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

16–19 April 2013

San Sebastian, Spain



**ICES**

International Council for  
the Exploration of the Sea

**CIEM**

Conseil International pour  
l'Exploration de la Mer

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## Executive summary

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The Working Group on Fisheries Acoustic Science and Technology (WGFASST) met at the Aquarium, Donostia-San Sebastian, Spain, from the 16–19 April 2013. Nils Olav Handegard (Norway) served as Chair and Verena Trenkel (France) as rapporteur. There were 75 participants from 21 countries who contributed to the five terms of reference with 46 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 and the study group on Calibration of acoustic equipment.

### Highlights

The major themes addressed during the meeting included:

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

A separate session was held for each theme, where the participants first presented the latest results of their work, followed by a discussion which in particular addressed future challenges within each theme. The abstracts and discussion summaries are given in the report.

The primary themes covered in the Acoustic properties of marine organisms session included establishment of target strength (TS) relationships for several target species, often combining *in situ* measurements with model derived TS relationships or additional observations, e.g. videos. The increased use of multiple frequencies, broadband systems and sonars adds new dimensions to the classical two-dimensional target-strength-body-length relationship. It was stressed that TS values are not deterministic, but subject to multiple sources of variability. What matters in terms of biomass estimates is their joint effect, i.e. their part in the error budget of acoustic abundance estimates. Both models and *in situ* measurements are needed to move our knowledge of TS relationships forwards.

The presentations in the session on Applications of acoustic methods to characterize ecosystems illustrated that acoustics information is now widely and routinely used in conjunction with environmental observations, but also various other sample data to investigate pelagic ecosystem spatial patterns and their properties. The investigations covered a wide range of spatial scales, from local studies to ocean basins. To carry out this work data availability is crucial. WGFASST recommends making processed acoustics data available as much as possible to the wider ecological scientific community to extend and promote the use of acoustic data. Several presentations used the dB-difference method or some variants of it in different ecosystems around the world to separate zooplankton from fish. A recurrent issue was layers of bubbles or gas-bearing organism which can mask less strong scatterers such as zooplankton - the identity of these bubbles remains elusive despite various attempts at identifying their source.

Behaviour remains a central area of activity for WGFASST. The studies presented in this session fall into three broad categories: 1) studies for obtaining information to ensure acoustic results, e.g. abundance estimates, are unbiased or bias is known; 2) studies of individual fish behaviour to gain new insights into behavioural ecology or

information which can be used to optimize survey design; 3) studies of population behaviour, in particular their spatial and temporal distribution patterns in relation to abundance and environmental changes. The population behaviour perspective offers a way to introduce behaviour into the analysis and study of ecosystem processes and changes. WGFASST encourages these types of studies and expects to see more of them in future.

The last theme session was devoted to emerging technologies, methodologies, and protocols, which is a core activity of WGFASST. Recent advances in low energy demands of the current generation of autonomous instruments opens up possibilities for a more widespread deployment of acoustic and other sensors. The expansion of the use of multibeam and omnidirectional sonars was demonstrated. Calibrating sonars is becoming more accessible and refined. Several contributions illustrated new methods for extracting information on school morphology and dynamics from multibeam sonar data and fish orientation from multibeam echosounder data using advanced statistical methods or the comparison of simulation models with data. A variety of platforms are now routinely used for collecting data. For example, it was illustrated how acoustic data collected on fishing vessels can be used for studying a variety of ecological questions as well as fleet behaviour. Wider use of data collected on fishing vessels is expected in future. The challenge will be to develop a kind of "self calibration" methodology. Technological progress is also needed for real-time compression and transmission of large amounts of data.

## 1 Opening of the meeting

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Nils Olav Handegard, WGFASST Chair opened the meeting, and welcomed the working group members to San Sebastian. He thanked the host Guiellermo Boyra for his hospitality and noted the long-standing contributions of AZTI-Tecnalia to marine science. Adolfo Uriarte, Director of the marine research division of AZTI-Tecnalia welcomed the membership of WGFASST to the aquarium in San Sebastian. The president of the aquarium, Vicen Zaragueta, welcomed the participants to the aquarium (in Spanish, translated by A. Uriarte). He addressed the progress of technology and its use and misuse, and used the accident of the cruise liner Costa Concordia to reflect upon the impact of human failure when blindly trusting technology. He stressed the importance of the balance between technology and ethics - technology is not good or bad as such, it depends on how it is used. He went on to reflect on the role of education for mastering technology.

