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6–9 May 2014

New Bedford, Massachusetts, USA



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International Council for
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Contents

Executive summary	1
1 Opening of the meeting.....	2
2 Adoption of the agenda.....	2
3 TOR a: List of papers originating in the community of the WGFASST Working Group 2013–2014	4
4 TOR b: Applications of acoustic methods to characterize ecosystem.....	5
4.1 Contributions to the session	5
4.2 Summary of session.....	10
5 TOR b: Acoustic properties of marine organisms	12
5.1 Contributions to the session	12
5.2 Summary of session.....	15
6 TOR b: Emerging technologies, methodologies, and protocols.....	17
6.1 Contributions to the session	17
6.2 Summary of session.....	24
7 TOR b: Biomass estimation: Best practice and guidance	25
7.1 Contributions to session	25
7.2 Summary of session.....	29
8 TOR d: Organize international acoustic symposium.....	30
9 TOR e: Organize joint sessions at ICES ASC	31
10 Reports and updates from associated groups and miscellaneous issues	31
10.1 Update from SSGIEOM.....	31
10.2 Study Group on Calibration of Acoustic Equipment (SGCAL)	32
10.3 Topic Group on metadata standards	32
10.4 Working group on acoustic multi- frequency target classification (WGTC)	32
10.5 Workshop on fishing vessels as scientific platforms	33
10.6 Miscellaneous issues	33
Annex 1: List of participants.....	34
Annex 2: Agenda.....	37
Annex 3: Group photo	39
Annex 4: WGFASST multi-annual terms of reference (TORs) for the period 2014–2016	40

Executive summary

The Working Group on Fisheries Acoustics, Science and Technology (WGFASST) met in New Bedford, Massachusetts, USA, from 6–9 May 2014. Verena Trenkel (France) served as Chair and Stephane Gauthier (Canada) as rapporteur. There were 66 participants from 14 countries who contributed to the four terms of reference with 49 presentations of new and exciting research in a diversity of subjects related to fisheries acoustics as well as reports from the topic group on Metadata standards, the study group on Calibration of acoustic equipment, the newly formed Working Group on Acoustic Target Classification (WGTC), and other initiatives.

Highlights

- The major themes addressed during the meeting included:
- Applications of acoustic methods to characterize ecosystems
- Acoustic properties of marine organisms
- Emerging technologies, methodologies, and protocols (special topic: Biomass estimation: Best practice and guidance)

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 exemplified the broad range of ecosystem-related problems to which acoustic methods are currently being applied within the wider ICES community. A recurrent theme was the importance, and often difficulty, of effective ground-truthing. A great deal of interest currently surrounds work on mesopelagic fish, which are challenging to work with due to their variable acoustic properties. Multiple examples illustrated that acoustic surveys are well positioned to provide indices for Integrated Ecosystem Assessment (e.g. zooplankton and euphausiid abundance indices). With regard to acoustic properties, the contributions illustrated the range of activities that are being carried out, especially now that multifrequency discrimination of species is becoming standard practice. The development of wideband acoustic systems is rapidly advancing, as is the integration of acoustic systems into new technologies (e.g. gliders), and the development of calibration methods for existing and new acoustic systems. Acoustic technologies are applied at both large and small temporal and spatial scales to biological and non-biological questions. From the presentations and discussions it emerged that scientists using acoustics for biomass estimation have invested much thought and effort into identifying and estimating sources of uncertainty and into reducing these uncertainties when possible, e.g. by improving TS equations, ground-truthing using optics, analysing vertical distributions and diel variations, carrying out simulations, etc. Paradoxically however, these efforts to understand and quantify sources of uncertainty can lead users to erroneously conclude that acoustic biomass estimates are too unreliable to be useful, compared with, for example, commercial landings data or bottom-trawl survey abundance indices for which bias and uncertainties caused by spatio-temporal variations in catchability, gear performance, species behaviour, etc. remain largely unexplored and therefore are commonly ignored.

1 Opening of the meeting

Verena Trenkel (Ifremer, France), WGFAST chair, opened the meeting, and welcomed the working group members to New Bedford. She thanked the host Mike Jech for his hospitality and for organising the meeting.

The chair Verena Trenkel introduced the structure of the working group and the terms of reference. Study groups and other initiatives will be reporting on progress. Stephane Gauthier (DFO, Canada) was appointed as rapporteur for the meeting.

2 Adoption of the agenda

The Working Group on **Fisheries Acoustics, Science and Technology** (WGFAST), chaired by Verena Trenkel, France, will meet in New Bedford, USA, May 5–9 2014, to work on ToRs and generate deliverables as listed in the Table below.

WGFAST will report on the activities of 2014 (year 1) by 30 June 2014 to SSGESST.

ToR descriptors

ToR	Description	Background	Duration	Expected deliverables
a	Produce a list of papers originating in the community of the WGFAST working group	The WGFAST community produces several papers every year, and an update on recent WGFAST activities that acknowledges ICES is important.	Year 1, 2 and 3	An updated list of references
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	Write a review to showcase the work of WGFAST with particular emphasis on its relevance to the ICES/ACOM strategies plans	After three years a review paper will be written to showcase the work of WGFAST	3 year	Write a review paper showing the WGFAST contribution over the last 3 years
d	Organize international acoustic symposium	Organize the 8th international symposium with working title “Marine Ecosystem Acoustics – observing the ocean interior across scales in support of integrated management”	2015	Symposium and special issue in ICES Journal of Marine Science
e	Organize joint sessions at ICES ASC	Organize joint sessions with survey working groups to foster collaboration regarding the use of acoustics data and cross-fertilization	2 or, 3	Topic session at ICES ASC

Details for Tor b)

i. Applications of acoustic methods to characterize ecosystems.

This session concerns the application of acoustic methods, often developed within the WGFAST community, and the application of those techniques in ecosystem studies. This includes acoustically derived metrics, indices and indicators to support the ecosystem approach to fisheries management, and the use of acoustics in combination

with other observation tools to assess, understand and quantify ecosystem patterns and processes. The focus should be on larger scale systems, and examples of using data from platforms other than research vessels are encouraged, e.g. observatories, gliders etc., in addition to re-analysing historical data. Guests outside the community are particularly welcomed (Chair: Gareth Lawson).

ii. Acoustic properties of marine organisms.

This is a core activity for WGFAST, as the scattering properties of marine organisms must be understood to make biologically relevant conclusions from acoustic measurements. This includes models and measurements of target strength (in particular for multiple inclination angles), and acoustic target classification, including the use of multiple frequencies techniques or broadband systems. (Chair: Richard O'Driscoll).

iii. Behaviour.

Joint Session 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) on Monday May 5.

iv. Emerging technologies, methodologies, and protocols.

The use of acoustics and complementary technologies for fish surveys has been and still is a core activity of WGFAST. This session welcomes contributions on acoustic based single and multispecies surveys and how they relate to traditional assessment work, including error structures and error budget modelling. In response to a request by several acoustic survey coordination working groups a special emphasis will be put on providing an overview and guidance on best practice for processing acoustic survey data for deriving abundance indices for stock assessment. The session also includes updates on the application of new technology in relation to such surveys, and more purely technological advances, such as advances in calibration and post-processing techniques, and development of new acoustic and optical sensors. (Chair: Tim Ryan).

Additional topics for the meeting:

f) Review the reports and receive updates from:

- i. Report from the Study Group on Calibration of Acoustic Equipment (SGCAL; David Demer).
- ii. Engagement with SPRFMO (Francois Gerlotto).
- iii. Report from new working group on Acoustic target classification (WGTC; Rolf Korneliussen).

During the FAST meeting, time will be available for presentations and discussions on general interest topics including the report of the SCICOM Steering Group on Ecosystem Surveys Science and Technology (SSGESST) and how it influences future FAST research topics. WGFAST business including recommendations for future WGFAST meetings and ICES ASC topics are scheduled for discussion during the meeting.

3 TOR a: List of papers originating in the community of the WGFAST Working Group 2013–2014

Below are listed publications and reports for which WGFAST participants made significant contributions and which benefited from discussions during WGFAST meetings.

Peer-reviewed publications

- Escobar-Flores, P., O'Driscoll, R. L., and Montgomery, J. C. 2013. Acoustic characterization of pelagic fish distribution across the South Pacific Ocean. *Marine Ecology Progress Series* 490: 169–183.
- Fässler, S. M. M., O'Donnell, C., and Jech, J. M. 2013. Boarfish (*Capros aper*) target strength modelled from magnetic resonance imaging (MRI) scans of its swimbladder. *ICES Journal of Marine Science*, 7: 1451–1459.
- Gastauer, S., Fässler, S. M. M., Couperus, B., and Keller, A. M. 2013. Target strength and vertical distribution of smelt (*Osmerus eperlanus*) in the IJsselmeer based on stationary 200 kHz echosounder recordings. *Fisheries Research*, 148: 100–105.
- Huse, G., MacKenzie, B. R., Trenkel, V., Doray, M., Nøttestad, L., Oskarsson, G. (In Press) Spatially explicit estimates of stocks sizes, structure and biomass of herring and blue whiting, and catch data of bluefin tuna. *Earth Syst. Sci. Data Discuss.*
- Macaulay, G. J., Peña H., Fässler, S. M. M., Pedersen, G., Ona, E. 2013. Accuracy of the Kirchhoff-Approximation and Kirchhoff-Ray-Mode Fish Swimbladder Acoustic Scattering Models. *PLoS ONE* 8(5): e64055.
- McQuinn, I. H., Dion, M., and St-Pierre, J.-F. 2013. The acoustic multifrequency classification of two sympatric euphausiid species (*Meganyctiphanes norvegica* and *Thysanoessa raschii*) with empirical and SDWBA-model validation. *ICES Journal of Marine Science*, doi:10.1093/icesjms/fst004.
- O'Driscoll, R. L., Oeffner, J., and Dunford, A. J. 2013. In situ target strength estimates of optically verified southern blue whiting (*Micromesistius australis*). *ICES Journal of Marine Science* 70: 431–439.

Reports

- Bagley, N. W., O'Driscoll, R. L., Oeffner, J. 2013. Trawl survey of hoki and middle-depth species in the Southland and Sub-Antarctic areas, November–December 2011 (TAN1117). New Zealand Fisheries Assessment Report 2013/23. 70 p.
- Bagley, N. W., O'Driscoll, R. L., Oeffner, J. 2014. Trawl survey of hoki and middle-depth species in the Southland and Sub-Antarctic areas, November–December 2012 (TAN1215). New Zealand Fisheries Assessment Report 2014/12.
- O'Driscoll, R. L. 2013. Acoustic biomass estimates of southern blue whiting on the Bounty Platform in 2012. New Zealand Fisheries Assessment Report 2013/4. 26 p.
- O'Driscoll, R. L., Bagley, N. W., Ballara, S. L., Oeffner, J. 2014. Trawl and acoustic survey of hoki and middle depth fish abundance on the west coast South Island, July–August 2012 (TAN1210). New Zealand Fisheries Assessment Report 2014/9. 102 p.
- O'Driscoll, R. L., Oeffner, J., Ross, O., Dunford, A. J., McMillan, P. J. 2013. Pilot acoustic survey for jack mackerel on the west coast New Zealand (JMA7). New Zealand Fisheries Assessment Report 2013/1. 53 p.
- Stevens, D. W., O'Driscoll, R. L., Oeffner, J., Ballara, S. L., Horn, P. L. 2014. Trawl survey of hoki and middle depth species on the Chatham Rise, January 2013 (TAN1301). New Zealand Fisheries Assessment Report 2014/02. 110 p.

4 TOR b: Applications of acoustic methods to characterize ecosystem

4.1 Contributions to the session

Trends in mesopelagic biomass using time-series of acoustic backscatter data from trawl surveys

Richard L. O'Driscoll, Johannes Oeffner, Stephane Gauthier

Acoustic data have been opportunistically collected during annual bottom-trawl surveys of the Chatham Rise, New Zealand, since 2001. A time-series of acoustic indices of mesopelagic fish abundance was developed based on the vertically migrating component of the total backscatter. There was no clear trend in mesopelagic fish biomass on the Chatham Rise over the last 12 years. There were consistent spatial patterns in mesopelagic fish distribution in all years, with highest densities observed on the western Chatham Rise. Abundance in areas of high mesopelagic fish density tended to be more variable between years. Spatial patterns in mesopelagic fish abundance closely matched the distribution of hoki (*Macruronus novaezelandiae*), a major predator and important commercial species. Temporal changes in mesopelagic fish abundance were not strongly correlated with hoki biomass, but there was a link between hoki condition and mesopelagic prey abundance. Recent work has focused on developing decision-tree models to partition total mesopelagic backscatter into individual species components using multifrequency acoustics, mark morphology and environmental data.

