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

4-7 April 2017

Nelson, New Zealand

ICES
International Council for the Exploration of the Sea

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Executive summary

The ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST) is the only international forum where individuals working in fisheries acoustics can network to discuss ongoing developments in the technique. As such, it has been highly successful, attracting 63 participants from 16 countries to its meeting in Nelson, New Zealand from 4-7 April 2017.

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 to characterize a fast growing list of ecosystem characteristics and features, as well as for abundance estimation surveys. Advancing technology, increased collection of ancillary data (e.g. environmental variables), and use of alternative sampling methods has led to improvements in interpretation of acoustic data, but these are not always applied in analyses of abundance estimates. Discussions identified a need for future research for improved methods to refine survey gear, and quantify trawl selectivity across a broad range of species and sizes. WGFAST also suggested two theme sessions for consideration for the ICES Annual Science Conferences (ASC) planned in 2018 and 2019: 1) to consider use of survey products in assessments; and 2) application of new technologies (e.g. wideband acoustics) for fisheries surveys and ecosystem investigation.

Several presentations highlighted research and increasing applications of acoustic wideband technologies. Wideband systems are expected to replace the current standard narrowband scientific echosounders. To accompany this change, WGFAST organised an ICES Training Course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics' in December 2016, with a second course scheduled in December 2017. Members of WGFAST also met in a workshop in La Jolla, USA in September 2016 and published a CRR evaluating the Simrad EK80 wideband echosounder for fisheries and marine ecosystem science.

WGFAST held a joint session with the ICES Working Group on Fishing Technology and Fish Behaviour (WGFTFB) (JFATB) on 3 April 2017. A workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD), the Working Group on Target Classification (WGTC), and a Topic Group on 'Defining a data format for omni fisheries sonars' were also held in conjunction with the 2017 WGFAST meeting.

1 Administrative details

Working Group name

Working group Fisheries, Acoustics, Science and Technology (WGFAST)

Year of Appointment within the current cycle

2016

Reporting year within the current cycle (1, 2 or 3)

1

Chair

Richard O'Driscoll, New Zealand

Meeting venue

Nelson, New Zealand

Meeting dates

4–7 April 2017

2 Terms of Reference a) – e)

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

Recommendation from WGIPS	The Simrad EK60 scientific echosounder, commonly used in WGIPS surveys, will no longer be available for purchase as it has been superseded by the Simrad EK80 broadband system. A quantitative study needs to be undertaken to confirm that collected 38 kHz narrowband data are comparable between both systems.	2016
Recommendation from HAWG	HAWG recommends that WGFAST and WGIPS have an active role in developing the 6a-7bc herring industry acoustic survey that is being planned for 2016 under the auspices of the PELAC (Pelagic Advisory Council). The inclusion of industry acoustic surveys into the data sources for expert groups is an important new development that would benefit from expertise on acoustics and survey design. A review of the foreseen 2016 industry acoustic survey in the 2017 is needed to assess the quality of the survey for further inclusion in the ICES advisory system. It is envisaged that WGIPS and WGFAST would be involved in this review process.	2016
Recommendation from WGTC	Challenges connected to wideband acoustics need to be solved	2016

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:

- ICES. 2016. A metadata convention for processed acoustic data from active acoustic systems v1.10. Series of ICES Survey Protocols SISP 4-TG-AcMeta. 48 pp.
- Demer, D. A., Andersen, L. N., Bassett, C., Berger, L., Chu, D., Condiotty, J., Cutter, G., R., *et al*. 2017. 2016 USA–Norway EK80 Workshop Report: Evaluation of a wideband echosounder for fisheries and marine ecosystem science. ICES Cooperative Research. Report No. 336. 69 pp. http://doi.org/10.17895/ices.pub.2318
- Korneliussen, R. J., Heggelund, Y. Macaulay, G. J., Patel, D., Johnsen, E., Eliassen, I. K. 2016. Acoustic identification of marine species using a feature library. Methods in Oceanography 17: 187-205.

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 US 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 ASC session on 'Fisher collected acoustic data (FCAD)' (2016). The session was attended by approximately 30–40 participants. There were 16 presentations on three themes: (1) realized and potential applications of acoustic data from commercial fishing vessels; (2) improved biological understanding of Pacific jack mackerel (*Trachurus murphyii*) and anchovy (*Engraulis ringens*), their behaviour and relation to habitat and hydrography; (3) best practices in sustained cooperation between industry and science.
- ICES Training course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics' (Bergen, Norway, December 2016). There were 20 participants from 13 countries. Due to high demand, a second course is scheduled in December 2017.
- USA-Norway EK80 Workshop. The Simrad EK60 echosounder, long used for fisheries surveys, has been recently superseded by the EK80. To facilitate a transition to the EK80, an international Workshop was held in La Jolla, California, USA, 6-23 September 2016. This was attended by 18 participants from USA, Norway, France, and Australia. ICES Cooperative Research Report No. 336 outling the results of this workshop has been published.
- ICES Training course on 'Introduction to abundance estimation from fisheries acoustic surveys' (ICES Secretariat, Copenhagen, Denmark, June 2017)
- ICES workshop on 'Collecting Quality Underwater Acoustic Data in Inclement Weather' (WKQUAD) met in Nelson, New Zealand, 31 March-2 April 2017. There were 17 participants from 7 countries. The participants addressed the terms of reference with focus on developing standard procedures and

methods for identifying unsuitable survey conditions, proposing methods for dealing with degraded data, and comparing procedures and methods on selected datasets. The group identified potential diagnostics and metrics to assess data quality based on the percentage of ping 'dropouts', the depth of the observed bubble layer, and the movement of the vessel. The workshop report and recommendations are being prepared.

- Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] and the Working Group on Fisheries Acoustics Science and Technology [WGFAST] (JFATB) chaired by Paul Winger (Canada) and Alex De Robertis (USA) met in Nelson, New Zealand on 3 April 2017. The meeting discussed novel research under two themes: (1) how platforms and instruments affect the behaviour of aquatic fauna; (2) image analysis and machine learning techniques for efficient data processing.
- ICES WGFAST Topic Group on 'Defining a data format for omni fisheries sonars' met in Nelson, New Zealand on 4 April 2017, with 19 members, including representatives of sonar producers and post-processing software providers. A draft document describing the suggested netCDF4 file format has been prepared. At the meeting, it was agreed that example netCDF-4 files will be distributed to members of the topic group for testing and for implementation in existing software. After the test period, and refinement of the data format document, the document will be send to ICES to start the process of publication. The group expect to deliver the final version in September 2017.
- ICES Working Group on Target Classification (WGTC) chaired by Rolf Korneliussen (Norway) met in Nelson, New Zealand on 1–2 April 2017 to make the final edits on the draft Cooperative Research Report. The work of the 8 participants focused on simplifying the report, especially chapters 7 (Approaches to multifrequency target classification), 8 (Reconciling classification with sampling) and 9 (Future objectives, recommendations and conclusion). The remaining work is to finalize the existing case studies, and to incorporate two case studies (1. Artificial neural network; 2. Random forest).

5 Progress report on ToRs and workplan

5.1 Progress and fulfilment 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 2017 WGFAST meeting is in Annex 3. Abstracts for all work presented in 2017 are found in Annex 4.

Behaviour

As well as three presentations in WGFAST, there were seven presentations in the joint session (JFATB) which were related with studies on behaviour of target species.

Results from measurements using alternative platforms (i.e. sail drone) during acoustic surveys supported observations in previous studies using buoys systems of fish reaction to silent research vessels (De Robertis). Studies using optical methods for species identification showed the problem of fish reaction (attraction or avoidance) to the observation platform (light, movement of platform, bioluminesce) (Gauthier, O'Driscoll, Ryan, Jarvis). For moorings, timed light seemed to make it possible to observe the aggregation in undisturbed state on the first few video frames (O'Driscoll). In some cases, the target species did not react and optical observations proved to be a valuable and complementary tool to traditional trawling.

Fish behaviour was also studied in controlled experiments, investigating the effect of crowding in the reaction of mackerel to a predator stimulus (Handegard). The challenge of carrying out this type of mesoscale experiments and the transfer of the experimental findings to real field applications (e.g. fish slipping in purse-seine fisheries) was noted.

Dedicated measurements to observe the behaviour of mesopelagic fish revealed correlation to changes in light intensity, for communities at shallow and deep waters (Kaartvedt). It was noted that it would be good to make light intensity profile part of our standard measurement, maybe by putting light sensors on CTDs, to help understand observed behaviour.

