting several U.S. scientists to develop PyEcholab, a python-based system for reading, processing, and visualizing water-column echosounder files. The international Southern Ocean project (MESOPP) has also identified the need for open source software tools that can be fully automated to deal with the data challenge for global observing systems and is working towards that goal. Coordination of these international efforts and input from the community are key to the success of both projects and the resulting tool's applicability to the broader scientific community. During this discussion group, we will examine the work completed to date, identify areas for better coordination or integration, and explore additional desired functionality to be developed in future. Our long-term vision is to engage the community in an open-source effort that continually grows the capabilities of this new suite of freely available tools and expands the use of water-column sonar data. Supporting and encouraging the development and use of standardized data structures (and file formats) is a part of this vision.