The distribution of blue whiting west of the British Isles and Ireland

Sven Gastauer, Sascha M. M. Fässler, Ciaran O'Donnell, Åge Høines, Jan Arge Jakobsen, Alexander I. Krysov, Leon Smith, Øyvind Tangen, Valantine Anthonypillai, Ebba Mortensen, Pierre Petitgas

Blue whiting is one of the commercially most important species west of the British Isles and Ireland. Although large fluctuations in the stock biomass have been observed in recent years, little remains known about the influence of the environment on the distribution and abundance of the population. The Northeast Atlantic blue whiting stock has undergone striking changes in abundance in the last 15 years. The stock increased in the late 1990s due to a succession of eight unusually strong year classes and dropped again after 2005 when the recruitment collapsed to former levels. It has been shown that this occurred nearly simultaneously with unusual changes in the North Atlantic ecosystem and oceanography, which suggests a causal linkage and the possibility of forecasting recruitment and spawning stock distribution. Over the past 9 years the International Blue Whiting Spawning stock Survey (IBWSS) has collected simultaneous fish abundance and environmental data. In order to analyse spatial patterns and characterize properties of the spatial distribution, a geostatistical analysis was performed computing geostatistical indices and modelling the distribution of blue whiting in dependence of environmental conditions using co-kriging with external drift in order to track changes occurring in the spatial distribution due to ongoing changes in the environmental conditions.

Comparative approach of fish communities in large estuaries through acoustic observations: the Zeeschelde estuary (Belgium) vs. the Gironde estuary (France)

Valéry Samedy, Jan Breine, Mario Le Page

At the interface between marine environment and fresh waters, estuarine ecosystems are complex and highly dynamic natural environments. As a result, effective assessment of fish densities in these areas creates a set of particular challenges. The use of hydroacoustics is compatible with current best practices in traditional fish surveys. Indeed it is an effective tool providing robust data on fish populations. Successful application of such techniques has been demonstrated in various aquatic ecosystem but was rarely applied in large estuaries. The objective of this study was to compare the acoustic structure and abundance of the estuarine fish population in the Gironde (France) and Zeeschelde estuaries (Belgium) in order to better understand the ecological functioning of fish population and to move towards the implementation of the standardization of procedures. For each estuary, a series of two echo-surveys have been conducted between July and October 2013. Each survey was carried out under identical conditions, i.e. around high tide, during daytime and at different fixed stations along the salinity gradient of estuaries. Simrad EK60 split-beam echosounders were used, operating simultaneously at two frequencies (70 and 120 kHz). This comparative study highlights the variability description of the fish distribution at large-scales. This applied approach allows determining standard procedures by acoustic approach in estuarine ecosystems. Additionally it demonstrates the relevance of using acoustic equipment alongside traditional approaches to fish sampling, especially as internationally accepted standards need to be created and outlined in order to ensure comparability of results.

Estimate of fish biomass using geostatistics

Dezhang Chu

Geostatistics focuses on the discrete spatial data and predicts the probability distribution of the unknown quantity of interest. In our application, the biomass estimate of Pacific hake (*Merluccius productus*) is obtained using geostatistics based on the acoustic and biological data collected during the acoustic surveys. Special treatments are applied to characterize the anisotropy of hake distribution that is concentrated along the continental shelf break that is geographically winding. Ordinary kriging, a local estimator that provides the best linear unbiased estimate (BLUE) is used in predicting the biomass, and the maps of biomass and variance distributions are obtained at the same time. By incorporating the biological sampling data, a length-age-sex structured biomass estimate can be obtained. Sensitivities of the predicted biomass are investigated in terms of the semi-variogram and kriging parameters.

Biomass estimates for selected herring schools using omnidirectional fisheries sonar and echo sounder

Hector Peña, Egil Ona

Detailed inspections of individual herring schools were made with research vessel and a cooperating fishing vessel in 2012 and 2013, both carrying calibrated Simrad EK60 echo sounders and Simrad SX90 fishery sonar. In the school inspection mode, the target is encircled repeatedly with the vessels at about 5 knots speed, keeping a fixed distance to the school. Some of the schools were also crossed with the research vessel for obtaining a conventional echo sounder estimate of school biomass. The method for estimating biomass in both systems will be described, together with a discussion of the critical parameters involved. Also an experimental measurement against a confined biomass of 30 tons herring inside an acoustically transparent net pen will be shown.

Exploration of the relationship between micronekton composition and frequency response in the framework of the NECTALIS surveys in the New Caledonian ZEE

A. Lebourges-Dhaussy, V. Alain, C. Menkès

During July and November-December 2011, two cruises were performed onboard the IRD RV Alis in the ZEE of New Caledonia. The aim of this NECTALIS project is to study the mid-level trophic levels of the pelagic ecosystem, by means of acoustics as well as biological sampling in order to model it. The final goal is a better understanding of the tuna's preys' behaviour for better explain the tunas-preys relationships within the Caledonian ZEE. The two seasons sampled correspond to two fishery peaks but with physico-chemical conditions very different. The abiotic and biotic environment were thus studied during the cruises. In particular a four frequencies Simrad ER60 echosounder (30/70/120/200 kHz) was used to detect the micronektonic layers and the organisms were sampled by means of a micronekton trawl of about 10 m horizontal and vertical apertures. The frequency responses corresponding to the trawled layers were determined and from this acoustic information, the possible composition of the layer was explored and classification was assessed in the light of samples. The uncertainties caused by the limited number of frequencies are highlighted.

The distribution and behaviour of mesopelagic fish west of the British Isles

Sven Gastauer, Matthias Schaber, Sascha Fässler, Eric Armstrong, Joe Freijser, James Keating, Jeroen Brandhof

Mesopelagic fish species are widely distributed over the world's oceans and due to their abundance and biomass play an important role in the marine ecosystem. However, we generally lack even the most basic understanding of what is happening in depths greater than 500 m. routinely executed acoustic surveys have been proven to be the best available tool to monitor pelagic ecosystems. During these surveys, the deep scattering layer containing or consisting of mesopelagic fish can often be detected as a prominent feature on the echograms and be distinguished from other organisms and classified with high accuracy. The international blue whiting acoustic survey West of the British Isles provides a unique dataset consisting of acoustic recordings and information on mesopelagics as bycatch species from blue whiting trawls as well as from dedicated mesopelagic trawls (at +/- 1000m) . Hydroacoustic information allows a detailed resolution of the diurnal vertical migration pattern of mesopelagic fish species. Coupled with catch data, detailed information on distribution and composition of the mesopelagic deep scattering layer can be derived. We applied geostatistics to derive distribution patterns of mesopelagic fish species for a survey time-series from 2009–2014. Additionally, GAM analysis was used to detect effects of ambient hydrography

and other species such as blue whiting on the distribution and behaviour of the migrating mesopelagic layer.

Acoustically derived zooplankton abundance in the northern North Sea

Sascha M. M. Fässler, Lorna R. Teal, Susan M. Lusseau, Piet Ruardij

Acoustic fish surveys commonly collect data at a frequency range of 18 - 200 kHz. This is done primarily to facilitate target species identification and distinction from other fish based on differences in frequency-dependent scattering properties. Indeed, acoustic data contain qualitative and quantitative information on various trophic levels within an ecosystem, ranging from plankton to larger predators. Generally, however, backscatter information coming from plankton or other non-target fish species is discarded during the process of producing estimates of abundance and biomass of the target species. We applied a bi-frequency algorithm to multifrequency data collected in the northern North Sea during acoustic surveys for herring from 2003 to 2010. This algorithm has previously been used on data from the Bay of Biscay and waters off Peru to identify acoustic backscatter coming from macrozooplankton. Here, the same method allowed production of high-resolution maps of distributions, abundances and biomass of macrozooplankton in the northern North Sea. Forage fish species like herring feed directly on macrozooplankton, which are mainly composed of copepods or euphausiids. Knowledge of the location and abundance of food (macrozooplankton) and environmental conditions (temperature) may be used to identify preferable habitat for herring.

A decade of Tasman Sea bioacoustics

Kloser, Rudy*, Gordon Keith, Caroline Sutton, Tim Ryan, and Ryan Downie

The Tasman Sea is a region that is predicted to be a climate change hot spot, due in part to the strengthening and extension of the East Australian Current (EAC). A bioacoustic and CPR transect at 41°S was established to monitor the decadal effects of this change on the zooplankton and micronekton communities at basin scales. This sampling was complemented with ad-hoc physical sampling on research and fishing vessels. The bioacoustic transect data is compared to these net derived and other metrics for the basin such as CPR, net primary productivity from ocean colour and metrics of the strength of the EAC. The ecological relevant metrics that can be derived from the monitoring program to detect decadal changes is explored. Often changes in habitat are used to infer changes to the structure and function of the ecosystem as direct sampling of biota is often costly and complicated. Our ad-hoc physical net sampling of the macro-zooplankton and micronekton of ~2 to 20 cm length (small crustaceans, gelatinous, squid and fish) that dominate the mesopelagic open ocean basins in this region complements the acoustic observations for monitoring metrics such as density, diversity, trophic linkages and energetic transfer. Our ability to detect changes in these ecological units with our remote observing system is limited and will require a systematic approach of physical net sampling that is cost-effective and well-targeted both spatially and temporally using information derived from the acoustic observing system and the development of physical, biochemical and ecological models.

Use of commercial fishing vessels for surveying herring in the Gulf of Maine

Katharine Wurtzell, Michael Jech, Graham Sherwood

Herring movement and distribution in the Gulf of Maine are not well understood due to difficulties surveying coastal areas. During autumn of 2012, an acoustic survey was conducted to monitor the population of Atlantic herring in coastal Gulf of Maine, an area that supports a large portion of the New England herring fishery. We conducted acoustic sampling using Simrad 38/200kHz Combi-D single-beam transducers hull mounted on ten lobster boats. The use of multiple boats allowed us to sample the entire coast of Maine simultaneously. Although calibration of single-beam systems is typically limited, we applied a novel technique of utilizing a split-beam transducer to help guide the sphere to the center of the single beam system. Each boat conducted weekly systematic transects during autumn of 2012, resulting in more than 4,200nmi of acoustic data. The survey coincided with the herring spawning season. Due to the repetitive transects throughout the season, we were able to observe the spatio-temporal dynamics of the population, as well as gain insight into spawning behaviour and timing. One short-coming of this survey is the lack of ground-truth sampling to perform target identification.

Bubble release in pelagic fish species – what are the causes and implications?

O. R. Godø, G. Macaulay and M. Jech

It is well known that herring release gas and associated sound production has been studied. Bubble release might be used for communication purposes, but the literature also describes air release as a defence mechanism towards attacking sea mammals. Both functions are associated with herring as a hearing specialist. They can potentially communicate through sound in the frequency spectrum of the emitted sound (>2 kHz) caused by the air release and they can hear the sound production of attacking whales and thus initiate air release and start diving in time to escape.

During a study of capelin in the Barents Sea we repeatedly observed bubble releases associated with their diel vertical migration. The releases occurred always during the evening ascent from depths of 200–300 m to surface and we recorded air release as deep as 150m. From our data it seems to be a commonly occurring phenomenon not associated with external factors other than change of depth.

The echograms are normally scrutinized with full bottom depth range, and the bubble records therefore become small and non-striking features not attracting much attention. This might explain the lack of description of this phenomenon before. The compelling question is why do capelin release gas at 150m? If they fill their swimbladder at the surface, then there should not be excess gas when they return to the surface. Is there gas production in pelagic species not yet described? These issues and their implications for target strength and abundance estimation are presented for discussion based on the described findings.