In the discussion, it was noted that most behaviour observations are coming from standard surveys (e.g. O'Donnell, Kaljuste), and there was often not time for dedicated behaviour studies to understand the driving forces of the changes observed. A suggestion was made, to define a fraction of the survey time for dedicated behaviour studies (e.g. 10% of the ship time should be allocated to dedicated experiments during the standard surveys). Separate experiments (detached from surveys) have the risk that results may not be representative of the conditions observed during the survey.

Environmental and behavioural observations are sometimes collected which are not used in analysis of survey results, and additional resources should be allocated to allow this. Ancillary data (observations of light, water properties with CTD, etc.) should be checked during surveys, as it has been noted that data recorded without supervision are sometimes of poor quality.

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* organisms, ranging from copepods to tuna. These were coupled with ancillary data, e.g. water temperature, to inform TS models and classification algorithms. Also, potential habitat is being used increasingly to aid the design of surveys and the interpretation of resulting data.

Korneliussen *et al.* presented target classification software that uses a "feature library" to classify multifrequency echoes averaged in pixels, grid cells, or schools. The efficacy of the method was evaluated using scattering from known species. The library is populated with frequency responses of candidate species, but this may be refined with the addition of non-acoustic metrics, e.g. potential habitat, aggregation characteristics, and behaviour.

Gastauer *et al*. estimated the biomass of goldband snapper by combining a geostatistical analysis of 38 and 120 kHz acoustic data with TS estimates of *in situ* snapper. The TS measurements were matched with fish lengths derived from video observations. Total error was estimated as the sum of estimated sampling and measurement errors; although the survey bias is unknown.

Sakinan *et al.* investigated the variation in TS for copepod *Calanus finmarchicus*, and northern krill *Meganyctiphanes norvegica*, due to small changes in sound speed and density contrasts. A distorted wave Born approximation (DWBA) model was used to predict TS of both species. For the copepod, estimates of density contrast were estimated by measurements of a lipid-based health supplement. The modelled TS varied with depth and season due to physiological changes. The sound speed contrast for the copepod varied due to ontogenetic changes during overwintering. Physical ocean model data were used to generate a water column profile of temperature and predict lipid sound speed contrast, which resulted in wide range of TS at 333 kHz, from -71 to -80 dB. This approach could be used to improve our conversion of volume scattering to volumetric density.

Boyra *et al*. measured TS of *in situ* skipjack tuna around Fish Aggregating Devices (FADs), refined those data using a variety of published methods, and estimated TS vs. length relationships. Following each of the experiments, almost 100% of the fish around the FAD were caught, which provided another opportunity to estimate the tuna TS.

Ona *et al.* used three platforms (a four-frequency TS probe; a tiltable drop-keel mounted 200 kHz transducer; and a WBAT buoy equipped with underwater video) to measured TS of *in situ* Atlantic mackerel in both dorsal and lateral aspects, at multiple frequencies. The lateral TS data are needed to interpret sonar data. The measurements were compared to a model of scattering from Atlantic mackerel flesh and backbone, using a uniform distribution [0 to 360 deg] of lateral incidence angles. Dorsal TS was measured and modelled to be ~5 dB higher than lateral TS.

Gastauer *et al.* presented preliminary wideband ~90–150 kHz TS of tethered preserved Antarctic krill in an environmental controlled tank. Krill orientation was observed in real time using high-resolution video camera. Future work will involve live and free-swimming krill.

Emerging Technologies, Methodologies, and Protocols

During the discussion on new broadband technologies there were four presentations that discussed calibration and comparison of the EK60 and EK80 echosounders (Verma, Demer, Macaulay, Abe). Discussion on calibration highlighted the need for depth compensation and cross talk between frequencies. Two talks (Demer, Macaulay) discussed in detail the comparison of the EK60 and EK80 echosounders operating in narrowband discussed in Section 5.1.6 below.

There were six other talks that discussed the general topics of emerging methodologies technologies and protocols. These involved issues of lost quadrants during surveys (Lawrence), and new low-power echosounders on new platforms (Buermans), novel tuna counting in net pens (Hamano), new open source software for acoustic analysis (Ladroit), advanced data processing (Pena), and the combined use of baited traps and conventional acoustics (Figueroa). These talks highlighted the diversity of application that acoustics can be applied to and the ongoing developments of methodologies, technologies and protocols. **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

Presentations contained a series of interlinked topics that could be categorized in five general topics: the characterization of epi-, meso- and bentho-pelagic layers and organisms (Escobar-Flores, Jarvis, Downie, Kloser); the ecology of krill (Jech, and Cox); predator–prey dynamics (Pedersen, given by Macaulay); pelagic habitat variability and linkages to organism distribution (Domokos, van der Kooij); and novel approaches to address challenges in monitoring ecosystems (Demer). Each of the presentations touched on issues that could fit in other categories, emphasizing the interconnectivity and relevance of acoustics as a tool to study ecosystems and spatial ecology.

A common thread in many of these presentations is the fact that studying ecosystems at large scales often rely on opportunistically recorded data, due to the paucity of dedicated research. This means that there are often large gaps in sampling and ground-truthing that remains to be addressed. It has also been acknowledged that tools to sample pelagic organisms are often biased or ineffective (in particular for gelatinous organisms that gets destroyed by nets, as well as squids and other highly mobile nekton), and do not cover the full range of ecosystem components. Several members suggested that this could be the topic of a special session (or perhaps of a joint session with WGFTFB): **Quantify biases in tools used to sample pelagic organisms**. There was also indication that as a community we should aim to progress from qualitative descriptions to more quantitative approaches, particularly in the context of describing behavioural responses to sampling platforms (i.e. "transition from pictures to numbers").

Acoustics offers a tool that can allow us to assess a wide range of species and functional groups that are considered in ecosystem models, and we could use these measurements to test/validate the outputs of models, as well as the numerous assumptions that are attached to model parameters. WGFAST recognized that reciprocal communications, proactive discussions, and exchanges with the modelling community are essential to improve our understanding and characterization of ecosystems.

Other

Trenkel compared time-trends of biomass estimates for small pelagic species derived from acoustic and trawl data. Discussion noted that how acoustic abundance indices

and their associated uncertainty are incorporated into stock assessment models varies widely between assessments. **WGFAST recommended that an ASC session in 2018 considers use of survey products in assessments**.

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' is scheduled to be held 12–16 June at ICES Secretariat, Copenhagen, Denmark, with course instructors John Horne and Paul Fernandes. On 9 March 2017 there were 6 applicants, with a course capacity of 20. The application deadline is 5 May 2017. A request was sent to the chair of SSGIEOM during the meeting to distribute the course notice to WG chairs.

5.1.4 ToR d Provide guidance for calibrating echosounders on fishing vessels

WGFAST noted the 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 agreed to review the SPRFMO calibration protocol to assess its consistency with ICES CRR 326, and to provide advice on whether the SPRFMO protocol may also be useful for ICES members. This review will occur over the next year and will be discussed at the 2018 WGFAST meeting.

5.1.5 ToR e Organize joint sessions at ICES ASC

WGFAST recommended an ASC session in 2018 to consider 'use of survey products in assessments'. A proposal will be developed by Verena Trenkel (France) and Richard O'Driscoll (New Zealand) and submitted to SCICOMM in September 2017.

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 Other ToRs

Recommendation from WGIPS received in 2016

The Simrad EK60 scientific echosounder, commonly used in WGIPS surveys, will no longer be available for purchase as it has been superseded by the Simrad EK80 broadband system. A quantitative study needs to be undertaken to confirm that collected 38 kHz narrowband data are comparable between both systems

The Simrad EK60 echosounder, long used for fisheries surveys, has been recently superseded by the EK80. To facilitate a transition to the EK80, an international Workshop was held in La Jolla, California, USA, 6–23 September 2016. Results show that the EK60 and EK80, each transmitting single-frequency 'narrowband' pulses, provide equivalent measures. The EK80 can also transmit 'wideband' pulses spanning a large range of frequencies and apply matched-filter processing to potentially improve range resolution, signal-to-noise ratio (SNR), and target identification. In addition to quantifying these new features, participants identified some practical limitations and recommended that Simrad allow: 1) channel-dependent logging ranges; 2) faster and programmable alternation between narrowband and wideband, and active and passive modes; 3) more user control over transmit signals and processing parameters; and 4) collection of passive data prior to transmit pulses to estimate SNR. Due to the increased potential and complexity of the EK80, additional workshops are needed to develop standard operating procedures for wideband calibrations, target strength estimations, and echo classifications.

WGFAST received two independent presentations (one lab-based and one field-based) that showed operating a Simrad EK80 in narrowband mode will give similar (within 0.5 dB) results to the EK60 (taking normal care with calibration and software processing). Further tests in different environments are planned and will be reported next year.