The Chair Nils Olav Handegard introduced the structure of the working group and the terms of reference. Several study groups and other initiatives will be reporting on progress. The new Chair Verena Trenkel from Ifremer (France) was introduced (co-Chair in 2013 and chairing from 2014).

## 2 Adoption of the agenda

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The **Working Group on Fisheries Acoustics Science and Technology** (WGFASST), chaired by Nils Olav Handegard, Norway, will meet in 2013 in San Sebastian, Spain, April 16-19 2013. The TG-AcMeta (topic group on meta data standard) will meet Monday 15 April and the SGCAL will meet Saturday 20 April in Paseia at Azti-tecnalia.

- a) In response to the ICES strategic plan 2009 – 2013, WGFASST will document how acoustic and complementary methods will contribute to the goals of an ecosystem approach with benthic and pelagic observations to improve assessment and management of living marine resources, understanding mechanisms and processes of change and stability, and parameterize and evaluate models of ecosystem structure and function. Four main categories of work will be addressed:
  - i) Applications of acoustic methods to characterize ecosystems. This session concerns the application of acoustic methods, often developed within the WGFASST 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 utilizing data from other platforms are encouraged, e.g. observatories, gliders etc., in addition to reanalysing historical data. Guests outside the community are particularly welcomed (Chair: Arnaud Bertrand).
  - ii) Acoustic properties of marine organisms. This is a core activity for WGFASST, 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: Mathieu Doray).
  - iii) Behaviour. This section address both the use of acoustics to measure (fish) behaviour and the impact of acoustic stimuli on behaviour, including the measurement uncertainty caused by target behaviour. There has been an increase in the use of acoustics to observe behaviour in ecological studies, and this represents an opportunity to engage others to learn more about and apply the tools and techniques developed within the WGFASST (Chair: Francois Gerlotto).
  - iv) Emerging technologies, methodologies, and protocols. The use of acoustics and complementary technologies for fish surveys have been and still are a core activity of WGFASST. 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. 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: Ian McQuinn).

- b) Based on our use of active sound in the ocean there is a need to review and document its footprint and place this in context with other natural and anthropogenic sources and the relative impact on marine biota. We will present a paper in the "Behaviour" session where the time, volume and levels will be addressed (coordinated by Rudy Kloser).

This TOR could not be addressed as Rudy Kloser was unable to attend the meeting.

- c) Review the reports and receive updates from:
  - i) Report from the Study Group on Calibration of Acoustic Equipment (SGCAL; David Demer).
  - ii) Report from the Topic Group on metadata standards (Tim Ryan).
  - iii) Engagement with SPRFMO (Francois Gerlotto).
  - iv) Pre-meeting workshop (Mathieu Doray).
- d) It was decided at the meeting to start working towards a new study group on acoustic target classification. A core group composed of Stephane Gauthier, Ann Lebourges-Dhaussy, Rolf Korneliussen, John Horne, Ian McQuinn, and coordinated by Rolf Korneliussen will start initial discussions and present terms of reference for such a group to be endorsed by WGFASST and sent to SCICOM for consideration (Rolf Korneliussen).
- e) The next acoustic symposium is currently being developed, and the status of the planning process will be presented at the meeting (WGFASST Chair, Nils Olav Handegard)

WGFASST will report by 30th June 2013 for the attention of the SCICOM steering committee.

### 3 Acoustic properties of marine organisms

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#### 3.1 Contributions to the session