Marine Ecosystem Surveys

David A. Demer and Juan P. Zwolinski

Fish stocks are naturally governed by their environments, prey, and predators, which generally transcend national boundaries and policies. The sustainable harvest of trans-boundary marine fish stocks requires cooperative management with an ecosystem approach. To do this, fisheries scientists must gather and assimilate large quantities of interdisciplinary data. Presented here are the models, tools, and results of one investigation of basin-scale forcing of local ecosystem dynamics, and how data for multiple

species and their environment have been integrated to predict trends in stock recruitment, migration, and size. A dual-phase model was developed which links the environment in the North Pacific, indicated by the Pacific Decadal Oscillation index (PDO), to the recruitment of the northern stock of Pacific sardine (*Sardinops sagax*) in the California Current. The model identifies summer feeding seasons conducive to good adult condition factor followed by spring-spawning seasons supportive of good larval retention and growth. A probabilistic generalized additive model was also developed using a 12-year dataset including the presence and absence of sardine eggs and concomitant remotely sensed oceanographic variables. Based on significant relationships identified between eggs and sea surface temperature, chlorophyll-a concentration, and the gradient of sea-surface height, the model accurately predicts the habitat and seasonal migration pattern of sardine, irrespective of spawning condition. These model predictions have been used to optimize sampling in multispecies, acoustic-trawl method (ATM) surveys conducted off the west coasts of the United States (US) and Canada, and to better interpret the survey results. In addition to providing information about the abundance, migratory behaviour, and size and age distributions of sardine, the ATM surveys concurrently yielded information on the biomasses and spatial distributions of multiple other coastal pelagic fish species within the survey areas. Collectively, these results show that the PDO has recently transitioned to a cold period, consequently the reproductive condition and productivity of sardine has been poor, the population has been reduced to a small number of cohorts that are unlikely to produce an appreciable new cohort, the population is declining, its migration is contracting, and other forage fish species may be thriving. Affected are fisheries in Mexico, the US, and Canada.

4.2 Summary of session

The presentations in this session exemplified the broad range of ecosystem-related problems to which acoustic methods are currently being applied. Multiple presentations involved ecological studies of commercially exploited species targeted by acoustic surveys (e.g. blue whiting), revealing interesting behaviours and patterns of distribution associated with environmental conditions. A large number of presentations also examined micronekton and mesopelagic fish, leveraging the frequency responses of these organisms in multifrequency analyses. In some cases these organisms were the focus of the surveys but often they were non-target organisms sampled incidentally and opportunistically during surveys for other species.

A recurrent theme throughout the session was the importance, and often difficulty, of effective ground-truthing. This is particularly the case for non-target organisms less effectively sampled with traditional net types (e.g. zooplankton, mesopelagic fish) and for less traditional habitats (e.g. estuaries). Optical methods were suggested during question periods a number of times as alternatives or supplements to typical net-based ground-truthing. Multiple presentations highlighted new methods, both in terms of instrumentation (e.g. biomass estimation from omnidirectional sonar) and statistical interpretation (e.g. kriging to interpolate fish biomass away from survey transects). Interesting linkages between population distribution and dynamics with climate (e.g. the Pacific Decadal Oscillation, variability of the position of the North Atlantic Subpolar Gyre) were observed in some of the studies presented.

A great deal of interest currently surrounds work on mesopelagic fish. Such fish pose a difficult challenge for quantitative acoustic study. In many species, the swimbladder becomes partly or fully lipid-filled with ontogeny, and these small gas-bearing structures often resonate at or near typical survey frequencies of 18 and 38 kHz in a way

that varies with depth and hence with vertical migrations. Current acoustic methods and technologies do allow mesopelagics to be surveyed and insightful indices of abundance/biomass have been generated via relatively simple approaches, but multiple challenges remain in their acoustic study. More work is needed on their acoustic properties, and even with emerging broadband technologies, ground-truthing of these small fish can be difficult. There was consensus that a joint effort addressing the problem of “how shall we measure mesopelagics” is warranted. Although these fish have traditionally not held commercial value, exploratory fisheries are emerging in some parts of the world’s oceans and increasingly these species are appreciated for their role as prey in off-shelf ecosystems.

The session also confirmed again that acoustic surveys are well positioned to provide indices for Integrated Ecosystem Assessment. Multiple examples of such indices were discussed (e.g. zooplankton and euphausiid abundance indices). For the most part these indices are only actually used peripherally in stock assessments, but increasingly the acoustics community is being approached by those in assessment looking for such indices. In addition to ecosystem-based management, these kinds of indices hold value for other purposes, such as monitoring ecosystem responses to climate variability and climate change, assessing critical habitat, trophic dynamics, and designing MPAs.

5 TOR b: Acoustic properties of marine organisms

5.1 Contributions to the session

Improved fishing selectivity by using multifrequency species identification methods

Sascha M. M. Fässler, Sven Gastauer, Dirk Burggraaf, Yngve Heggelund, Inge K. Eliassen, Rolf Korneliussen

The EU regulates the catch of mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*) by use of quotas. Pelagic freezer-trawlers encounter mixed fish schools towards the end of the mackerel fishing season when their quota for mackerel is nearly depleted but horse mackerel can still be targeted. A good selectivity of the target species is therefore necessary to reduce bycatch of species for which less quota is left. The echosounder on a pelagic freezer-trawler was upgraded to a scientific Simrad EK60 with 4 operating frequencies (38, 70, 120, and 200 kHz). Acoustic multifrequency test data were then collected during fishing operations targeting mackerel and horse mackerel. Using scientific species identification methods, algorithms were developed to classify the species from multifrequency data. The approach makes use of variations in sound reflection properties at different frequencies between the fish species investigated. The algorithms were implemented in a software tool to help skippers make more objective decisions when targeting mackerel and horse mackerel aggregations.

A tale of two coasts: Material properties of North Pacific nekton and zooplankton and coastal Atlantic forage fish

Joseph D. Warren, Kaylyn N. Becker

Material properties (density and sound speed) of aquatic organisms are important inputs to theoretical scattering models, and small differences in these parameters can cause large changes in the target strength and acoustically derived biomass estimates of these organisms. Measurements of density and sound speed were made on Pacific hake (*Merluccius productus*), Humboldt squid (*Dosidicus gigas*), and two species of myctophids (*Symbolophorus californiensis* and *Diaphus theta*) collected off the coast of Oregon during summer of 2012. Significant differences were found in the material properties of these organisms, both for different tissues within a single organism and the same type of tissue among different species. We also measured the material properties of 11 different species of common North Pacific zooplankton including euphausiids, amphipods, gelatinous zooplankton, and larval fish. Several Atlantic coastal forage fish were CT-scanned to investigate 3-D variations in material properties within an individual. Variations in swimbladder shape along the length of the fish were observed. In addition to the scattering contributions from the swimbladder and skeleton, another part of the animal not typically considered to be acoustically important may contribute significantly to the scattering properties of this fish.

Comparison of the Z- score and +MVBS techniques in use of multifrequency data for discriminating the backscattering of the Black Sea copepod *Calanus euxinus*

Serdar Sakinan, Ali Cemal Gucu

One of the problems faced in fisheries acoustics is zooplankton swarms contaminating the data. This may be particularly important when the fish do not form peculiar schools but are rather dispersed in the water column. A problem of such, has been faced in the Black Sea where sprat and the zooplankton species *Calanus euxinus*, coexist at the same layer. The copepod *C. euxinus* migrates vertically in the water column with the bulk of

their biomass moving towards the surface at sunset and sinking to depth during sunrise. Their distribution in the water column is distinct during the day characterized by a dense concentration layer at the Oxygen Minimum Zone (OMZ). Due to their size which is about 3.0–3.5 mm, they scatter the acoustic waves at the Rayleigh zone for the transducer frequencies commonly used for fisheries acoustics such as 38, 120 and 200 kHz. The remarkable changes in the level of backscattering at different frequencies help detect them acoustically and precisely. However at night, their distribution overlaps with other sound scatterers of different sizes occupying the surface layer such as fish and other zooplankton species (e.g. Chaetognaths). In this study we assumed that if their frequency response can be characterized at their well isolated mid-day distribution, then using this multifrequency data it may also be possible to discriminate them at night when mixed with others. To test this hypothesis, we used the acoustic data and net samples collected during the cruise conducted in the Black Sea in July 2013. Two different methods, the Z- score and +MVBS120+38 methods have been applied, compared and combined for the backscatter classification. The Z- score as proposed by De Robertis *et al.* (2010) was employed to summarize the relative responses at different frequencies; and the second multifrequency technique, MVBS120+38, was applied to discriminate the plankton from the fish, which, in essence, is incapable of discriminating the different plankton groups. The results showed that, these methods when combined together work better for the definition and discrimination of *Calanus euxinus* distribution, which would in turn facilitate estimation of the fish biomass in question.

Target strength of Atlantic mackerel

Ben Scoulding, Paul Fernandes

Atlantic mackerel is a small pelagic, migratory fish common throughout the Northeast Atlantic Ocean, which is subject to an extremely valuable commercial fishery. As mackerel do not have swimbladders they are individually described as weak scatterers of sound, however, they do amass in huge schools reaching billions of individuals which are easily detectable using acoustic techniques, especially by higher frequency devices. Estimates of mackerel abundance in the Northeast Atlantic are currently based catch data and a single fishery-independent data point, derived from egg production surveys, every third year, and do not yet consider acoustic data. Improving our knowledge of mackerel target strength (TS) may allow for annual abundance estimates and the study of mackerel distributions throughout the year. TS is a complex function of; geometry, physiology, angle of orientation, material properties, and acoustic frequency. The objective of this study was to provide in situ TS of Atlantic mackerel derived from measurements made at sea based on data collected at 18, 38, 120 and 200 kHz. A single target filtering procedure has been modified to produce reliable estimates of mackerel TS. An adapted Distorted Wave, Born-Approximation model was then used to estimate the mean TS of mackerel at 18 and 38 kHz. Model parameters were estimated using a Bayesian approach to account for levels of uncertainty and make use of prior knowledge of model components.

Categorization acoustic multifrequency survey-data

Rolf Korneliussen, Yngve Heggelund, Daniel Patel, Inge K. Eliassen

Data from multifrequency echo sounders working simultaneously with nearly identical and overlapping acoustic beams were used to generate new, synthetic echograms which allow for school-detection and identification of scrutinize categories (i.e. “acoustic species”). The raw echo sounder data were processed stepwise in a modular sequence of analyses to improve categorization of the acoustic targets. Special attention is given to the acoustic-feature library applied for automatically grouping the acoustic returns into categories. The relative frequency response and scattering strengths are the main acoustic features used to characterize the backscatter. One sample survey is analysed both manually and automatically to demonstrate the method.

Acoustic Scattering Web Tool

Michael C. Ryan, J. Michael Jech

A common paradox in science is a researcher's authoritative understanding of a particular theory and their need to apply that theory in their research. Acoustic scattering theory is an example of this. For example, echo sounder calibrations require input of a theoretical target strength (TS) of a calibration sphere, yet not everyone who calibrates an echo sounder knows how to derive the theoretical calculations for backscattering by a solid, elastic sphere. Another example is backscattering by fish, zooplankton, and other aquatic organisms. Theoretical predictions of target strength (i.e. frequency responses) are becoming more prevalent in the literature, and they will become critical information as the community transitions to broadband technology. We are developing a web-based acoustic scattering tool as a high-level interface to calculate and output TS and frequency responses for standard shapes (e.g. sphere and cylinder), and more complex shapes such as bodies and swimbladders (e.g. Kirchhoff ray mode). Currently this interface encompasses a set of user-friendly tools to assist acousticians and biologists in calculating these functions, allowing scientists to make better use of their time and skills. The software is written in Java Script, an open source language, and the user has the option of utilizing the web-based graphic interface only, delving into the algorithms, or writing their own algorithms and code to supplement and enhance the applicability of this tool to the community.

Field Measurements of Volume Backscattering Strength from Fish and Zooplankton over a Wide Frequency Band (15 - 400 kHz)

Gareth Lawson, Michael Jech, Andone Lavery, Victoria Price, Nicole Charriere, Christopher Roebuck

Target identification remains a key challenge in the application of active acoustics to fisheries assessments and ecological studies. Measurements of acoustic scattering made over wide and continuous frequency bands allow the frequency response of scatterers to be characterized more fully, thus offering the potential for substantial improvements over traditional narrowband methods in species discrimination. Kongsberg Simrad has developed Wide Band Transceivers (WBTs) capable of operating in the 10 - 500 kHz band that take full advantage of the broadband and split-beam capabilities of their existing composite transducers. In January of 2014 we conducted field applications of a system composed of five WBTs, and one 18 kHz GPT, from the F/V Karen Elizabeth at the New England continental shelf break. Transducers with center frequencies of 18, 38, 70, 120, 200, and 333 kHz were installed in a surface towed body. Acoustic data spanning a variety of bands within an overall range of 15 - 400

kHz were collected with the EK80 software in regions of relatively mono-specific aggregations of adult butterfish (*Peprilus triacanthus*), spiny dogfish (*Squalus acanthias*), and krill (*Meganyctiphanes norvegica*). Biological data were collected with bottom and midwater trawls for fish and Bongo nets for zooplankton. Here we highlight key strengths and limitations of the WBT systems when applied to these non-gas bearing fish and zooplankton species.