Several agencies indicated they will be doing further tests and these should be presented to the ICES FAST next year.

The meeting discussed if WGFAST could recommend without reservation the use of EK80's for continuation of survey time-series. While it is expected that the risk for unexpected issues is low we can not discount unexpected results that fall outside existing testing regimes. Transition from one survey instrument to another can be a long-term process as discovered by the transition of the Simrad EK500 to the Simrad EK60 where some issues were not discovered until the EK60 had been in use for some time. Therefor it cannot be guaranteed that there are no further issues with transitioning to the EK80 and this transition will need further comparisons for different lab-based and field operations over the next years.

Recommendation from HAWG

HAWG recommends that WGFAST and WGIPS have an active role in developing the 6a-7bc herring industry acoustic survey that is being planned for 2016 under the auspices of the PELAC (Pelagic Advisory Council). The inclusion of industry acoustic surveys into the data sources for expert groups is an important new development that would benefit from expertise on acoustics and survey design. A review of the foreseen 2016 industry acoustic survey in the 2017 is needed to assess the quality of the survey for further inclusion in the ICES advisory system. It is envisaged that WGIPS and WGFAST would be involved in this review process.

In 2016 surveys were carried out on known herring spawning grounds to the west of Scotland and Northwest Ireland. Surveys were carried out on commercial vessels, using calibrated echosounders and funded using scientific quota. Dedicated spawning surveys were carried out as an alternative measure of individual stock components to that carried out during summer HERAS (Malin Shelf survey) where the stock(s) are mixed on the feeding grounds. Stock discrimination is the primary focus of this survey and forms part of a larger ongoing project.

Support will be provided through WGIPS, as the primary survey coordination group in this region. WGIPS has been proactive in the development of standardized survey

design and analysis methods across the national and international survey programs coordinated by the group. Annual review of this survey, in terms of design and results, will be incorporated into the work program of the group. Any aspects requiring additional expertise outside the capability of the group will be followed up using the established pathway to WGFAST.

Recommendation from WGTC

Challenges connected to wideband acoustics need to be solved.

During the discussion on new broadband technologies there were four presentations that discussed calibration and comparison of the EK60 and EK80 echosounders. Discussion on calibration highlighted the need for depth compensation and cross talk between frequencies. The potential for wideband technology for target classification is still to be realized under survey conditions. Once enough experience is gained, WGFAST will provide guidance.

5.2 Changes/ Edits/ Additions to ToR

Not required.

5.3 Cooperation with other WGs

On 3 April 2017, a joint meeting (JFTAB) took place with the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) in association with the WGFAST meeting in Nelson, New Zealand.

The Workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD) was created in response to Workshop on Scrutinisation Procedures for Pelagic Ecosystem Surveys (WKSCRUT). Seventeen representatives from seven countries participated in WKQUAD from 31 March to 2 April 2017 in Nelson, New Zealand. The participants addressed the terms of reference with focus on developing standard procedures and methods for identifying unsuitable survey conditions, proposing methods for dealing with degraded data, and comparing procedures and methods on selected datasets. The goal was 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 set general criteria that can be applied broadly, in relative terms. Their priority was 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. They did not address single-beam wide bandwidth, multibeam water column systems, or multibeam bathymetric systems, because they are not currently used for abundance estimates.

WKQUAD separated effects of inclement weather into two broad categories: complete signal loss (transmit and received signal is attenuated to level below the analysis threshold), aka “ping dropouts”; and signal degradation due to transducer motion, bubble attenuation, and noise. Their primary diagnostic was to monitor the areal backscatter from a layer that has consistent values over space and time, such as the seabed or the deep-scattering layer, and relate that to the proportion of ping “dropouts”, or if motion data are available, to pitch and roll measurements. Their secondary diagnostic was to monitor the level of surface bubbles and relate that to areal backscatter from a consistent layer or the seabed echo.

Using selected datasets, the results suggested vessel specific responses. Two datasets showed clear relationships of reduced seabed backscatter in response to increased

number of ping dropouts, suggesting degraded data quality, whereas other data suggested a more variable response. In some cases, clear recommendations for a specific vessel could be made, and in other cases, more data will be required to make recommendations. In general, pitch appears to have greater influence on data quality than does roll, and specifically, the rate of change of pitch. The reason for this is that the pitch motion allows greater bubbles under the hull than does roll.

WGFAST identifies that this work is important and **supports the creation of a Working Group to continue research on Collecting Quality Underwater Acoustic Data in Inclement Weather.**

5.4 Cooperation with Advisory structures

In 2016, WGFAST reviewed the acoustic metadata standard for the proposed ICES acoustic database design created by the ICES Data Centre.

5.5 Cooperation with other IGOs

In 2016, a member of WGFAST took part in the meeting of the ISO Underwater Acoustic subcommittee (ISO/TC 43/SC 3) for which ICES has a category A liaison. Progress was reported at the 2017 WGFAST meeting.

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 is currently developing protocols and automated methods to analyse acoustic data collected by krill fishing vessels during both fishing operations and directed surveys. If the Working Group Collecting Quality Underwater Acoustic Data in Inclement Weather is created there is likely to be a substantial benefit from close collaboration with SG-ASAM. WGFAST requested that its Members engaged in the work of SG-ASAM provide an update to WGFAST in 2018.

As noted in Section 5.1.4, WGFAST agreed to review the South Pacific Regional Fishery Management Organisation (SPRFMO) calibration protocol to assess its consistency with ICES CRR 326, and to provide advice on whether the SPRFMO protocol may also be useful for ICES members. This review will occur over the next year and will be discussed at the 2018 WGFAST meeting.

5.6 Science Highlights

EK60/EK80 Workshop USA-Norway EK80 Workshop.

The Simrad EK60 echosounder, long used for fisheries surveys, has been recently superseded by the EK80. To facilitate a transition to the EK80, an international Workshop was held in La Jolla, California, USA, 6–23 September 2016. This was attended by 18 participants from USA, Norway, France, and Australia. ICES Cooperative Research Report No. 336 outlying the results of this workshop has been published. Table 2.16 below is reproduced from this report.

Table 2.16. Differences in sphere-S_A (a) measured with GPT and processed with ER60 vs. measured with WBT and processed with EK80 (ER60–EK80), (b) measured with GPT and processed with EK80 vs. measured with WBT and processed with EK80 (EK80–EK80), and (c) measured with GPT and recorded with EK80 for p_{et} = 1000 W, else ER60, and processed with Echoview vs. measured with WBT and processed with Echoview (Echoview). Note that some differences (grey values) are anomalously large, resulting from too few single targets, noise, or both.

Frequency (kHz)	Transmit power (W)	Pulse duration (ms)	S_A difference (dB)		
			ER60–EK80	EK80–EK80	Echoview
38	1 000	0.512	-	0.00	0.04
		1.024	-	–0.08	–0.05
		2.048	-	0.78	0.80
	2 000	0.512	–0.13	0.02	–0.12
		1.024	–0.03	0.00	–0.01
		2.048	0.33	0.10	0.27
200	110	0.512	–0.04	–0.01	–0.02
		1.024	0.14	–0.01	0.16

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 2016. 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 of 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

Due to high demand, a second course is scheduled on 8–12 December 2017.

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 2016.

6 Revisions to the work plan and justification

Not required.

7 Next meetings

WGFAST proposes that its 2018 meeting will be in Seattle, USA at the School of Aquatic and Fishery Sciences (SAFS), University of Washington. The proposed meeting dates are 19–23 March 2018 for the WGFAST meeting, 17–18 March and/or 24–25 March for Topic Groups.

We have received an invitation from the Marine Institute, Ireland, to hold the 2019 WGFAST meeting in Galway Ireland on 22–26 April 2019.