##### **Backscattering properties of southern Baltic herring (ICES Subdivision 26)**

Jakub Idczak, Natalia Gorska

Acoustic techniques are used in the Baltic herring abundance estimation. Investigations of the relationship between the Baltic herring individual target strength TS and the total fish length L, significant in the acoustic assessment, demonstrated its dependence on study area location. It motivated the detailed analysis of the relationship for herring from the southern Baltic ICES Subdivisions 24, 25, 26, in which Poland is responsible for the acoustic herring abundance assessment. The modelling approach, basing on the Modal Based Deformed Cylinder Model approximation, was used to study the backscattering. The detailed shape of the swimbladder and body of herring individuals was considered. To obtain the model input data (individual morphometric data) the optimal methodology of the morphometry study was developed for southern Baltic herring (ICES Subdivision 26). The morphometric data were obtained using the X-ray images of herring individuals. The impact of the fish morphometry and the orientation differentiation of the aggregated herring individuals on the backscattering average characteristics were investigated. The contribution of the backscattering by fish body in the total backscattering was analysed. Statistical analysis was performed for two morphometric datasets - for herring individuals from the Polish coastal zone (ICES Subdivision 26; data collected by us) and from the Sweden coastal zone (ICES Subdivisions 25, 27, 29; set developed by our predecessors). The analysis is important for understanding the set representativeness and their comparison. It could help to explain the observed differences in the backscattering characteristics of herring individuals from different parts of the Baltic Sea.

##### **More in-situ measurements of the individual acoustic backscatter of European anchovy (*Engraulis encrasicolus*), with concurrent optical identification**

Mathieu Doray, Laurent Berger

A methodology has been devised to measure specific small pelagics TS in controlled environments, to further investigate the adequacy of TS length equation used to derive fish stock estimates for clupeids in European waters (ICES 2011). New experiments have been conducted using this methodology during the PELGAS2012 sea cruise. TS measurements have been conducted in an area populated by pure 14 cm anchovy schools. A total of 6660 single targets belonging to 2165 fish tracks have been recorded at a -80 dB minimum TS threshold. The mean strength of these targets was -68 dB. The targets tilt angles have been estimated based on the initial and final track depths. The target tilt angles distribution showed two modes, one around 0 degrees (horizontal targets) and the other around 40° (diving targets). A Pacific Sardine backscatter model using Kirchoff-ray-mode (KRM) approximation from a detailed swimbladder shape (Cutter Jr and Demer, 2007) was used to investigate the TS variation range of 12 to 16 cm fish as a function of its tilt angle.

### **Target strength of *Sardina pilchardus* and *Sardinella aurita* in the Atlantic northwestern Africa coast**

Salaheddine El Ayoubi (INRH), Tadanori Fujino, Abdelmalek Faraj (INRH), Naoki Tojo (JICA), Koki Abe (NRIFE), Kazuo Amakasu (Tokyo Kaiyo Uni.), and Kazushi Miyashita (Hokkaido Uni.)

Target strength (TS) measurement of *Sardina pilchardus* and *Sardinella aurita* were conducted at 38 kHz using large freshwater tank by tethering method. Fish samples were collected off the coast of Morocco by R.V. Al Amir Moulay ABDALLAH (of INRH, 298t) and purse-seine fishing vessels. The fish samples were frozen and transported to Japan by air after collection, then defrosted just before the TS measurement experiment in the National Research Institute of Fisheries Engineering. TS were measured from the dorsal aspect for each 1degree between -50° 50° tilt angle. Soft X-ray were also conducted before the TS measurement to confirm the swimbladder condition. Assuming that the swimming tilt angle followed normal distribution of average -5°, ± 15°, relationship TS and total length (TL) were derived  $TS=20\log_{10}L-66.2$  (TL 10.8~18.7 cm, N=18) for *S. pilchardus* and  $TS=20\log_{10}L-67.2$  dB (TL 19.3~35.9 cm, N=13) for *S. aurita*.

### **Target strength and vertical distribution of smelt (*Osmerus eperlanus*) in the Ijsselmeer based on stationary 200 kHz echosounder recordings**

Sven Gastauer, Sascha Fässler, Bram Couperus, Marieke Keller

Smelt, *Osmerus eperlanus*, is a common species all over Northern Europe, residing in both fresh- and brackish water bodies. The smelt population in the shallow (mean depth 4.4 m), eutrophic, freshwater lake Ijsselmeer is known to be in decline since 1990. Smelt plays an important role as prey in the lake Ijsselmeer ecosystem (The Netherlands). Low abundances can have a direct effect on piscivores water birds populations, for whom smelt is the main prey species. Previous studies have identified hydroacoustics as the ideal tool to estimate the abundance of smelt and similar species, focusing however mainly on lakes with greater depths. In order to establish the usefulness of acoustics in the Ijsselmeer, a sound knowledge of the acoustic properties such as target strength and an understanding of the behaviour of smelt in the area to be analysed are crucial. Target strength (TS) of smelt (*Osmerus eperlanus*) was measured using a bottom deployed Simrad EK60 200 kHz echosounder in the lake Ijsselmeer. Acoustics in combination with biological samples and auxiliary environmental information were used to reveal the diurnal vertical migration of smelt and analyse its key driving factors (environmental parameters and prey-predator interactions).