Combining optics and acoustics to determine in situ acoustic properties of zooplankton and marine snow

Christian Briseño-Avena, Jules S. Jaffe, Paul L. D. Roberts, Peter J. S. Franks

Marine pelagic ecosystems are diverse in planktonic living and non-living (e.g. marine snow) particles. While acoustic properties of common crustacean and large gelatinous organisms are better understood, other particles have been widely overlooked in acoustic studies. Righteously so, since most acoustic data ground-truthing involves invasive methods that destroy or under sample fragile taxa, and more so marine snow. Furthermore, obtaining *in situ* acoustic measurements of any planktonic particle has multiple practical challenges. Relating specific acoustic returns to individual plankters collected with nets over large volumes of water is practically impossible. And laboratory settings, while instrumental to understand individual acoustic properties can also be time consuming. This work addresses some of these challenges by combining a broadband, high frequency (1.5–2.5 MHz) system along with a stereoscopic system (which we refer to as ZOOPS-O²) to co-register the *in situ* echo from the specific target being imaged. ZOOPS-O² was deployed during a one-day cruise and was profiled repeatedly while obtaining *in situ* measurements from individual targets ranging from copepods to euphausiids and from hydromedusae to doliolids to marine snow. Interestingly, this study found that in addition to small (<3 cm) gelatinous zooplankton, marine snow significantly reflects sound. Since marine snow layers are ubiquitous features in coastal oceans, such fragile targets, when aggregated, can certainly be part of what an echo-sounder senses.

Use of efficient boundary integral equation solvers for fish target strength calculation

Geir Pedersen, TBD

The Finite Element Method (FEM) and Boundary Element Method (BEM) have gained popularity for calculating scattering by marine organisms. Target strength (TS) calculations using for instance commercial software such as COMSOL Multiphysics (FEM) enables calculation of scattering from realistic representations of fish, without constraints on frequency and sound incidence angle. These methods are computationally expensive, and running such calculations on ordinary PCs effectively limit possible fish size and frequency. More efficient methods for solving boundary integral equations have been developed in recent years, and implementing this in TS calculation increases the possible size and frequencies on ordinary PCs. Performance, validation and examples are presented and discussed.

5.2 Summary of session

The major themes discussed in this session were

- Multifrequency discrimination of species
- Development of wideband acoustic systems as an extension of existing multifrequency methods

- Making multifrequency species classification algorithms and acoustic scattering models more widely available to scientific community and fishers for practical applications
- Challenges of working on micronekton due to their variable acoustic properties
- Requirement for ongoing research on target strength

Study of the acoustic properties of marine organisms remains a core activity of WGFAST. It was noted that a number of methods developed by WGFAST over the past 10 years are now being practically applied by scientists and fishers alike.

There is general recognition of the utility of multifrequency methods for acoustic discrimination of species based on differing frequency response. Presentations illustrated how multifrequency methods can be applied successfully for ecosystems studies, in analysis of resource surveys, and to aid fishers target desirable species. Wideband acoustic systems have been developed and provide increased resolution of the acoustic frequency response and potentially the ability to determine the size of the target. The advantages of wideband systems over multifrequency methods using a number of discrete narrowband frequencies was likened to the advantages of high-definition television over regular television.

There has been a trend towards making acoustic methods more accessible. For example, development of custom software based on frequency response algorithms has allowed commercial fishers to discriminate between horse mackerel and Atlantic mackerel in near real-time. Similarly, automated multifrequency acoustic classification can reduce the need for manual scrutiny in analysis of data from resource surveys. Another nice example of increasing accessibility was development of a publically available acoustic scattering web tool which provides an online calculator for acoustic scattering models. This generated discussion about whether theoretical constraints on scattering models should be enforced by the software or whether appropriate application depended on the knowledge of the user. Recent advances in computing technology and mathematics have also increased the usefulness of more complex scattering models (e.g. boundary element method models).

Target strength (TS) continues to be a key area of research. Two presentations showed that TS is complex, variable, and highly dependent on material properties. It was noted in discussion that variability of TS is not a problem for abundance estimation per se, as long as the mean TS is well estimated. The micronekton represent a particular challenge for acoustics. This was a key theme of the session on applications of acoustic methods to characterize ecosystems, and was reinforced by a presentation that illustrated the complexity of material properties of North Pacific nekton and zooplankton. The use of acoustics to estimate micronekton and macrozooplankton in integrated ecosystem assessments is a potential topic for a future special session.

6 TOR b: Emerging technologies, methodologies, and protocols

6.1 Contributions to the session

Pilot Study using a Wave Glider towed echo-sounder system for fisheries acoustic surveys

Lawrence C. Hufnagle Jr., Dezhong Chu

Ecosystem-based management of marine resources requires accurate information for stock assessments of multiple species and their associated habitats. While demands for stock assessments on more species are increasing, the available vessel time is expected to diminish due to budgetary limitations for the foreseeable future. In this presentation, a potential application of using a vessel-independent system, Wave Glider with a towed echo-sounder system (WG-TES), to collect important information on fish/zoo-plankton school distribution is provided. Operations or surveys with multiple WG-TES systems allow us to collect data including multifrequency acoustic data and other oceanographic and biochemical data over extended temporal and spatial scales than any of the vessel-based data collection systems. Preliminary results from a series of trial experiments will be presented and discussed, demonstrating promising results of its applicability to fisheries acoustic surveys. It can serve as a benchmark and model for the way fisheries acoustic surveys are conducted in future.

Characterization of bubble sweep-down occurrence on the Research Vessel Thalassa

Berger Laurent, Delacroix Sylvain and Germain Gregory

Bubble sweep-down on oceanographic vessels generates acoustic perturbations. We propose in this work to characterize the subsurface bubbles occurrence conditions from acoustic data from vertical and horizontal echosounders with the research vessel Thalassa. The methodology of data analysis used in this work allows to characterize the sailing conditions influence on bubble sweep-down occurrence. The correlation between sailing conditions and acoustic perturbations tends to demonstrate that the presence of bubbles under the hull is clearly related to the windspeed and natural aeration.

Using acoustic data to quantify and predict extreme events in monitoring programs

John K. Horne, Dale A. Jacques, and Lauren Wiesebron

An increasing number of marine research applications are using acoustics to detect and monitor biomass in the water column. One common objective among applications is to detect change and to identify extreme events. Extreme events are rare but potentially catastrophic occurrences. Extreme value analysis provides objective techniques to determine thresholds of extreme events, model the right tail of the distribution, and to estimate probabilities and periodicities of extreme events. Peaks-over-threshold (POT, i.e. the right tail of the distribution) can be modelled using a Generalized Pareto Distribution (GPD). Discontinuities from linearity in a Mean Residual Life (MRL) plot are used to identify a threshold. Shape and scale parameters for the GPD are estimated by maximizing the log-likelihood of the acoustic data. By using the GPD to model probabilities of events beyond the threshold, the return period (i.e. mean time until an event at least as strong) of each observed value can be inferred. We illustrate the utility of the approach by quantifying change, effect, and impact of tidal turbines on pelagic biomass at a proposed Marine Renewable Energy site in Puget Sound, Washington.

Experimental validation of DIDSON data and data analysis optimization using Sonar5-Pro

François Martignac, Aurélie Daroux, Jean-Luc Bagliniere, Dominique Ombredane, Jean Guillard

The DIDSON acoustic camera (Dual-frequency Identification Sonar) can record morphological and behavioural characteristics of fish on high definition images. Unlike the previous generation of echosounders, data analysis considers images and not acoustic properties from the targets: fish lengths are measured on images and are not estimated from acoustic target strength. To improve the efficiency of the data analysis, our study has two main objectives: 1) to ensure that fish morphological properties that could be exported from DIDSON data are accurate by experimental measures; 2) to reduce the time consuming of data analysis with an automatic tracking tool, Sonar5-Pro software.

To evaluate the accuracy of the measures through DIDSON data, 36 fish of known length have been recorded. Our results show that fish mean lengths measured by the operators are not significantly different from their true lengths. According to our results, the fish species and the fish position in the beam, such as the distance from the sonar or the fish body angle in the beam, are not influencing the accuracy of the measure.

Then, to assess the Sonar5-Pro software efficiency, sixteen files of thirty minutes DIDSON data have been analysed with the automatic tracking tool, set to detect large fish. Every exported track has been visually validated and manually measured. More than 97% of the fish crossing the DIDSON beam have been detected. Nevertheless, the results show that the abundance of truly fish is largely overestimated: only 50% of detected targets are individual fish. The fish swimming behaviours, such as the swim direction and the position in the beam are correctly estimated. The morphological characteristics results are more complex: the measured length accuracy for the smallest fish (< 45 cm) show good results. For larger fish, there is an important influence of the fish trajectory in the beam: the length estimation precision decreases when the fish moves away from a perpendicular trajectory to the beam. As expected, this method is largely our results show that DIDSON records provide accurate fish morphological information which can be efficiently exported with automatic tracking tools such as Sonar5-Pro. Nevertheless, the species identification must integrate both length and behaviour observations to maximize its efficiency and a selected targets visual validation is essential to provide an accurate fish abundance.

Investigation of array processing on the SX 90 omnidirectional multibeam fisheries sonar

Sindre Vatnehol, Dezhang Chu, and Egil Ona

An omnidirectional multibeam fisheries sonar, Simrad SX90 can provide much larger areal coverage and sample volume, and is capable of tracking fish schools in real-time. The system can also record high quality scientific data so that more advanced array processing techniques can be applied. However, due to its cylindrically shaped element configuration, it is difficult to obtain a high signal-to-noise ratio and low side-lobe levels using conventional array processing techniques for a uniform linear array (ULA). In this presentation, we investigate and compare a number of possible array processing techniques to reduce side-lobe levels. One of the techniques is to transform the non-uniform circular array (top view of a cylindrical array) to a virtual array, hence to be able to apply well known array processing algorithms. Numerical simulations

are presented to demonstrate the improvement of the proposed array processing techniques over the conventional ones.

Indirect calibration of backscatter measurements from acoustic Doppler current profilers, with application to Antarctic krill biomass estimation

Samuel S. Urmy, Joseph D. Warren

Quantitative acoustic estimates of nekton and plankton biomass and distribution rely on calibrated backscatter measurements. However, scientific echosounders are less widely deployed than other acoustic instruments, such as acoustic Doppler current profilers (ADCPs). Because ADCPs record a measure of acoustic backscatter, they have long attracted the interest of biologists, but the difficulty of calibrating them to an absolute reference level limits their usefulness for biomass estimation. We used concurrent measurements from a towfish with calibrated echosounders (38 and 120 kHz) and hull-mounted ADCPs (38 and 150 kHz) on the RV Laurence M. Gould near the South Shetland Islands and West Antarctic Peninsula to achieve an indirect calibration of the ADCPs to an absolute reference level. Qualitative patterns of backscatter estimated from the ADCPs compared well to those from the echosounders. Quantitatively, the ADCP backscatter was an unbiased estimator of the echosounder backscatter, but ADCP values varied widely about the true value, especially at short spatial scales. We also compared the calibrated ADCP backscatter to estimates of animal densities from net tows. The majority of near-surface backscatter is attributed to krill. Numerical density of krill, estimated from net tows, was positively correlated with ADCP backscatter at 150 kHz, but not at 38 kHz. These results suggest a procedure for calibrating ADCPs via short deployments of calibrated echosounders, potentially opening up a large number of “datasets of opportunity” to quantitative analysis.