Annex 1: List of participants

Participants in WGFAST meeting in Nelson, New Zealand, April 2017 (Photographer Matthias Schaber is missing from photo)

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Annex 2: Recommendations

Recommendation	Adressed to
1. Develop terms of reference for a joint session in 2020. We further 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 estimates of species and size distributions, which is a key source of uncertainty in acoustic-trawl 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 methods to estimate trawl selectivity. A subset of WGFTFB and WGFAST members and others from outside the group have expertise that is relevant in this area. WGFAST proposes Stéphane Gauthier (Canada) as co-chair of the joint session.	WGFTFB, WGIPS, WGBIFS, WGACEGG
2. WGFAST recommends an ASC session in 2018 to consider 'use of survey products in assessments'. A proposal will be developed by Verena Trenkel (France) and Richard O'Driscoll (New Zealand)	SCICOM
3. WGFAST recommends 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 April 4 2017	Session
8:45-9:00	House keeping	
9:00-9:20	WGFAST opening	
9:20-10:00	Introductions	
10:00-10:30	**COFFEE BREAK**	
10:30-10:50	Relations of mesopelagic fish to light ***Stein Kaartvedt, Anders Røstad, Dag L. Aksnes***	**Behaviour and Other** Chair: Hector Pena
10:50-11:10	Field observations of herring in the Celtic Sea ***Ciaran O'Donnell***	
11:10-11:30	Temporal and spatial dynamics of vendace (*Coregonus albula*) in the Bay of Bothnia ***Olavi Kaljuste, Zeynep Pekcan-Hekim, Mikaela Bergenius and Johan Lövgren***	
11:30-11:50	Discussion (including of relevant Behaviour issues from JFATB)	
11:50-12:10	Review and comparison of acoustic and bottom-trawl survey data for stock assessment of pelagic species ***Verena Trenkel***	
12:10-13:40	**LUNCH BREAK**	
13:40-14:00	Why we are here - update on WGFAST TORs ***Richard O'Driscoll***	**WGFAST business** Chair: Richard ODriscoll
14:00-14:10	Report from ICES ASC 2016 (session on Fisher collected acoustic data) ***Verena Trenkel***	
14:10-14:20	Training course on Introduction to abundance estimation from fisheries acoustic surveys ***John Horne, Paul Fernandes (presented by Richard O'Driscoll)***	
14:20-14:30	Training course on Principles and methods of broadband/wideband technologies: application to fisheries acoustics ***Gavin Macaulay, Dezhang Chu, Egil Ona***	
14:30-14:40	Update on ICES acoustic database and update of meta-data standard ***Tim Ryan***	
14:40-15:00	Update from ISO underwater acoustics sub-committee ***Gavin Macaulay***	
15:00-15:30	***TEA BREAK***	
15:30-15:50	Acoustic identification of marine species using a feature library from multifrequency or wideband echosounders ***Rolf J Korneliussen, Yngve Heggelund, Gavin J Macaulay, Daniel Patel, Espen Johnsen, Inge K. Eliassen***	**Acoustic properties of marine organisms** Chair: David Demer
15:50-16:10	Estimates of variability of goldband snapper target strength and biomass in three fishing region ***Sven Gastauer, Ben Scoulding, Miles Parsons***	
16:10-16:30	Variability of copepod and krill acoustic material properties associated with season and lipid composition ***Serdar Sakinan, Gareth L. Lawson, Peter H. Wiebe, Dezhang Chu***	
16:30-16:50	Target strength of in situ skipjack tuna (*Katsuwanus pelamis*) around fish aggregating devices ***Guillermo Boyra, Gala Moreno, Bea Sobradillo, Isabel Arjona, Igor Sancristobal, David Demer***	
16:50-17:10	Observations and modelling of the target strength of adult Atlantic mackerel ***Egil Ona, Gavin Macaulay, Rokas Kubilius Dezhang Chu***	
18:00-	**Topic Group on Defining a data format for omnidirectional fisheries sonars**	

	WEDNESDAY April 5 2017	Session
8:45-9:00	House keeping	
9:00-9:20	Ex-situ Target strength estimates of Antarctic krill ***Sven Gastauer, So Kawaguchi, Rob King, Martin J. Cox***	**Acoustic properties of marine organisms** Chair: David Demer
9:20-9:40	Discussion	
9:40-10:00	Incrementing data quality of acoustic ecograms with the Adpative Winner Filter (AWF) ***Marian Peña***	**Emerging technologies, methodologies and protocols** Chair: Gavin Macaulay
10:00-10:30	**COFFEE BREAK**	
10:30-10:50	Calibration of broadband sonars operating at depth ***Arti Verma, Alec Duncan, Rudy Kloser***	
10:50-11:10	2016 USA-Norway EK80 Workshop Report: Evaluation of a wideband echosounder for fisheries and marine ecosystem science ***David A. Demer, Korneliussen, R., Andersen, L. N., Bassett, C., Berger, L., Chu, D., Condiotty, J., Cutter Jr., G.R., Hutton, B., Le Bouffant, N., Macaulay, G., Michaels, W.L., Murfin, D., Pobitzer, A., Renfree, J.S., Sessions, T.S., Stierhoff, K.L., Thompson, C.H.***	
11:10-11:30	Updated comparisons of Simrad EK60 and EK80 echo integrals ***Gavin J Macaulay, Egil Ona, Sascha Fässler, Ben Scoulding***	
11:30-11:50	Report on the current situation of the EK80 introduced in RV KAIYO-MARU ***Koki Abe, Kouichi Sawada, Tomohito Imaizumi, Tomohiko Matuura, Kohei Hasegaw***	
11:50-12:10	EK80 discussion	
12:10-13:40	**LUNCH BREAK**	
13:40-14:00	Integrating on non-standard frequencies and the effects of quadrant dropout ***Joshua M Lawrence, Paul G Fernandes***	
14:00-14:20	Adapting a high-frequency multichannel acoustic backscatter instrument for observations from small moving platforms. ***Jan Buermans, David Lemon, Svein Vagle***	
14:20-14:40	Development of a new counting method of caged bluefin tuna using multi-transducer sonar and pinger ***Akira Hamano, Toyoki Sasakura, Noboru Sakakibara, Takaki Nomura, Takeshi Nakamura, Susumu Namari, Shunsuke Ito, Hideaki Tanoue***	
14:40-15:00	ESP3: an open source software for fisheries acoustic data processing ***Yoann Ladroit, Richard O'Driscoll Alexandre Schimel***	
15:00-15:30	***TEA BREAK***	
15:30-15:50	Using acoustic and optic methods in fish spatial distribution assessment ***Marcela Montserrat Landero Figueroa, Iain Parnum, Miles Parsons, Benjamin Saunders***	
15:50-16:30	Discussion	
18:00-	**Meet for transport to conference dinner at Seifried Estate Winery**	

	THURSDAY April 6 2016	Session
8:45-9:00	House keeping	
9:00-9:20	Spatio-temporal variability of two North Pacific fronts and their effects on micronekton using multifrequency acoustics ***Réka Domokos***	**Applications of acoustic methods to characterize ecosystems** Chair: Stephane Gauthier
9:20-9:40	The use of acoustics to characterize mid-trophic levels of the Southern Ocean pelagic ecosystem ***Pablo Escobar-Flores, Richard L. O'Driscoll, John Montgomery***	
9:40-10:00	Detection and characterization of deep-sea bentho-pelagic animals from an AUV-mounted MBES ***Toby Jarvis, Katherine M. Dunlop, Kelly J. Benoit-Bird, Chad M. Waluk, David W. Caress, Hans Thomas, Kenneth L. Smith Jr***	
10:00-10:30	**COFFEE BREAK**	
10:30-10:50	Concurrent active and passive acoustic observations of foraging mammals and mesopelagic prey layer ***Geir Pedersen, Espen Storheim, Lise Doksæter Sivle, Olav Rune Godø, Lars Alf Ødegaard***	
10:50-11:10	Basin scale bio-acoustic observing and change detection: from little things big things grow ***Ryan A. Downie, Rudy J. Kloser, Tim Ryan, Haris Kunnath, Amy Nau***	
11:10-11:30	The Role of Euphausiids in Atlantic Herring Consumption and Ecosystem Models of the Georges Bank/Gulf of Maine Region from 1999-2012 ***Michael Jech, G. Lawson, M. Lowe, S. Lucey, P. Fratantoni***	
11:30-11:50	Mobile Acoustic Surveys of Salmon-Smolt Predators and their River Habitat ***David A. Demer, George R. Cutter, Jr., Suzanne Manugian***	
11:50-12:10	Describing the spatial distribution of Antarctic krill ***Martin Cox, Gastauer S., Kawaguchi, S.***	
12:10-13:40	**LUNCH BREAK**	
13:40-14:00	Exploring the slope/offshore Great Australian Bight (GAB) pelagic habitat paradox ***Rudy Kloser***	
14:00-14:20	Habitat drivers of small pelagic fish in the Celtic Sea ***Jeroen van der Kooij, Peter Miller, Serena Wright, Elisa Capuzzo***	
14:20-15:00	Discussion	
15:00-15:30	**TEA BREAK**	
15:30-15:50	LSSS update ***Rolf Korneliussen***	
15:50-16:10	WGTC update ***Rolf Korneliussen***	**WGFAST** Chair: Richard ODriscoll
16:10-16:30	Report from Workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD) ***Mike Jech, Matthias Schaber***	
16:30-16:50	Report on topic group for defining data format for sonar ***Hector Pena***	
17:00-18:00	Simrad update session ***Lars Anderson***	