### **Target strength measurements and experiments on sandeel (*Ammodytes marinus*)**

Egil Ona, Ronald Pedersen, Rokas Kubilius and Espen Johnsen

No abstract provided.

### **Target strength variability using long tracks**

Adam Dunford, Richard O'Driscoll and Johannes Oeffner

Acoustic target strength (TS) is a highly variable quantity. Recent measurements from synchronized video and acoustic platforms (sometimes known as acoustic optical systems (AOS)) have shown that the TS for an individual fish can vary on the order of 10 dB. Correctly accounting for this variability is important, particularly when combining TS data to develop a TS-length relationship for use in stock assessment. Using data from very long tracks of tethered fish we found that there is potential for positive bias when using small samples with short tracks, such as in AOS experiments. Recent New Zealand and Australian hoki / blue grenadier (*Macruronus novaezelandiae*) AOS data are considered as an example.

### **Accuracy of the Kirchhoff-approximation and Kirchhoff-ray-mode fish swimbladder acoustic scattering models**

Gavin Macaulay, Héctor Peña, Sascha Fässler, Geir Pedersen, Egil Ona

The acoustic backscatter from pressure release prolate spheroids and a three-dimensional representation of a fish swimbladder (Chilean jack mackerel) was calculated using four target strength models (Kirchhoff-approximation, Kirchhoff-ray-mode, finite element solution of the Helmholtz equation, and prolate-spheroid-modal-series). Smoothly varying errors were found in the Kirchhoff-approximation and Kirchhoff-ray-mode model results when compared to the other models, and provide objective criteria for constraining the use of the KA and KRM models. A generic correction technique is also proposed for the prolate spheroid estimates and tentatively tested on a jack mackerel swimbladder, resulting in improvements to the target strength estimates from the Kirchhoff-approximation and Kirchhoff-ray-mode models.

### **Acoustics-equipped frame for simulating and measuring sea bottom gas leak**

Rokas Kubilius, Terje Torkelsen and Jostein Loe

Increasing awareness about unmonitored high seas methane gas seeps led to the re-evaluation of active acoustics as a tool to observe and possibly discriminate gas seeps from fish. We began by releasing gas bubbles in controlled conditions and measuring their acoustic characteristics. A specially designed aluminium bar frame (2x2x7m) was built and equipped with calibrated split-beam echosounders (70, 120, 200, 333 kHz), stereo-photo and web cameras, as well as gas release nozzles. The frame was deployed at 50m depth from a moored vessel in a sheltered Norwegian fjord with communication achieved via fibre optic cable. The echosounders and cameras were oriented horizontally to observe a measurement volume at a few meters range, with bubbles being released below the beam. The method for orienting the echosounders so as to illuminate a single point (at 5m) will be discussed as well as the design of the frame allowing for low side-lobe detections. Example results from air bubble measurements will be shown.

### **Field applications of broadband techniques for discriminating among sources of scattering and quantifying zooplankton**

Gareth L. Lawson, Andone C. Lavery, Peter H. Wiebe, J. Michael Jech, Jonathan R. Fincke, and Nancy J. Copley

Discriminating among sources of scattering remains a key problem in ecological and assessment-related applications of active acoustics. This is particularly true in studies of zooplankton, which are often found in heterogeneous communities with species of different scattering properties. Broadband measurements can provide substantial improvements in species discrimination by characterizing more fully the frequency spectrum of scatterers relative to traditional single- and multifrequency narrowband techniques. Here, we present findings from a series of cruises associated with two field projects, the first examining patchiness in the distribution of euphausiids in the Gulf of Maine and the second examining the vertical distribution of pteropods in the Northwest Atlantic and Northeast Pacific in the context of ocean acidification. A customized, commercially available, broadband system spanning a frequency band of 35 to 600 kHz, with some gaps, was deployed in a towed body to depths of 500 m from research vessels. Concurrent measurements made with a surface-towed multifrequency system (43, 120, 200, 420 kHz) along with ground-truthing information from depth-stratified net sampling and a video plankton recorder allow an assessment of the strengths and limitations of broadband methods for remotely discriminating among sources of scattering and for estimating the abundance and size of zooplankton.