On the way towards using hydroacoustic multifrequency techniques to assess Northeast Atlantic mackerel (*Scomber scombrus*)

Matthias Schaber, Tim Kirchner, Matthias Kloppmann, Sascha Fässler, Jeroen van der Kooij, Jens Ulleweit

The triennially conducted, ICES-coordinated mackerel and horse mackerel egg survey (MEGS) is carried out as a series of individual cruises from January until August. The main goal of the survey is, among others, to produce both an index and direct estimate of the biomass of the Northeast Atlantic mackerel stock. This survey is the only source providing fishery-independent information on this stock. SSB of the mackerel stock is estimated based on the daily egg production method (DEPM). Therefore, the amount of freshly spawned eggs on the spawning grounds is quantified and the fecundity of spawning females is assessed. A combination of realized fecundity of the females, freshly spawned eggs and spawners' sex ratio then provide an estimate of the spawning-stock biomass. Generally, hydroacoustic measurements of backscatter values are accepted as the best available tool to provide stock estimates of pelagic schooling fish. Up to now, application of traditional acoustics has only been applicable to a limited extent to mackerel, given they lack a swimbladder and hence are weak scatters on the traditionally used 38 kHz echograms. However, due to their peculiar backscattering characteristics at different sounder frequencies, mackerel can be hydroacoustically detected applying multifrequency techniques. We present results of a hydroacoustically derived SSB estimate of mackerel from multifrequency echosounder data sampled during the 2013 German MEGS survey and provide a comparison of the results to the indices derived from the established DEPM.

Fish sizing trials on the border of schools using broadband methods

Edil Ona, Gavin Macaulay, Armin Pobitzer and Lars Nonboe Andersen

The fishing industry has expressed special requests for methods extracting information on individual fish size in schools before the fishing operation with purse-seine. This could also potentially give valuable information in scientific acoustic surveys in future. Based upon measurements of mean and border densities in typical herring schools, we have tried to adapt the acoustic method to the problem. As the purse-seiners inspect the schools prior to fishing operation by encircling the school at a fixed distance, we have used a side-mounted narrowbeam transducer to ensonify the school with a broadband signal. Using a pulse compression and a narrowbeam, we are able to resolve targets on the border of the schools at 50 to 100 m distance. On resolved targets on the closer edge of the school, target tracking using split-beam and frequency response of the individual targets are extracted together with the orientation of the fish from the tracking information. Sizing of the fish is explored through an inversion between the measured matrix and a model matrix of the expected target response as a function of size. The measured backscattering of individual herring in the lateral orientation is also tried incorporated in the model.

Biomass estimation by echo integration using omnidirectional fishery sonar

Arne Johannes Holmin, Hector Pena, Edil Ona

Omnidirectional fishery sonars are widely used by the commercial fishing fleet, and recently also available onboard research vessels. These modern sonars have the capacity to deliver digital output the raw data. Currently, however, little has been done to exploit these data for abundance estimation of pelagic fish. In the present study echo integration methods were developed for omnidirectional fishery sonar, and the validity of the methods tested means of simulation. Schools of herring were distributed uniformly in a 20 by 20 nautical mile area, and data from the Simrad SX90 (26 kHz) sonar were simulated from a 12 hour survey of five transects. Additionally, data from a Simrad EK60 (38 kHz) echo sounder were simulated in order to compare biomass estimates of the two systems. The biomass estimates were evaluated in relation to the true biomass used as input to the simulations.

Automated extraction and parameterization of scattering layers

Roland Proud, Martin Cox, Simon Wotherspoon, Andrew Brierley

Scattering Layers have been known of since the 1960s, but no consistent method for identifying them has been established. We describe an automated and reproducible method for extraction that is independent of the acoustic frequency and spatial scale of the data. We describe an example from hull-mounted echosounders operating at 38 kHz, over two distinctly different regions of the world ocean, the Southwest Indian Ocean and the Tasman Sea. Data were obtained from the Integrated Marine Observing System. Biological Scattering Layers were extracted and defined by a set of Layermetrics that described their geographical location and extent, indicated community structure and variance, and where available, included mean physical properties. These metrics were related to the known physical and biological characteristics of the two different regions, highlighting their potential as key water column descriptors. The method has many potential applications including the rapid assessment and monitoring of ocean communities, the study of predator-prey interactions of deep diving mammals with their prey field and also the parameterization of the biological components of physical models.

EchoCAL: A mobile wireless calibration system for echosounders

Joseph Godlewski, Michael Ryan

Methods for calibrating echosounders vary widely, depending on available hardware at the research centers. The hardware can range from manually controlled downriggers, to elaborate computer controlled hardwired motorized downriggers. To date, the Northeast Fisheries Science Center in Woods Hole has relied on hardwired Cannon Downriggers to remotely steer a calibration sphere underneath the research vessel's EK60 transducers. This system worked reasonably well, but was cumbersome, and the hardware was tied to the vessel. It could not be used on other research vessels that did not have calibration hardware installed. Researchers at the Northeast Fisheries Science Center are currently developing a mobile wireless calibration system called EchoCAL that can be used on any research vessel. This system is capable of controlling up to four downriggers wirelessly. A software graphical user interface (GUI) is being developed to allow the operator to control the downriggers using either a USB joystick or buttons on the GUI that will mimic the behaviour of a joystick. The software is also capable of operating the downriggers automatically without operator input. The goal of EchoCAL is to provide the researcher with a mobile calibration system that will reduce the amount of time needed for calibrating an echosounder.

Acoustic remote sensing of sea bottom gas seeps with multibeam and multifrequency echosounders

Berger Laurent, Stéphanie Dupré, Le Bouffant Naig and Scalabrin Carla

Observation of a persistent gas seeping activity from the seabed has been demonstrated using acoustic on the continental shelf of the Bay of Biscay. Acoustic echoes from the seeps are mixed with echoes from pelagic fish and plankton in the area but can be individually resolved using the elongated form of the flares rooted at the seabed. Angular and frequency response of the bubble streams is analysed and compared to simple backscatter models.

Increasing the impact of water column sonar data through the development of a national archive

Carrie Wall, Charles Anderson, Susan McLean

Multibeam echosounders are employed routinely on NOAA fishery vessels to estimate biomass, conduct trophic- and species-level identification, measure school morphology and behaviour, and characterize habitat for commercially important species. These surveys deliver valuable information for ecosystem-based fisheries management but they also produce massive amounts of data that are costly and difficult to maintain. With its ability to store and preserve large datasets, NOAA's National Geophysical Data Center is acquiring and archiving acoustic data collected from NOAA and academic fleets. Through these efforts, an accessible archive of acoustic water column sonar data will be made available to researchers and the public around the world. To meet the archive's goal of providing access to high quality and well-documented data, a metadata editor has been developed to streamline entry at the data acquisition side and automatically generate standardized ISO metadata. A web-based search engine will allow users to query fields within the metadata (e.g., collection site, instrument type), and access the raw data and associated products. Years of decreasing funding for the sciences have necessitated our ability to get more information and more users out of data currently collected. Efforts to provide a common set of metadata terminology and definitions are critical to preserving the usefulness of large data volumes collected across a variety of vessels, geographic areas, years, and sonar equipment.

Further, standard metadata supports interoperability and sharing allowing this globally accessible archive to be linked to and fed into other public databases.

Assessing the potential of underwater gliders for ecosystem monitoring: a proof of concept study

Lavinia Suberg, Russell B Wynn, Jeroen van der Kooij, Liam Fernand, Sophie Fielding, Damien Guihen, Douglas Gillespie, Mark Johnson, Kalliopi-Charitomeni Gkikopoulou, Ian J Allan, Branislav Vrana, Peter Miller, David Smeed and Alice R Jones

A combination of scientific, economic, technological and policy drivers are behind a recent upsurge in the use of marine autonomous systems (and accompanying miniaturized sensors) for environmental mapping and monitoring. Increased spatial-temporal resolution and coverage of data, at reduced cost, is particularly vital for effective spatial management of highly dynamic and heterogeneous shelf environments. This proof-of-concept study involves integration of a novel combination of sensors onto buoyancy-driven submarine gliders, in order to assess their suitability for ecosystem monitoring in shelf waters at a variety of trophic levels. Two shallow-water Slocum gliders were equipped with CTD and fluorometer to measure physical properties and chlorophyll, respectively. One glider was also equipped with a single-frequency echosounder to collect information on zooplankton and fish distribution. The other glider carried a Passive Acoustic Monitoring system to detect and record cetacean vocalisations, and a passive sampler to detect chemical contaminants in the water column. The two gliders were deployed together off southwest UK in autumn 2013, and targeted a known tidal-mixing front west of the Isles of Scilly. The gliders' mission took about 40 days, with each glider traveling distances of >1000km and undertaking >2500 dives to depths of up to 100m. Controlling glider flight and alignment of the two glider trajectories proved to be particularly challenging due to strong tidal flows. However, the gliders continued to collect data in poor weather when an accompanying research vessel was unable to operate. In addition, all glider sensors generated useful data, with particularly interesting initial results relating to subsurface chlorophyll maxima and numerous fish/cetacean detections within the water column. The broader implications of this study for marine ecosystem monitoring with submarine gliders are discussed.

Allocating backscatter using a flexible, non-parametric Bayesian mixture model

Ian E. Fraser, John K. Horne

Partitioning backscatter among species is a crucial step when processing data for abundance estimates. Methods used to classify data are typically subjective categorizations by an analyst, or objectively rule-based with little or no quantification of uncertainty. We have adapted a semi-supervised, non-parametric Bayesian mixture model to allocate backscatter between known and unknown categories (e.g. species, age groups, species mixtures). This Dirichlet Process Mixture Model is not constrained to a predetermined number of categories; after starting with available verified categories the model creates additional categories in response to data attributes as new data are encountered. Using unclassified 2007 Eastern Bering Sea Pollock survey data at four frequencies (18, 38, 120, 200 kHz), and single-species dominated trawl verified observations from the same survey, we demonstrate methods for interpreting the Markov Chain Monte Carlo output categorization, and the creation of Bayesian credible intervals around Sv estimates for the interpreted categories. Our output includes multiple categories for known species groups, mixed species categories, and several unknown categories. In most cases the resulting credible intervals are reasonably tightly bounded, and overlap point estimates from previous analyses of the data. This model-

based approach is semi-automated, has flexible structure, and objectively categorizes data while quantifying model and sample allocation uncertainty.

Estimation of the Catchability of Redfish and Blue Whiting for Survey Trawls in the Norwegian Sea

Eckhard Bethke, Benjamin Planque

Biomass estimates of fish, derived from hydroacoustics registrations are generally dependent on biological information from trawl catches. Catch composition is necessary for accurate quantitative allocation of acoustic energy to the different species present in the water column. For this purpose, the species composition in the trawl catch must be representative of the true species composition in the ocean, which requires that the catchability of the trawl for individual species is known. The catchability is expected to be trawl- and species-specific as a result of variations in fish behaviour in front of the trawl, fright reactions, swimming speeds and other factors which can affect the chance of fish being caught or escaping. We show that catchability estimates for several species can be simultaneously derived from combined trawl-acoustics samples through a simple and straightforward optimization method. We apply the method to estimate the catchability of two important pelagic species in the Norwegian Sea, beaked redfish (*Sebastes mentella*) and blue whiting (*Micromesistius poutassou*) when fished with a large pelagic trawl, the Gloria 2048.

The Norwegian Ocean Observatory LoVe – objectives, technology and results

Olav Rune Godø

The cabled LoVe observatory was launched in September 2013 and has been collecting data since then. Passive and active acoustic instruments collect information about biomass distribution and densities as well as of their vocalisation. A time lapse camera monitors a deep water coral reef with high resolution. The environment is sampled with oceanographic and other environmental sensors. The real-time data can be observed at the data portal (<http://LoVe.statoil.com>) and historic data can be downloaded. Although the observatory is already collecting a lot of interesting data the potential will be realized and the main objectives obtained only when the planned full observatory transect is in place. We foresee that such an infrastructure will play an important role in routine monitoring and modelling of ocean climate. New knowledge of migration dynamics and recruitment mechanisms of the great oceanic stocks visiting the area are other expected outcomes. The observatory is complementary to rather than replacing existing monitoring although further geographic expansion of observatories might change this in future. Some examples of the acoustic and camera results will be presented and discussed.