	FRIDAY April 7 2016	Session
8:45-9:00	House keeping	
9:00-9:20	Creation of topic group 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**	
10:30-11:50	***Discussion***	
11:50-12:10	***Meeting closure***	

Annex 4: Abstracts of Contributions

WGFAST 1. Behaviour and Other

Relations of mesopelagic fishes to light

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Mesopelagic scattering layers are ubiquitous in the worlds' oceans. Their components are poorly identified and biomass is uncertain since acoustic abundance estimates require knowledge of the backscatter from individual targets. Yet, mesopelagic fish likely prevail. The mesopelagic zone is defined both relative to depth (200–1000 m) and light level. This "twilight zone" is characterized with too little light for photosynthesis, but still enough light for organisms with very sensitive eyes to detect the downwelling irradiance. Mesopelagic organisms appear to have preference for a range of light intensities that typically span some orders of magnitude and responses to light are key elements in mesopelagic ecology. Diel vertical migration of organisms forming mesopelagic scattering layers is well documented, although include much variation. Light-related behaviour also occurs on additional temporal as well as geographic scales. Here we present data both from submerged, stationary echosounders and acoustic surveys in demonstrating light-related patterns at various temporal and geographic scales. We also show how the composition of mesopelagic scattering layers can be identified by taking advantage of their responses to light.

Field observations of herring in the Celtic Sea

Ciaran O'Donnell ciaran.odonnell@marine.ie

The Atlantic herring stock located to the south of Ireland in the Celtic Sea has two stock substock components classified by spawning period. The stock undertakes annual feeding/spawning/overwintering migrations. Feeding grounds are located offshore in the south Celtic Sea around the Celtic Deep and Labadie Bank area. Historically feeding grounds were primarily centred on the Labadie Bank area and to a lesser extent further east in the Celtic Deep. From 2010 onwards the pattern of distribution changed with a notable and persistent shift of the entire stock eastwards. Coupled with the eastward distribution was an observed change in aggregation behaviour at school level. Pre-2010 aggregations were often variable in size and number and could form anywhere around the wider feeding grounds with no defined temporal or spatial pattern. Post-2010 behaviour was characterized by a highly persistent hyper-aggregation containing almost the entire migratory stock in a defined and localized area. The study period of 2006–2015 covers the pre/post event using data from directed fishing effort (VMS), acoustic survey and hydrographic data. Survey and fishing effort focused on prespawning aggregations during the fourth quarter of the year. This study aims to investigate the causes of this defined and persistent change in the offshore distribution of herring at stock level. We investigate if this change can be linked to environmental drivers, feeding opportunity and changes in stock dynamics. Behavioural changes at stock and at aggregation level have implications for robust survey design and analysis methods for reliable stock abundance estimates.

Temporal and spatial dynamics of vendace (*Coregonus albula*) in the Bay of Bothnia

Olavi Kaljuste, Zeynep Pekcan-Hekim, Mikaela Bergenius and Johan Lövgren olavi.kaljuste@slu.se

Vendace (European cisco) is a small pelagic freshwater fish species that also occurs in the brackish waters of the Bothnian Bay in the northernmost Baltic Sea (Norrbotten Archipelago). Vendace fisheries is one of the most economically important coastal fisheries in Sweden. Vendace is mainly caught for its roe using bottom trawls. Hydroacoustic surveys were initiated in 2009 in order to collect fishery-independent data to complement the stock assessment of vendace. Due to the complex migratory behavior of vendace in both space and time (compared with vendace behaviour in lakes) and difficulty of finding an appropriate survey platform within the budget, deciding on the most appropriate time to conduct the survey has proved to be challenging. Vertical and horizontal distribution of vendace varies remarkably during the year due to changes in water temperature, diel conditions and life history, and this makes it difficult to detect the fish with hydroacoustics. The timing of the survey has varied from year-to-year in order to find the optimum season for estimating the size of the vendace stock and this has provided us important knowledge of vendace behaviour.

Review and comparison of acoustic and bottom–trawl survey data for stock assessment of pelagic species

Verena Trenkel verena.trenkel@ifremer.fr

The question whether data from bottom-trawl surveys is informative for population changes of pelagic species comes up recurrently. In this presentation I will review the type of data used for stock assessment of pelagic species and compare time-trends of acoustic and trawl data derived biomass estimates for a range of small pelagic species in several ecosystems.

WGFAST 2. Acoustic properties of marine organisms

Acoustic identification of marine species using a feature library from multifrequency or wideband echosounders

Rolf J Korneliussen, Yngve Heggelund, Gavin J Macaulay, Daniel Patel, Espen Johnsen, Inge K. Eliassen rolf.korneliussen@imr.no

Sonars and echosounders are widely used for remote sensing of life in the marine environment. There is an ongoing need to make the acoustic identification of marine species more correct and objective and thereby reduce the uncertainty of acoustic abundance estimates. In our work, data from multifrequency or wideband echosounders working simultaneously with nearly identical and overlapping acoustic beams are processed stepwise in a modular sequence to improve data, detect schools and categorize acoustic targets by means of the Large Scale Survey System software (LSSS). Categorization is based on the use of an acoustic feature library whose main components are the relative frequency responses. The results of the categorization are translated into acoustic abundance of species. The method is tested on acoustic data from the Barents Sea, the Norwegian Sea and the North Sea, where the target species were capelin (*Mallotus villosus* L.), Atlantic mackerel (*Scomber scombrus* L.) and sandeel (*Ammodytes marinus* L.), respectively. Manual categorization showed a high conformity with automatic categorization for all surveys, especially for schools.

Estimates of variability of goldband snapper target strength and biomass in three fishing region

Sven Gastauer, Ben Scoulding, Miles Parsons sven.gastauer@utas.edu.au

Goldband snapper (*Pristipomoides multidens*) is an ecologically and economically important species in the Northern Demersal Scalefish Fishery (NDSF). The Carolina M, a

trap fishing vessel operating in the NDSF, was equipped with Simrad ES70 echosounders, operated at 38 and 120 kHz. In 2014, acoustic data, in combination with optical recordings of the catch, were opportunistically collected during routine operations. In December 2014, pure, low density goldband snapper schools were observed on the echograms. In situ target strength (TS) estimates were derived and linked to length distributions of catch information, using a curve fitting method. Three fishing grounds, where near simultaneously recorded acoustic and optical information was available were selected. Fish school densities observed within the 38 kHz acoustic data, were disaggregated according to catch proportions using kriging. Density estimates were derived. Sampling variance was estimated using geostatistics (coefficient of variance, CV) and other errors, namely signal-to-noise ratio, variation in the acoustic signal due to fluctuations in temperature and salinity, effects of diurnal vertical migration, variability of catch information and influence of tilt angle on TS were considered.

Variability in copepod and krill acoustic material properties associated with season and lipid composition

Serdar Sakinan, Gareth L. Lawson, Peter H. Wiebe, Dezhang Chu ssakinan@whoi.edu

The acoustic material properties of an organism, notably its density and sound speed contrasts relative to the surrounding seawater, are key parameters influencing target strength. These parameters may change depending on the season and life history of the animals due to changes in their biochemical composition. We examined the variability in the material properties of zooplankton associated with season and lipid content. The density and sound speed of live individuals of the euphausiid *Meganyctiphanes norvegica* and the copepod *Calanus finmarchicus* were measured in the laboratory in fall 2016 and spring 2017 to assess seasonal variability. Sampling was timed to target different points in *C. finmarchicus* life history and associated different depths in their ontogenetic migration. Additionally, the speed of sound in lipid extracts from *C. finmarchicus* and *Euphausia superba* were measured to assess temperature- and pressure-related effects mediated by changes in lipid molecular arrangement. The sound speed measurements were done from -2°C to 17°C and from 0 bar to 1000 dbar. Density was measured at atmospheric pressure within this same temperature range and pressure dependent density change was inferred from sound speed measurements. Density contrast variation in copepod lipids relative to temperature and pressure was small (0.870–0.897) while sound speed contrast ranged more widely (0.963–1.135), due to the opposing effects of temperature and pressure on the compressibility of lipids relative to seawater. The observed variability of these material property measurements will be discussed in light of DWBA-based model predictions of copepod and krill target strength.