Nearfield calibration of a broadband acoustic system

Dezhang Chu, Grant Eastland

In many applications in fisheries acoustics, acoustic signatures in the nearfield can play an important role in predicting the backscattering quantities accurately. It is, therefore, desirable and demanded to develop a theoretical model to accurately quantify calibrations in nearfield. In this presentation, the theoretical model, numerical simulations, and laboratory experiments in the nearfield of both target and transducer will be presented. A single transducer with a mono-static or backscattering configuration using a standard target, a 25-mm tungsten carbide sphere (WC25) was used in the experiments at different distances in the nearfield of both the transducer and the sphere. Theoretical

simulations and laboratory experiments revealed that although the shape of the frequency responses of the received echoes at different distances varied significantly, the null positions were essentially invariant, a unique characteristic that was used to determine the compressional and shear wave speeds in the calibration sphere. The agreement between the theoretical predictions and the experiment data were remarkably good. Since the transducer was located in the nearfield, the signal-to-noise ratio was high, resulting in a much wider useable bandwidth than the nominal bandwidth.

6.2 Summary of session

This session featured 27 presentations under the theme of emerging technologies, methods protocols, with emphasis of the last 10 presentations focused around the question of biomass estimation (summarized separately below). A notable feature of the presentations was the diversity of topics. These explored the integration of acoustic systems into new technologies (e.g. gliders), development of applications and calibration methods for existing and new acoustic systems (e.g. broadband, ADCP, imaging and omnidirectional sonar) and novel applications (e.g. feature extraction from publicly available acoustic datasets and quantify risk associated with extreme events). The technologies were applied at both large and small temporal and spatial scales and to non-biological questions (gas bubble seeps, vessel bubble sweep-down).

There was an emphasis on improving the use of resources in a number of ways. A presentation revisited the calibration of ADCP's proposing a method that could open up opportunities for wider exploitation of this type of acoustic data. Another presentation looked at quantifying optimal spatial densities for moorings where there are obvious cost implications if densities are higher than needed for required coverage.

Some of the new technologies and methods presented were motivated by pressing practical needs. A new broadband system was used to provide accurate size estimates of fish to guide the fishing skipper as to whether fish were of the desired length prior to executing net capture. Similarly multifrequency methods were used to inform the skipper of species in real-time in order to avoid unwanted bycatch.

Other common themes were the importance of calibration, real-time data and its public availability, integration of acoustics with complementary data, and methods to extract new information from existing datasets.

The presentations highlighted the importance of the WGFAST as a methods development forum, and members demonstrated how they were more than just purchasers of technology by presenting their methods to refine, validate, and improve precision of acoustic instrumentation. It was noted in discussions that the work presented can be at a small-scale and are feasibility studies, in keeping with a methods development focus. However, the next phase is to realize advances to wider adoption and practical application, for example to feed into the management processes.

7 TOR b: Biomass estimation: Best practice and guidance

7.1 Contributions to session

EU MEDIterranean Acoustic Survey on Small Pelagics “MEDIAS”

Magdalena Iglesias, Marianna Giannoulaki, Angelo Bonanno

In the Mediterranean Sea direct acoustic surveys on small pelagic fish have been regularly held by the European Union (E.U.) states in a regular basis since the early 00s: Iberian coast (IEO), Gulf of Lions (Ifremer), Adriatic Sea (Italy and Slovenia; ISMAR-FRIS), Croatia (IOF), Strait of Sicily - Malta (IAMC-MRRA) and Aegean Sea (HCMR). These surveys, cover the major stocks of anchovy (*Engraulis encrasicolus*) and sardine (*Sardina pilchardus*) in the Mediterranean European Union waters. These surveys are part of the Pan-Mediterranean acoustic survey (MEDIAS), funded by the Data Collection Framework (EU) and since 2009 consists an internationally coordinated acoustic survey with a common protocol. This protocol involves optimization of the survey design, standardization and harmonization concerning target strength, acoustic and biological sampling and post-processing of the acoustic data. Moreover, the MEDIAS protocol includes additional data collection during the surveys (e.g. environmental variables, zooplankton etc.) and the estimation of ecosystem indicators. Recently, other EU countries operating in the Black Sea (e.g. Romania and Bulgaria) have joined the MEDIAS protocol and scientists from North African Mediterranean countries (e.g. Morocco, Algeria and Tunisia) and Turkey working on fisheries acoustics assist regularly the MEDIAS meetings.

Dealing with mixed species in estimating abundance from New Zealand acoustic surveys

Richard L. O'Driscoll

Partitioning of acoustic backscatter from mixed species marks is one of the major sources of uncertainty in acoustic surveys of New Zealand deep water species, including hoki, orange roughy, and oreo. The most common approach has been to use estimates of species composition from trawl samples, but more recently attempts have been made to improve estimates using novel camera and acoustic technologies. Estimates based on trawl samples are dependent on knowledge of the acoustic target strength of the target and associated species, and assumptions about relative catchability. A Monte Carlo simulation method is used, which combines uncertainties associated with various aspects of the acoustic methodology including species' composition and target strength. The resulting estimate of precision (expressed as the coefficient of variation or c.v.) is used to weight the results from each acoustic survey in stock assessment models. The effect is that surveys with a large proportion of the target species in mixed marks are treated as less certain than surveys from predominantly single-species aggregations.

StoX – an open source approach to acoustic and swept area survey calculations

A. Totland, Å. Skålevik, H. Gjøsæter, N. O. Handegard, S. Lid, and E. Johnsen

StoX is open source software developed at IMR, Norway to calculate survey estimates from acoustic and swept area surveys. The program is a stand-alone application build with Java for easy sharing and further development in cooperation with other institutes. The underlying high resolution data matrix structure ensures future implementations of e.g. depth dependent target strength and high resolution length and species information collected with camera systems. Despite this complexity, the execution of

an index calculation can easily be governed from user interface and an interactive GIS module, or by accessing the Java function library and parameter set using external software like R. Accessing StoX from external software may be an efficient way to process time-series or to perform boot-strapping on one dataset, where for each run, the content of the parameter dataset is altered. In the first version a stratified transect design is assumed (e.g. the IESNS survey plan 2014) and standard statistical methods to estimate mean and variance of abundance will be used. Other methods will be implemented, however, expert specification demands, documentation and statistical rigorousness is essential in the development of “StoX”. The software will be fully tested on data collected on the blue whiting acoustic survey carried out west of Ireland and Britain in 2014.

WGIPS coordinated surveys- an overview of the groups work

ICES Working Group on International Pelagic Surveys (Chairs: Ciaran O'Donnell, Ireland and Karl-Johan Staehr, Denmark)

Ciaran O'Donnell

WGIPS coordinates 29 individual acoustic surveys undertaken in the Northeast Atlantic by nine countries (Ireland, Germany, UK (England, Scotland and Northern Ireland), Russian Federation, Norway, Netherlands, Faroe Islands, Denmark and Iceland), totalling 519 sea days annually. Four multinational coordinated surveys are undertaken as well as 4 individual surveys at national level.

The group reports on the distribution and abundance of stocks of herring, blue whiting, mackerel, boarfish and sprat to ICES for inclusion into the stock assessment process. Geographical coverage extends from 46°N to 74°N and from 30°E to 18°W. The group also reports on herring larval surveys carried out in the North Sea and zooplankton biomass in the Norwegian Sea.

WGIPS surveys are constantly evolving to meet the requirements of the assessment groups and providing data for ecosystem modelling. New research has allowed for the quantitative measurement of 'new' species such as boarfish and the group works actively to help develop techniques that can be applied to key species including mackerel.

The use of opportunistically recorded acoustic data to supplement dedicated fisheries independent surveys

Jeroen van der Kooij, Sascha M. M. Fässler, Susan M. Lusseau, Cormac Nolan, Kjell R. Utne and D. Stephens

Fisheries independent monitoring of widely distributed pelagic fish species which conduct large seasonal migrations is logistically complex and expensive. One of the commercially most important examples of such a species in the Northeast Atlantic Ocean is mackerel for which up until recently currently only an international triennial egg survey contributed to the stock assessment. In this study we explore whether fisheries acoustic data, recorded opportunistically during the English component of the North Sea International Bottom Trawl Survey (Q3 IBTS) and during a dedicated international herring survey (HERAS), can contribute to an improved understanding of mackerel distribution and provide supplementary data to existing dedicated monitoring surveys. Using a previously published multifrequency acoustic mackerel algorithm we extracted the distribution and abundance of schooling mackerel for the North Sea between July and September for several years. In 2013 we had the opportunity to compare the opportunistic data to a dedicated mackerel survey, which extended beyond

the usual survey coverage further south into the North Sea. Different sampling methods are compared and interpreted. The quality of the opportunistically recorded data is discussed and, despite inevitable compromises, we recommend that fisheries acoustic data, even when not the primary aim of the fieldwork, should be recorded more widely as they can provide relatively cheap, valuable scientific information. In the case of mackerel we hope that the improved understanding of mackerel distribution during the feeding season may contribute to a sustainable management plan.

Progress in Developing an Acoustic Method to Estimate Biomass and Abundance of Hawaiian Semi-DEMERSAL Fish for Stock Assessment Models

Réka Domokos

Currently, only fisheries dependent methods are used for stock assessment models of economically important 6 Hawaiian snapper species and an endemic grouper (the “Deep 7”). The application of acoustics methods to assess these fish is challenging due to high rugosity and mixed associations of these fish in their habitat. To define acoustic descriptors to identify the Deep 7 as a group, and, if possible, separate species, a variety of methods are used. A TS-SL relation is estimated from data points obtained from in situ TS measurements of fish with known sizes and from simultaneous acoustic recordings during stereo-video camera observations and fishing. Available data points ($n = 12$) give $TS = 23.75 \cdot \log_{10}(SL) - 72.08$, although more points are needed to increase the accuracy of the TS-SL equation. Available data indicate that size and shape of aggregations and dB differencing of TS and Sv might help in classification of Deep 7 echoes. Preliminary analyses suggest that differences in aggregative behaviour of fish with various sizes, as well as their species-dependent preferences of depth, relief type, and distance from bottom, can also be used for separation of Deep 7 from other bottomfish species and for separation of Deep 7 into species or into smaller groups. Using the established acoustic descriptors, biomass and abundance of Deep 7 were estimated from data collected on 4 surveys during 2012–2013. While improving acoustic descriptors will change absolute biomass and abundance estimates of the Deep 7, these values can be currently used as relative indices to monitor changes in bottomfish stocks over time.

Standard Target Calibration of Simrad EK80 Wide Band Transceivers (WBTs)

Andone Lavery, Gareth Lawson, Michael Jech, Dezhang Chu, Lars Nonboe Andersen, Jeffrey Condiotty, Thomas Weber, Carlo Lanzoni, Gavin Macaulay

Kongsberg Simrad has developed a broadband echo sounder transceiver (aka “Wide Band Transceiver” or WBT) with the capability of transmitting and receiving continuous wave (CW) or chirp (linearly modulated frequency) signals over a frequency range of 10 to 500 kHz. While the WBT has a very wide operating frequency range, transducers limit the transmit/receive spectrum for each WBT. We define broadband as spanning a continuous spectrum whereas the wideband approach encompasses multiple broadband signals and even narrowband signals to widen the overall frequency content. Broadband technology greatly increases the amount of data, but it is imperative to translate this data into information, and more importantly into useful metrics that will improve our ability to understand the aquatic environment. The first step in this translation is calibration. As with narrowband echo sounders, WBTs must be calibrated and the logistics of using standard targets is common between the two types of echo sounders. However, because broadband processing adds another dimension – frequency – the analytical complexity is substantially greater. We calibrated six WBT/split-beam transducer pairs (transducer center frequencies of 18, 38, 70, 120, 200, and 333 kHz) using standard targets (15, 21.2, and 38.1 mm tungsten carbide; 20 mm

stainless steel; 200 and 300 mm aluminium). We discuss the commonalities and differences between narrowband and broadband single beam and split-beam calibrations, suggest best calibration practices and methods of determining optimal operating parameters, such as bandwidth, signal duration, and power, as well as approaches to diagnose and evaluate broadband calibration, and illustrate the significant improvement in calibration ease and accuracy when employing a broadband split-beam system vs. a broadband system without split-beam capabilities, particularly at high frequencies.

Deepwater acoustic surveys for sustainable fisheries management impact

Kloser R. J., Ryan T. E.

The path to impact for acoustic surveys is often determined by the fishery and governance structure of the fishery being managed. For small-scale deep sea remote fisheries the combined use of fishing vessels with novel technologies has proven useful. To highlight this we review a 10 year time-series of acoustic surveys on the blue grenadier fishery that are based on fishing industry led surveys. The impact of these surveys for management was done when we could refine the species in situ target strength using a net attached acoustic optical system (AOS). The acoustic data could then be used as an absolute estimate and provide a lower bound to stock assessment model sensitivity tests. A different example has been the small-scale orange roughy fishery that has changed its governance structure over a 24 year period. Over time the acoustic survey method and technology is having a large affect the fishery assessment mainly due to the refinement of the species target strength, two frequency biomass estimates and lowering of the error estimate. Novel sampling methods of using a net attached AOS to carry out the surveys has meant these surveys are cost-effective and can be done in remote locations. Uptake by the Australian and New Zealand fishing industry has been a tangible outcome. The protocols and software tools are also discussed.

Acoustic and Trawl-based Atlantic herring population estimates in the Gulf of Maine

J. Michael Jech

Estimates of Atlantic herring (*Clupea harengus*) abundance and biomass in the Gulf of Maine were derived from annual acoustic/midwater trawl surveys and bottom-trawl surveys with concurrently collected acoustic data. Acoustic data were collected continuously with Simrad EK500 and EK60 echo sounders operating at 12 or 18, 38, and 120 kHz. Abundance estimates derived from the acoustic data collected during the bottom-trawl and acoustic surveys show similar trends, which are not consistent with trends from bottom-trawl catches. Spatial and temporal patterns of herring distribution are investigated to discern whether acoustic and trawl data can be used in concert to generate accurate population estimates. During spawning and prespawning conditions, herring aggregate in mono-specific shoals. At other times, they co-occur in trawl catches with other species such as Acadian redfish, silver hake, and dogfish, suggesting a mixing of species. The spatial resolution of a trawl may not be sufficient to address at what spatial scales species are segregated. Future development of broadband acoustics may provide the necessary spatial and spectral resolution to discern species and at what scales they co-occur.

7.2 Summary of session

At the workshop of SSGESST expert group chairs (WKESST), which met in September 2013, it was requested that *WGFASST should consider aiding survey groups with choosing the best practice methods for carrying out biomass estimation, also by pointing out software tools*. Biomass estimation is at the heart of WGFASST activities as was demonstrated by the ten presentations in this session but also numerous other presentations discussed in previous sessions.

Best practice for carrying out acoustic biomass can be decomposed into several issues, where each has its own uncertainties and biases which can impact final biomass estimates:

- a) Survey preparation (survey design, echosounder calibration, ...)
- b) Survey realization (trawling stations, acoustic and auxiliary data collection, quality control, ...)
- c) Data preprocessing (scrutinizing, data selection, filtering, echo-integration, ...)
- d) Target species biomass estimation (mixed species, layers and diffusely distributed individuals, ...)
- e) Non-target species and plankton estimation (multifrequency algorithms, mixed-species groups, ...)

Several presentations showed how these steps link together to provide final biomass estimates which will then be used as input for stock assessment models. An important dimension is the international nature of many survey programs, such as MEDIAS in the Mediterranean Sea and many of the acoustic surveys coordinated by WGIPS which stresses the need for efficient workflow organization, standardization, and data storage.

Several presentations focused on ways to estimated uncertainty; the methods ranged from Monte Carlo simulations to using “independent” biomass estimates based on different echosounder frequencies. Overall it emerged that scientists using acoustics for biomass estimation have invested much thoughts and effort into identifying and estimating sources of uncertainty and reducing these uncertainties when this is possible, e.g. by improving TS equations, ground-truthing using optics, analysing vertical distributions and diel variations, carrying out simulations, etc. Paradoxically however, these efforts to understand and quantify sources of uncertainty can lead users such as stock assessment scientists to erroneously conclude that acoustic biomass estimates are too unreliable to be useful, compared to, for example, commercial landings data or bottom-trawl survey abundance indices for which bias and uncertainties caused by spatio-temporal variations in catchability, gear performance, species behaviour, etc. remain largely unexplored and therefore are commonly ignored.

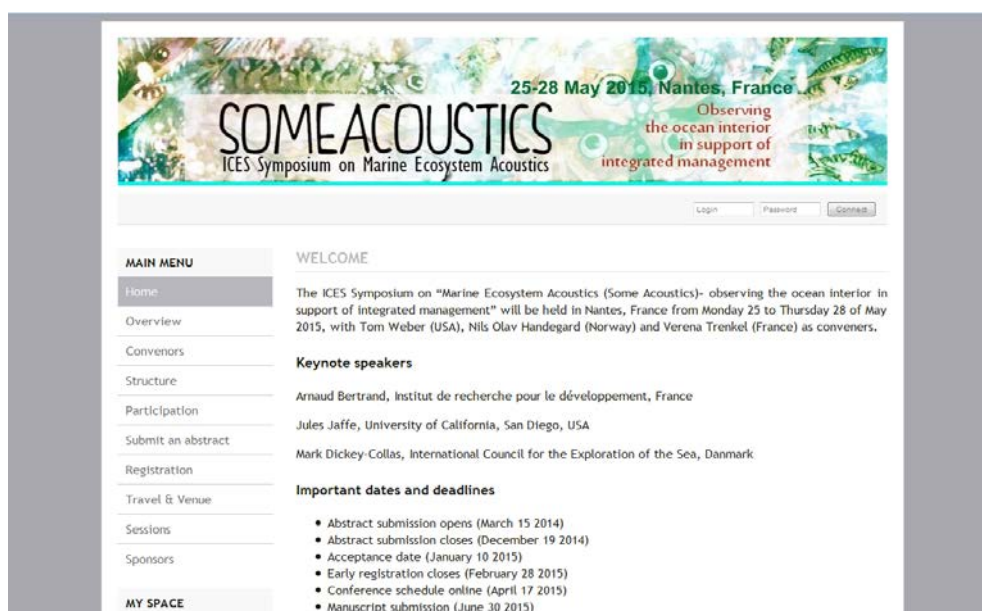
8 TOR d: Organize international acoustic symposium

The ICES Symposium on Marine Ecosystem Acoustics will be held in Nantes, France from 25–28 May 2015. The primary aim of the symposium is to bring together scientists and ideas from various fields to facilitate and catalyse interdisciplinary interactions, with acoustics as the central tool, to further the development of marine ecosystem acoustics. This will be the 7th ICES sponsored Symposium on Fisheries Acoustics and Technology investigating aquatic ecosystems.

The Symposium will be organized around three main themes:

- Recent developments in acoustic sensor and platform technologies
- Acoustic characterization of aquatic organisms, ecosystem structure, and ecosystem processes
- The contribution of acoustics to integrated ecosystem assessments and management.

Symposium website someacoustics.sciencesconf.org:



9 TOR e: Organize joint sessions at ICES ASC

WGFAST was solicited by the working group on Integrating Surveys for the Ecosystem Approach (WGISUR) to put forward a joint proposal for a theme session at the 2015 ICES Annual Science conference in Copenhagen. The working group on Marine Habitat Mapping (WGMHM) was also contacted. The tentative session title is "New tools and methods for integrated monitoring", with key sentences "Recent advances in marine sampling techniques, including fieldwork methodology, and data analysis and interpretation", "Focus on integrated monitoring and ecosystem approach" and "How to use resources efficiently". The possible content of this theme session was discussed during the WGFAST meeting and the following suggestions were made for additional keywords/sentences. "Joint use of optics and acoustics", "use of existing tools in innovative ways", "Survey design/logistics", "need to accommodate too many objectives/players under the ecosystem approach which can degrade quality of collected data (e.g. acoustics and trawling,..)". The chair of WGFAST will pursue the proposal together with WGISUR and WGMHM.

10 Reports and updates from associated groups and miscellaneous issues

10.1 Update from SSGIEOM

Nils Olav Handegard, co-chair of the new joint ACOM and SCICOM Steering Group on Integrated Ecosystem Observation and Monitoring (SSGIEOM), informed the working group about the 3-year TORs of SSGIEOM. An important main aim of the group is to provide a link between working groups and the "users". He then focused on TORs most relevant to WGFAST:

- g) Identify shortfalls in skills and knowledge needed to achieve the SG objectives, and where capacity building is needed in particular areas, so that ICES can develop training or other solutions.
- h) Map the EGs and their ToRs against the information and data that ICES needs to deliver the Science Plan and its advisory work, suitably prioritized (SP1.1).
- i) Promote continued improvements and innovation in the design and technology of surveys and other data collection schemes implemented in support of stock assessments and ecosystem studies, leading to gains in survey efficiency, increased diversity and resolution of data collected, and improvements in the interpretation, quality, utility and impact of the data in ICES advice (SP2.1,2.2).
- m) Promote the development within EGs of standards and guidelines for good practice in data collection covering the design and implementation of surveys, fishery and other related data collection programmes, the archiving and interpretation of data and samples, the analysis of data, provision of data quality indicators, and the documentation of procedures." (SP3.1)

Regarding g), WGFAST discussed the needs and contents of a potential acoustic training course (see section 9.5). The work presented during WGFAST contributes directly to i). Related to m), SSGIEOM launched an initiative to create an ICES database for acoustic survey data for surveys coordinated by survey groups which are under SSGIEOM.

10.2 Study Group on Calibration of Acoustic Equipment (SGCAL)

David Demer, Chair of the Study Group on Calibration of Acoustic Equipment, presented the current status of the CRR on Calibration of Acoustic Equipment. The ten chapters are drafted and are currently being edited. They cover a range of instruments from single and multibeam to broadband and ADCPs system deployed on various plate-forms. The final version of the CRR will be submitted in time for the ICES ASC in September 2014.

10.3 Topic Group on metadata standards

On Tuesday 6th of May a side meeting of the Topic Group on Acoustic Metadata was held at the WGFAST meeting in New Bedford with an update given to the working group on the 8th of May.

The primary work of the topic group is complete with the online publication of the metadata convention in September 2013 as part of the Series of ICES Survey Protocols (SISP). The URL for the document is: [http://www.ices.dk/sites/pub/Publication Reports/ICES Survey Protocols \(SISP\)/SISP-3 A metadata convention for processed acoustic data from active acoustic systems.pdf](http://www.ices.dk/sites/pub/Publication%20Reports/ICES%20Survey%20Protocols%20(SISP)/SISP-3%20A%20metadata%20convention%20for%20processed%20acoustic%20data%20from%20active%20acoustic%20systems.pdf).

Since its publication the following organizations or entities have indicated that they are intending to implement the metadata convention as part of their data management processes: Southern Ocean Network of Acoustics, IMOS (Australia), SPRFMO, NOAA (USA), Ifremer (France), IRD (France), ICES Acoustic Database, NIWA (New Zealand), Fisheries and Oceans Canada. As the implementation processes is realized it is expected that the metadata convention may require refinement of existing attributes or possibly the addition of new ones. Further, the implementation itself is likely to be an area of interest now that the metadata convention is complete. Already there have been productive discussions among members with sharing of database schemes that incorporate the metadata convention. For these reasons the Metadata Topic group intends to continue primarily as an email forum to address questions around the metadata convention and its implementation.

The metadata convention will be revised if appropriate with updated document (with revisions noted) published at the existing URL. FAST members or interested colleagues (e.g. data and metadata specialists) are welcome to join the email list by sending an e-mail to tim.ryan@csiro.au.

10.4 Working group on acoustic multi- frequency target classification (WGTC)

The Working Group on Target Classification met in New Bedford, USA, on Saturday 3 – Sunday 4 May. The meeting was chaired by Rolf Korneliussen (IMR, Norway). The group was created by WGFAST to prepare a Cooperative Research report (CRR) on acoustic target classification. The meeting was attended by 16 participants. This was the first meeting; there was essentially no written preparation required by the participants prior to this meeting. Nine presentations on target classifications were made. The content of the CRR was discussed, avoiding overlap with previous CRRs, e.g. CRR 238 on echo-trace classification and CRR 286 on acoustic seabed classification. The group discussed the term “Target Classification” and defined it to essentially mean “species identification”. Further, the contributors for each chapter were listed (all meeting participants will contribute to the CRR). It was agreed that the CRR will provide an overview and offer broad advice regarding target classification as well as include examples,

but it will not suggest strict recipes for how to classify targets. The meeting report will be finished in June 2014.