Target strength of in situ skipjack tuna (*Katsuwanus pelamis*) around fish aggregating devices

Guillermo Boyra, Gala Moreno, Bea Sobradillo, Isabel Arjona, Igor Sancristobal, David Demer gboyra@azti.es

This work presents target-strength (TS) measurements and a TS-length relationship of in situ skipjack tuna around Fish Aggregating Devices (FADs) in the Central Pacific Ocean. TS were measured at night, before and during fishing operations with a split-beam echosounder on the purse-seiner workboat at three frequencies (38, 120, and 200 kHz) and using two methods: the classic single targets method and the comparison method. For the single targets approach, a variant of the method developed by Demer *et al.* (1999) and improved by Conti *et al.* (2005) was used to filter echoes from unre-

solved targets, thus reducing the bias in the TS measurements. These TS data and concomitantly sampled skipjack lengths (L; cm) were fit to TS = 20log(L) + b20, using the method of least squares. As the purse-seiners frequently catch the whole aggregation in each FAD, we were able to produce alternative TS and b20 values, by comparison of the acoustic estimates (based on echo-integration and sonar dimensioning) and the actual catches. Different simulations were run based on X-rays images of this non-swimbladdered species (considering only the flesh and both flesh and backbone) to try to interpret the obtained TS results.

Observations and modelling of the target strength of adult Atlantic mackerel

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Target strengths in both dorsal and lateral aspects are needed for more precisely converting acoustic data from echosounder and sonar on singular school biomass and on averaged backscattering data over larger volumes. Direct target-strength measurements from dorsal and lateral aspects of adult Atlantic mackerel have been made by using a special, mechanically tiltable 200 kHz, high-resolution broadband transducer mounted on the surveying vessel and by using broadband standard transducers carefully lowered into mackerel schools and layers, observing the fish at close range. The measured target strength of mackerel is further compared with a frequency dependent analytical backscattering model that characterizes the scattering contributions from fish flesh and backbone at lower and higher frequency regions, respectively.

Ex-situ Target strength estimates of Antarctic krill

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Antarctic krill is a key species in the Antarctic ecosystem. Having a thorough understanding of its acoustic backscattering properties, and the variability of the latter, is a crucial step in the process of any acoustic biomass or abundance estimates. With the emergence of broadband echosounders, new insights into the target strength of krill can be gained. In order to work towards a better understanding of the influence of krill behaviour on TS, target strength estimates of tethered and free swimming krill were conducted within a tank setup, kept at temperatures around 0.5. The downwards-looking EK80 operated around 120 kHz with a 7 beam width, was mounted on top of the 3 m deep tank. Fishing reels were mounted around the tank at 120 angles, to allow for simple application of trigonometry in situations where angular positioning of targets in the beam is desirable, to be used in conjunction with optical recordings. Krill were obtained from a recent Antarctic voyage on board Aurora Australis and kept within the aquarium facilities of the AAD. Thorough calibration experiments were conducted prior to the experiments, including passive recordings of ambient noise, checks for reverberation and non-linearity at different power, pulse duration and ping rate settings.

WGFAST 3. Emerging technologies, methodologies, and protocols

Incrementing data quality of acoustic ecograms with the Adpative Winner Filter (AWF)

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Achieving acceptable signal-to-noise ratio (SNR) can be difficult when working in sparsely populated waters and/or when species have low scattering such as fluid filled animals. The increasing use of higher frequencies and the study of greater depths in fisheries acoustics, as well as the use of commercial vessels, is raising the need to employ good denoising algorithms. The use of a lower Sv threshold increases the relative background noise component in the echogram, demanding more effectiveness from

denoising algorithms. The Adaptive Wiener Filter (AWF) denoising algorithm is presented in this study. The technique is based on the AWF commonly used in digital photography and video enhancement. The algorithm first increments the quality of the data with a variance-dependent smoothing, before estimating the noise level as the envelope of the Sv minima. The AWF denoising algorithm outperforms existing algorithms in the presence of gaussian, speckle and salt and pepper noise, although impulse noise needs to be previously removed. Cleaned echograms present homogenous echotraces with outlined edges.

Calibration of broadband sonars operating at depth

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A key need for the pelagic component of the Great Australian Bight Research Program (GABRP) is the classification and biomass estimation of the zooplankton and micronekton communities. To achieve this a range of tools including optical, nets and acoustics are being used with broadband acoustics providing potential new insights. Prior to using quantitative broadband techniques requires an insight into the limitations of broadband systems and the effects these have on the precision and accuracy of results. Two sources of error are the variability of acoustic backscattering due to the target location within the acoustic beam and the variability due to environmental parameters including operating depth. Together these factors can have a significant effect on instrument performance, particularly in the case of sonars fitted to profiling systems. In this paper, these error sources are analysed, and results are presented to demonstrate their impact on measured data. After calibration, the variability of the Target Strength was within ±0.5 dB for off angles corresponding to the highest frequency. The depth induced variation was as low as 0.05 dB at depth of 600 m. The analysis would help improve current classification and biomass estimates providing inputs for marine ecosystem models. This study is being undertaken as part of the Great Australian Bight Research Program, a collaboration between BP, CSIRO, the South Australian Research and Development Institute (SARDI), the University of Adelaide, and Flinders University.

2016 USA–Norway EK80 Workshop Report: Evaluation of a wideband echosounder for fisheries and marine ecosystem science

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The Simrad EK60 echosounder has been recently superseded by EK80. To facilitate a transition for fisheries surveys, an international EK80 Workshop was held in La Jolla, California, USA, 6–23 September 2016. Results showed that similarly configured EK80 and EK60 provided equivalent 'narrowband' measures of echoes from spheres in a tank. EK80 can also transmit 'wideband' pulses and apply matched-filter processing to potentially improve range resolution, signal-to-noise ratio, and target identification. However, participants identified some limitations and recommended that Simrad allow: 1) frequency-dependent logging ranges; 2) faster and programmable alternation between narrowband and wideband, and active and passive modes; 3) more user control over transmit signals and processing parameters; and 4) collection of passive data prior to transmit pulses. Due to the potential and complexity of EK80, additional workshops are needed to develop standard operating procedures for calibration, target

strength estimation, echo classification, marine resource surveys, and ecosystem investigations.

Updated comparisons of Simrad EK60 and EK80 echo integrals

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Changing the equipment that contributes to a time-series of fish stock estimates requires a high level of caution and careful comparison to ensure that minimal unaccounted bias is introduced into the time-series. Acoustic backscatter surveys are currently undergoing such a change, with the move from Simrad EK60 to Simrad EK80 echosounders. We present a comparison of echo integrals from multiplexed EK60 and EK80 echosounders at several frequencies, backscatter densities, and geographical areas, calculated using two analysis programs. This updates a similar presentation at the 2016 ICES WGFAST meeting which showed large differences in the echo integrals. Work since then has identified several errors, misunderstandings, and complications that caused the 2016 presentation results to be incorrect. Differences in integrals between the two echosounders are now minor. This gives high confidence that moving from EK60 to EK80 echosounders will not affect survey results.

Report on the current situation of the EK80 introduced in RV KAIYO-MARU

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Last summer, a broadband type echosounder EK80 was introduced at RV KAIYO-MARU of the Fisheries Agency. In the process of conducting the test operation, a phenomenon which seemed to be mutual interference among the respective frequencies was recognized. Since this is a phenomenon affecting the echo integration results, it is suspected that the result of resource estimation by EK80 can be handled in the same way as a narrowband type echosounder so far. The ramping setting was slightly changed on the processing software, so the phenomenon weakened, but it has not completely disappeared.

Integrating on non-standard frequencies and the effects of quadrant dropout

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Biomass estimates from fisheries acoustic surveys are universally calculated from the integration of acoustic backscatter at a single frequency (e.g. North Sea herring biomass is estimated from 38 kHz data only). Technical problems can occur however, which might make this problematic or impossible (e.g. a dropped quadrant on the 38 kHz transducer). In such cases, integrating on a different frequency provides a solution, ensuring the cost of the survey is not wasted. Here, using data from a survey where all tranducers were functioning correctly, the efficacy of using mean volume backscattering strength values from confirmed herring schools to calculate adjusted TS-length relationships for density estimation was investigated. The values obtained were compared with those obtained through minimizing the difference in density estimates from integrated values for many schools combined. Then, data from a survey using a 38 kHz transducer with a dropped quadrant alongside fully functional 120 and 200 kHz tranducers were analysed so the biomass estimate from the faulty 38 kHz tranducer's data could be compared to those from the fully functional tranducers to examine the effect the dropped quadrant might have on survey estimates.

Values for TS-length relationships at 120- and 200-kHz obtained through minimizing the difference in estimated density across multiple schools produced results which

were significantly more consistent with the standard 38 kHz method's results than using the average mean volume backscattering strength from individual schools.