10.5 Workshop on fishing vessels as scientific platforms

A workshop on “Fishing vessels as scientific platforms: indicators and protocols for an Ecosystem Approach to Pelagic Fisheries” was organized by IREA (Instituto de Recursos Acuáticos) in the facilities provided by the Universidad del Pacífico (Monday, 28 April) and the UNDP offices (29 April – 2 May) with chair Francois Gerlotto. The main objective of the workshop was to inform the members of the fisheries acoustics community on the activities, projects, data and methods used by the Peruvian scientists to monitor the pelagic stocks, with particular attention to jack mackerel (*Trachurus murphyi*). The meeting focused on how to advance the use of acoustic data collected aboard fishing vessels for scientific research and specifically for jack mackerel.

The general conclusion from the meeting was that acoustic data from fishing vessels represent a unique source of extremely important information and that they can already be used for scientific purposes such as temporal and spatial movement of fish. To advance the use of fisheries acoustics for scientific purpose will require the adoption of a number of protocols for data collection, calibration, meta-data and database design and data quality that can be informed from the existing ICES WGFAST protocols in this area.

Given the wide use of fishers acoustics in South America and elsewhere there was support for an international network focused on the use of fishers’ acoustic data. Such a network should maintain the communications between the different partners, help to transmit information on the field of interest, organize meetings and workshops at a rhythm to be defined. It was proposed that IREA explore the possibility of such a structure and submit some proposal on its organization, objectives, activities, etc. It was also proposed that a series of scientific papers should be written and published in peer reviewed journals.

10.6 Miscellaneous issues

The question of organising a joint symposium with WGFTFB was raised during the joint session. The issue was further discussed during the WGFAST meeting. The general feeling was that the joint session had worked very well this year but it seemed less certain that there would be enough interest in a full-scale symposium in the near future, in particular with the ICES symposium on Marine Ecosystem Acoustics in 2015. So the consensus was not to pursue this possibility immediately.

The possibility to organize an ICES training course on fisheries acoustics was discussed. This issue will be pursued by a subgroup over the coming year.

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SURNAME	FIRST NAME	E-MAIL	AFFILIATION	COUNTRY
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Annex 2: Agenda

	TUESDAY May 6 2014	Session
8:45–9:00	House keeping	
9:00–9:20	WGFAS opening	
9:20–9:40	Trends in mesopelagic biomass using time-series of acoustic backscatter data from trawl surveys Richard L. O'Driscoll, Johannes Oeffner, Stephane Gauthier	Applications of acoustic methods to characterize ecosystems Chair: Gareth Lawson
9:40–10:00	The distribution of blue whiting West of the British Isles and Ireland Sven Gastauer et al.	
10:00–10:20	Comparative approach of fish communities in large estuaries through acoustic observations: the Zeeschelde estuary (Belgium)vs. the Gironde estuary (France) Valéry Samedy et al.	
10:20–10:40	Estimate of fish biomass using geostatistics Dezhang Chu	
10:40–11:10	COFFEE BREAK	
11:10–11:30	Biomass estimates for selected herring schools using omnidirectional fisheries sonar and echo sounder Hector Peña, Egil Ona	
11:30–11:50	Exploration of the relationship between micronekton composition and frequency response in the framework of the NECTALIS surveys in the New Caledonian ZEE A. Lebourges-Dhaussy, V. Alain, C. Menkès	
11:50–12:10	The distribution and behaviour of mesopelagic fish West of the British Isles Sven Gastauer et al.	
12:10–12:30	Acoustically derived zooplankton abundance in the northern North Sea Sascha Fässler et al.	
12:30–14:00	LUNCH BREAK	
14:00–14:20	A decade of Tasman Sea bioacoustics Rudy J. Kloser et al.	
14:20–14:40	Use of commercial fishing vessels for surveying herring in the Gulf of Maine Katharine Wurtzell et al.	
14:40–15:00	Bubble release in pelagic fish species – what are the causes and implications? Olav Rune. Godø et al.	
15:00–15:20	Marine Ecosystem Surveys David Demer and Juan Zwolinski	
15:20–16:00	Discussion	
16:00–16:20	TEA BREAK	
16:20–16:30	SICOM Update – Nils Olav Handegard	WGFAS
16:30–16:40	SGCal - David Demer	
16:40–17:00	WGFAS business	
17:00–19:00	User group meetings: Metadata, ..	
	WEDNESDAY May 7 2014	Session
8:50–9:00	House keeping	
9:00–9:20	Improved fishing selectivity by using multifrequency species identification methods Sascha M.M. Fässler et al.	Acoustic properties of marine organisms Chair: Richard O'Driscoll
9:20–9:40	A tale of two coasts: Material properties of North Pacific nekton and zooplankton and coastal Atlantic forage fish Joseph D. Warren, Kaylyn N. Becker	
9:40–10:00	Comparison of the Z- score and +MVBS techniques in use of multifrequency data for discriminating the backscattering of the Black Sea copepod <i>Calanus euxinus</i> Serdar Sakinan, Ali Cemal Gucu	
10:00–10:20	Target strength of Atlantic mackerel Ben Scoulding, Paul Fernandes	
10:20–10:40	COFFEE BREAK	
10:40–11:00	Categorization acoustic multifrequency survey-data Rolf Korneliussen, Yngve Heggelund, Daniel Patel, Inge K. Eliassen	
11:00–11:20	The Acoustic Scattering Web Tool Michael Ryan, Michael Jech	
11:20–11:40	Field Measurements of Volume Backscattering Strength From Fish and Zooplankton Over a Wide Frequency Band (15 - 400 kHz) Gareth Lawson et al.	
11:40–12:00	Discussion	
	THURSDAY May 8 2014	Session
8:50–9:00	House keeping	
9:00–9:20	Combining optics and acoustics to determine <i>in situ</i> acoustic properties of zooplankton and marine snow Christian Briseño-Avena et al.	Acou prop

9:20–9:40	Use of efficient boundary integral equation solvers for fish target strength calculation Geir Pedersen et al.	Chair OD
9:40–10:00	Pilot Study using a Wave Glider towed echo-sounder system for fisheries acoustic surveys Lawrence C. Hufnagle Jr. et al.	Emerging technologies, methodologies, and protocols Chair: Tim Ryan
10:00–10:20	Characterization of bubble sweep-down occurrence on the Research Vessel Thalassa Berger et al.	
10:20–10:40	Using acoustic data to quantify and predict extreme events in monitoring programs John K. Horne et al.	
10:40–11:00	COFFEE BREAK	
11:00–11:20	Experimental validation of DIDSON data and data analysis optimization using Sonar5-Pro François MARTIGNAC et al.	
11:20–11:40	Investigation of array processing on the SX 90 omnidirectional multibeam fisheries sonar Sindre Vatnehol et al.	
11:40–12:00	Indirect calibration of backscatter measurements from acoustic Doppler current profilers, with application to Antarctic krill biomass estimation Samuel S. Urmy, Joseph D. Warren	
12:00–12:20	On the way towards using hydroacoustic multifrequency techniques to assess Northeast Atlantic mackerel (<i>Scomber scombrus</i>) Matthias Schaber et al.	
12:20–12:40	Fish sizing trials on the border of schools using broadband methods Egil Ona et al.	
12:40–14:00	LUNCH BREAK	
14:00–14:20	Biomass estimation by echo integration using omnidirectional fishery sonar Hector Pena, et al.	
14:20–14:40	Automated extraction and parameterization of scattering layers Roland Proud et al.	
14:40–15:00	EchoCAL: A mobile wireless calibration system for echosounders. Joseph Godlewski, Michael Ryan	
15:00–15:20	Acoustic remote sensing of sea bottom gas seeps with multibeam and multifrequency echosounders Berger Laurent et al.	
15:20–15:40	Increasing the impact of water column sonar data through the development of a national archive Carrie Wall et al.	
15:40–16:00	TEA BREAK	
16:00–16:20	Assessing the potential of underwater gliders for ecosystem monitoring: a proof of concept study Lavinia Suberg et al.	WGFAST
16:20–16:40	Allocating backscatter using a flexible, non-parametric Bayesian mixture model Ian E. Fraser, John K. Horne	
16:40–17:00	Estimation of the catchability of redfish and blue whiting for survey trawls in the Norwegian Sea Eckhard Bethke, Benjamin Planque	Session
17:00–17:20	Metadata update - Tim Ryan	
17:20–17:40	WGTC update – Rolf Korneliussen	Emerging technologies, methodologies, and protocols Chair: Tim Ryan
	FRIDAY May 9 2014	
8:50–9:00	House keeping	
9:00–9:20	The Norwegian Ocean Observatory LoVe – objectives, technology and results Olav Rune Godø	
9:20–9:40	Nearfield calibration of a broadband acoustic system Dezhang Chu, Grant Eastland	
9:40–10:10	Discussion	
10:10–10:20	Request for providing guidance on biomass estimation methods by WGFAST Verena Trenkel	
10:20–10:40	EU MEDiterranean Acoustic Survey on Small Pelagics “MEDIAS” Magdalena Iglesias et al.	
10:40–11:10	COFFEE BREAK	
11:10–11:30	Dealing with mixed species in estimating abundance from New Zealand acoustic surveys Richard L. O'Driscoll	
11:30–11:50	StoX – an open source approach to acoustic and swept area survey calculations A. Totland et al.	
11:50–12:10	WGIPS coordinated surveys	

	<i>Ciaran O'Donnell</i>	
12:10–12:30	The use of opportunistically recorded acoustic data to supplement dedicated fisheries independent surveys <i>Jeroen van der Kooij et al.</i>	
12:30–14:00	LUNCH BREAK	
14:00–14:20	Progress in Developing an Acoustic Method to Estimate Biomass and Abundance of Hawaiian Semi-Demersal Fish for Stock Assessment Models <i>Réka Domokos</i>	
14:20–14:40	Standard Target Calibration of Simrad EK80 Wide Band Transceivers (WBTs) <i>Andone Lavery et al.</i>	
14:40–15:00	Deep water acoustic surveys for sustainable fisheries management impact <i>Rudy Kloser, Tim Ryan</i>	
15:00–15:20	Acoustic and Trawl-based Atlantic herring population estimates in the Gulf of Maine <i>J. Michael Jech</i>	
15:20–15:40	TEA BREAK	
15:40–16:15	Discussion on how to provide guidance on biomass estimation	
16:15–17:00	WGFAST business	WGFAST
17:00	Meeting closure	

Annex 3: Group photo



Annex 4: WGFAS multi-annual terms of reference (TORs) for the period 2014–2016

The **Working Group on Fisheries Acoustics, Science and Technology** (WGFAS), chaired by Verena Trenkel, France, will meet in Nantes, France, 29 May 2015, to discuss the outcome of the ICES Symposium on Marine Ecosystem Acoustics and generate deliverables as listed in the Table below.

WGFAS will report on the activities of 2015 (the second year) by 30 June 2015 to SSGIEOM.

ToR descriptors

ToR	Description	Background	Science plan topics addressed	Duration	Expected deliverables
a	Produce a list of papers originating in the community of the WGFAS working group	The WGFAS community produces several papers every year, and an update on recent WGFAS that acknowledges ICES is important..		Year 1, 2 and 3	An updated reference list
b	Present recent work within the topics “Applications of acoustic methods to characterize ecosystem”, “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	Write a review to showcase the work of WGFAS with particular emphasis on its relevance to the ICES/ACOM strategic plans	After three years a review paper will be written to showcase the work of WGFAS		3 year	Write a review paper showing the WGFAS contribution over the last 3 years
d	Organize international acoustic symposium	Organize the 8th international symposium with working title “Marine Ecosystem Acoustics – observing the ocean interior across scales in support of integrated management”		2015	Symposium and special issue in ICES Journal of Marine Science

e	Organize joint sessions at ICES ASC	Organize joint sessions with survey working groups to foster collaboration regarding the use of acoustics data and cross-fertilization	2 or, 3	Topic session at ICES ASC
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Supporting information

Priority	Fisheries acoustics and complementary technologies provide the necessary tools and methods to implement the ecosystem approach to fisheries management within ICES and research into their application and further development is vital.
Resource requirements	No new resources will be required. Having overlaps with the other meetings of the Working, Planning, Study and Topic Groups increases efficiency and reduces travel costs.
Participants	The Group is normally attended by some 60–70 members and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to ACOM and groups under ACOM	There are no obvious direct linkages.
Linkages to other committees or groups	The work in this group is closely aligned with complementary work in the FTFB Working Group. The work is of direct relevance to the survey planning groups within SSGESST and WGISUR.
Linkages to other organizations	The work of this group is closely aligned with similar work in FAO, the Acoustical Society of America, the South Pacific Regional Fisheries Management Organization and the American Fisheries Society.