Adapting a high-frequency multichannel acoustic backscatter instrument for observations from small moving platforms.

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The ASL Acoustic Zooplankton and Fish Profiler (AZFP), originally developed in the late 1990's for autonomous moored observations of zooplankton and fish, has successfully been modified to observe zooplankton and fish in time and space from small moving vessels, autonomous gliders and from rosette sampling casts. For small boat operation, the instrument operating software and firmware have been expanded to include real-time scrolling echograms for up to 4 frequencies to be displayed as data are collected along-transects. With the transducers mounted at a depth of 0.5 m on a strut over the side, it is possible to travel at speeds up to 2 m/s without flow interference; with a suitable fairing it is likely that higher boat speeds can be achieved without compromising the data quality. An example is shown of results from a small study in which the multifrequency aspects of the acoustical AZFP backscatter data are used to interpret fish and zooplankton dynamics. The AZFP has also been adapted to operate from an autonomous glider. A single frequency 200 kHz instrument has been installed in a Slocum glider, with the transducer installed in the glider's standard "ECOPuck" housing. The glider controls the operation of the echosounder and its configuration can be changed on-the-fly. Examples of data collected during a 14-day mission will be shown. A deep water (6000 m) version of the AZFP has also been developed which can be deployed on deep casts from oceanographic vessels as a tool to study deep-water zooplankton and micronekton.

Development of a new counting method of caged bluefin tuna using multi-transducer sonar and pinger

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For the Bluefin tuna farmer in Japan, to determine the number of farmed fish is one of the key issues to monitor the number of fish in addition to feed waste, escapement, behaviour, and dead fish. However, there currently exists no reliable method to count the number of Bluefin tuna in a cage. The most popular type of counter is currently the underwater stereoscopic camera system which has mainly been used by a diver for counting. However, this kind of counting method is not only labor-intensive, but its accuracy is low in dark or turbid water. The purpose of this study is to develop an accurate counting method for the farmed Bluefin tuna using the multi-transducer sonar and pinger. This new counting system is based on estimating the individual fish that has passed through the so-called "the sound curtain" consisting of 15 transducers (460 kHz). In addition, a pinger was used to clarify the behaviour and swimming speed of the caged fish. As a result, it was found that all of the fish regularly swim in a concentric circle in the cage space, and the lap time of one round at the distance from cage center was estimated by a linear equation. The total number of fish could then be calculated by multiplying this lap time and number of fish that have passed through "the sound curtain" per unit time. It was considered that this approach is effective for counting caged Bluefin tuna with the objective of practical use.

ESP3: an open source software for fisheries acoustic data processing

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ESP3 is a simple software designed to analyse and process acoustic data efficiently that will be distributed under MIT licence. It has been coded in object-oriented Matlab and is available both as a stand-alone application for windows 64 bits platform or as a Matlab "toolbox". The software is focusing mainly on the analysis and echo integration of acoustic surveys via the use of a simple scripting module built around the use of databases to keep track of versions and metadata. As of today, it reads a limited number of data formats: Simrad .raw, Furuno FCV30, and ASL data. It also has a build-in calibration module for single frequency or broadband allowing you to reprocess your calibrations easily. A number of algorithms have been included allowing the user to automatize bottom detection, bad transmits analysis, single target detection and tracking, background noise removal as well school detection and classification (based on user-defined classification tree). Overall, the software provides a controlled environment to create a standardized analysis for recurring surveys.

Using acoustic and optic methods in fish spatial distribution assessment

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The use of concurrent data from acoustic and optics observation methods to evaluate the distribution and abundance of fish combines the advantages of each technique to mitigate some of their limitations. If there are sufficient data points, for example, the visual data can help identify the species composition of a school, which is often non-trivial to attain with acoustic methods alone. The non-extractive and non-invasive characteristics of these techniques are useful, particularly in conservation areas, such as marine parks. The objective of this study was to compare the spatial distribution of fish using acoustic and optic methods over two different benthic habitats in Cockburn Sound, Western Australia. Acoustic data were collected using a single-beam echosounder at three frequencies 38, 120, and 430 kHz. Optical data were collected using stereo baited remote underwater video (stereo-BRUVs), deployed at ten different sampling points within the same region. Relative biomass per species was estimated using the stereo-BRUVs data for each point of deployment. The differences between backscatter in the 38 and 120 kHz frequencies were used to discriminate between fish and gelatinous organisms. Schools and single-targets were extracted and the target strength of the species representing the largest proportion of biomass, according to the stereo-BRUVs data were used as a preliminary way to convert the backscatter energy into relative biomass. Correlations between the relative biomass estimated with both methods were explored.

WGFAST 4. Applications of acoustic methods to characterize ecosystems

Spatio-temporal variability of two North Pacific fronts and their effects on micronekton using multifrequency acoustics

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Two fronts dominate the frontal zone where the cool, productive Subarctic Gyre waters sink below the warm, oligotrophic Subtropical Gyre waters: the physical Subtropical Front (STF) and the biological Transition Zone Chlorophyll Front (TZCF). This region aggregates economically important top predators and protected species by providing migratory routes and foraging grounds, although the biomass and distribution of their prey, predominantly micronekton, is not well understood. In this study, active multifrequency acoustics aided by limited trawl samples were used along with in situ and satellite oceanographic data from 2009, 2011, and 2015 spring to study the variability

of these fronts and their effects on micronekton. Results of this work indicate that in general, the position of TZCF was north of the STF by .1°-4° at the study site (along 158°W) and exhibited spatial variability on scales from a few days to several years. In contrast, the position of the STF seemed to vary less and on a larger spatial scale, which corresponded to large-scale SST anomalies associated with the 2011 La Niña and the 2015 El Niño events. Changes in micronekton MVBS, NASC, and δSv were strongly associated with the position of the STF, with the position of the TZCF playing a weaker role. Interannual variability of overall survey area MVBS/NASC were associated with changes in SSTA, eddy activity, mixed layer depth, and subsurface chlorophyll maxima, all seemingly the effects of mesoscale variability superimposed on atmospheric and oceanic changes associated with La Niña and El Niño events.

The use of acoustics to characterize mid–trophic levels of the Southern Ocean pelagic ecosystem

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Mid-trophic level (MTL) organisms play a key role in pelagic open-ocean marine ecosystems linking primary and tertiary consumers. Despite their importance, our knowledge of MTL organisms is still very limited. A unique 7-year time-series of acoustic data were used study and characterize the MTL of the pelagic open-ocean marine ecosystem in the New Zealand (NZ) sector of the Southern Ocean (SO). Acoustic backscatter (sa) at 38 kHz varied between years, but overall was reasonably stable. Vertical distribution showed diel vertical migration patterns, and seasonal differences in concentration and behaviour. Large-scale horizontal distribution patterns showed consistent and significant decrease from north to south. Catch information and available literature on species-specific target strength-length relationships used to convert sa into biological density, suggested that changes in backscatter with latitude reflected different species' composition, rather than changes in biological density. Deep scattering layers (DSL) detected in acoustic transects stopped north of the Ross Sea, which may be related to the temperature tolerance of DSL organisms. Explanatory and predictive model for sa, a proxy for MTL organisms, were developed for the epi- and mesopelagic zones. Models were tested in the NZ sector of the SO and also in an independent dataset in the Indian Ocean sector of the SO, and performed well. The findings establish an excellent baseline for detecting and monitoring future changes in the SO ecosystem and its MTL component. Predictive models provide a tool for inferring abundance and distribution of MTL in the NZ sector and other parts of the SO.

Detection and characterization of deep–sea bentho–pelagic animals from an AUV–mounted MBES

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Multibeam echosounders (MBES) deployed on autonomous underwater vehicles (AUVs) represent a promising technology for monitoring deep-sea bentho-pelagic animals at relatively high spatial and temporal resolution. However, application of this remote-sensing technology to the study of small (relative to the sampling resolution), dispersed and mobile animals at depth does not come without significant challenges with respect to data collection, data processing and vessel avoidance. As a proof of concept, we used data from a downwards-looking RESON SeaBat 7125 MBES mounted on a Dorado-class AUV to detect and characterize the location and movement of backscattering targets (which were likely to have been individual fish or squid) within 50 m of the seafloor at ~800 m depth in Monterey Bay, California. The large volume

and complexity of the data presented a computational challenge, while noise and reverberation in the data coupled with a marginal sampling resolution relative to the size of the targets caused difficulties for reliable and comprehensive target detection.

Nevertheless, the results demonstrate that an AUV-mounted MBES has the potential to provide unique and detailed information on the in situ abundance, distribution, size and behaviour of deep-sea bentho-pelagic animals. We provide detailed data-processing information for those interested in working with MBES water column data, and a critical appraisal of the data in the context of aquatic ecosystem research.

Concurrent active and passive acoustic observations of foraging mammals and mesopelagic prey layer

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Using echosounder and hydrophone data from the Lofoten-Vesterålen Cabled Ocean Observatory (LoVe, N 68°54.474', E 15 °23.145', 258 m depth) collected in 2015, we concurrently quantify the behaviour of both the mesopelagic prey layer and shallow foraging sperm whales (*Physeter macrocephalus*). The echosounder monitored the distribution and vertical and horizontal movement of the prey organisms, while click rate and type was monitored by the hydrophone. In one instance, a diving sperm whale was also detected by the echosounder allowing TS measurements and estimation of diving speed and angle. Additional data includes ocean current speed and direction, and information on the proximity of vessels. Combined with vessel noise measurements, this further allowed us to examine potential links between oceanographic conditions and noise on sperm whale behaviour and foraging, in addition to the presence of prey and predator. The results demonstrate the additional information obtained by combining data from active and passive acoustic sensors. The first part of the LoVe cross-disciplinary ocean observatory was established in 2013, and the extension is planned for 2018 covering the Norwegian shelf to approximately 2500 m depth. This will further expand the observatories capabilities for underwater acoustic monitoring and targeted scientific studies.

Basin scale bio–acoustic observing and change detection: from little things big things grow

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Australia's Bio-Acoustic Ships of Opportunity Program (BA-SOOP) started in 2010 as part of Australia's Integrated Marine Observing System (IMOS). Australia's contribution to Global Ocean Observing initiatives. The BA-SOOP delivers quality controlled bioacoustic mean volume backscatter data in 10 m depth bins (to 1200 m depth) every 1 km that relate to mid-trophic micronekton at mesoscales (10's km). These data can be used to inform of basin scale micronekton distribution in space and time and to parameterize mid-trophic components of ecosystem models. Through active collaborations with Australia and New Zealand's commercial fishing companies and research institutes the program has published 300 786 km of basin scale acoustic data from the Pacific, Indian, Southern and Atlantic oceans, from 17 vessels over a 6-year period. Data are acquired using predefine settings, collaborators not only collect data voluntarily but also contribute vessel time to calibrate vessels annually. This presentation provides an overview of a basin scale observing program that has been operating for 6 years, informing of the importance of calibration, collaborator communication and the type of qualitative and quantitative metrics that can be obtained from the data to inform on

ecosystem structure and change. Data from the southern Indian Ocean is used to highlight the issues associated with defining change over time to assess broad ecological change.

The Role of Euphausiids in Atlantic Herring Consumption and Ecosystem Models of the Georges Bank/Gulf of Maine Region from 1999–2012

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Euphausiids are a key link between primary production and higher-level trophic levels in the Gulf of Maine, but are not monitored well. Estimates of euphausiid biomass in the Georges Bank region of the Gulf of Maine were derived from annual acoustic/mid-water trawl surveys from 1999 through 2012. Acoustic data were collected with Simrad EK500 and EK60 echosounders operating at 18, 38, and 120 kHz, and euphausiids classified using a combination of empirically and theoretically based methods. Distorted-Wave Born Approximation (DWBA) scattering predictions of euphausiid target strength and biological metrics were used to scale acoustic data to biomass. We highlight approaches to incorporate DWBA predictions in classification algorithms, with emphasis on the z-score method. Biomass estimates were compared among classification methods and to depth-stratified quantitative net samples to evaluate whether the acoustically-derived biomass estimates were commensurate with historical estimates. We use updated biomass estimates to improve mass balance ecosystem models in a two-step process. First, krill biomass estimates are compared to gut evacuation rate model outputs for herring to examine the potential impact of consumptive removal of krill biomass by herring. Second, euphausiid consumption is used to inform ecosystems models and assess the importance of krill in the ecosystem and their trophic significance. This information fills critical knowledge gaps in our understanding of Gulf of Maine foodwebs.

Mobile Acoustic Surveys of Salmon–Smolt Predators and their River Habitat

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The major source of salmon-smolt mortality in the San Joaquin River (SJR), near Stockton, California, is thought to be predation by non-native fish. To survey these predators and their riverbed habitats, one or two multibeam sonars (500 kHz Simrad M3), one down-looking sonar (200 kHz Simrad ES15 or EK60), and one side- or forward-looking sonar (120 kHz Simrad EK60) were deployed from a small boat. Surveys of the SRJ, between Port of Stockton and Lathrop, were conducted between March and May 2014 and 2015. The multibeam sonar data were used to measure bathymetry, track fish, classify riverbed, and map submerged aquatic vegetation. The echosounder data were used to detect, track, and enumerate fish beneath, to the side, and in front of the boat. All of the acoustic data were geolocated using differential GPS positioning, and the bathymetry was compensated for pitch, roll, heave, and tide. Bathymetry data were used to constrain echosounder detections of fish. Models of frequency-specific backscatter vs. fish length were used to refine the fish detections and estimations of their numbers and sizes. Counts of fish per sampled volume were estimated from fish tracks, and converted to densities by compensating for the integrated sampled volumes of the acoustic beams weighted by detection probability. Data indicate temporal and spatial trends of predator densities and elucidate areas where predators and smolt may interact.

Describing the spatial distribution of Antarctic krill

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Results derived from acoustic surveys of Antarctic krill (*Euphausia superba*) are used as key inputs into management models which are, in turn, used to set fishery quotas. In addition, spatial analysis approaches allow us to move beyond point estimates of krill density, and examine krill spatial distribution that can provide insights into the drivers of krill predator behaviour and performance. Whereas much work has been carried out deriving krill survey error budgets, much remains unknown about the sensitivity of patchiness – a key parameter describing spatial distribution. It is postulated that smaller krill are found on-shelf and larger krill out to sea. Here, using conditional geostatistical simulations, we examine the influence of spatial segregated krill length frequency distributions on krill patchiness and density estimates. We base our simulations on data collected during a ship-based survey of krill conducted in 2016 variety of length–frequency distribution scenarios.

Exploring the slope/offshore Great Australian Bight (GAB) pelagic habitat paradox

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The central offshore/slope Great Australian Bight (GAB) is a pelagic habitat paradox with apparent high micronekton (small fish, crustaceans, squid and gelatinous organisms) biomass in a predicted low productivity region. To investigate this apparent paradox we undertook a voyage on the RV Investigator in December 2015 to understand the microbial, plankton and micronekton communities over the slope and deep-ocean and explore the fundamental knowledge gaps between the two regions. New observing tools were used to elucidate fine scale ocean mixing and production as well as describe the micronekton including gelatinous community with a new profiling acoustic and optical probe to 1000 m. We provide an overview of the bioacoustics and net capture component of the voyage placed in context with historical biological sampling focused on a program of bioacoustics and a continuous plankton recorder for broad scale spatial and temporal context. We outline the key bioacoustic findings and the remaining uncertainties and how this could affect the distribution and abundance of key species. This work was undertaken through the Great Australian Bight Research Program - a collaboration between BP, CSIRO, the South Australian Research and Development Institute (SARDI), the University of Adelaide, and Flinders University. The Program aims to provide a whole-of-system understanding of the environmental, economic and social values of the region; providing an information source for all to use.

Habitat drivers of small pelagic fish in the Celtic Sea

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Small pelagic fish (SPF) play a key role in shelf sea foodwebs, channelling energy from primary producers to top predators. Most SPF are short-lived and have lots of offspring. Ecological drivers are therefore thought to have a relatively direct effect on SPF, and changes in the physical oceanography may manifest itself in abrupt changes in abundance and distribution. The waters of the eastern Celtic Sea and western English Channel are home to a rich diversity of SPF, including sprat, sardine, mackerel and herring, and in recent years, other species have emerged, such as anchovy. This diversity can in part be attributed to the fact that the area represents a transition from the warmer Lusitanian waters in the south to the cooler boreal waters to the north, and distribution of species associated with both regimes overlap here. In this study we combine data collected during an integrated pelagic survey series with remote sensing products, to examine the different environmental drivers of these SPF. As part of this, focus is also on mesoscale features such as frontal zones. Frontal zones are generally

perceived to be ecologically important for large mobile marine vertebrates. In the study area, several piscivorous predators have been associated with these features, and this has generally been attributed to foraging and migration behaviour. However, there have been very few studies linking the SPF prey to frontal systems. The results contribute to a better understanding of some of the processes and interactions of the marine ecosystem in the southwest of the UK.