### **Acoustic properties of juvenile anchovy (*Engraulis encrasicolus*) in the Bay of Biscay**

Marian Peña and Enrique Nogueira

Since 2006 the Spanish Institute of Oceanography performs an autumn survey targeting juvenile anchovy (*Engraulis encrasicolus*) in the Bay of Biscay. Data from a Simrad EK60 with five frequencies (18, 38, 70, 120, and 200 kHz) from the 2009 survey is employed for a multifrequency analysis of the anchovy backscattering. Differences with sizes and depth are evaluated. Four simple backscattering models accounting for depth, tilt angle, swimbladder and body physiology are developed, and compared with observed values by means of an unsupervised neural network, the Self-Organizing Map. A revision of the inversion method is considered for the inference of anchovy sizes; several metrics and optimizers are compared and discussed. Techniques to facilitate convergence and frequency weighting are explored.

### **Progress on broadband acoustic investigations of individuals and schools**

Gavin Macaulay, Egil Ona, Lucio Calise

Backscatter spectra of individuals and schools from a range of species, measured by a prototype broadband split-beam echosounder, covering the frequency range 60 to 400 kHz (with some gaps), will be presented and compared to simple representative models. An important requirement for obtaining quantitative spectra is an accurate calibration of the echosounder as a function of frequency and methods for selecting suitable calibration spheres will be presented.

## **Development and test applications of autonomous acoustic systems deployed from underwater vehicles and animal platforms**

Gareth L. Lawson, Andone C. Lavery, Frédéric M. Jaffré, Peter H. Wiebe, Jonathan R. Fincke, Luis A. Hückstädt, and Daniel P. Costa

High-frequency active acoustic systems are increasingly being incorporated into a variety of autonomous platforms such as moorings, gliders, and Autonomous Underwater Vehicles (AUVs), allowing ecological systems to be sampled at spatial and temporal scales previously inaccessible based on traditional shipboard surveys. We have developed a compact, low-cost, low-power (ca. 1 W), fully autonomous, and internally recording acoustic backscattering system capable of narrowband or broadband transmission over frequencies from 100 kHz to 2 MHz and intended for use on a variety of autonomous platforms. The system is modular and can span large frequency ranges via multiple channels and transducers. Tests of a 3-channel, broadband version of the system (spanning a frequency range of 120 kHz – 1.2 MHz, with some gaps) were initially conducted from shipboard deployments in an estuary to image water column stratified turbulence and later from a REMUS-100 AUV over a coastal bank to study fish and zooplankton spatial distributions. A highly miniaturized, single channel, narrowband version of the system operating at the single frequency of 200 kHz was then developed for deployment on marine mammals. Test deployments on juvenile elephant seals of this 'sonar tag' have provided exciting new data confirming the promise of this system for quantifying the seals' prey. Insights into directions for future development and the limitations of such systems in terms of reduced sampling ranges and low signal-to-noise ratios associated with the low power consumption and other performance restrictions (e.g. reduced dynamic range) associated with component miniaturization and board design will be discussed.

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

Ian E. Fraser and 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 adapted a semi-supervised, non-parametric Bayesian mixture model to allocate backscatter between known and unknown categories (e.g. species, age groups, species mixtures). The Dirichlet Process Mixture Model is not constrained to a predetermined number of categories, but creates additional categories in response to data attributes as new data are encountered. This approach offers advantages including: (1) the ability to incorporate and train for known categories while simultaneously discovering new or unknown categories; (2) providing interpretable Bayesian credible intervals around Sv estimates for known classes; (3) adjusting clustering resolution to include knowledge of species communities; (4) the ability to incorporate prior knowledge for categories with similar acoustic properties; and (5) a statistical determination of the number of categories without a priori assumptions. Initial model implementation and testing using five trawl-validated categories (euphausiid, jellyfish, capelin, adult walleye pollock, juvenile walleye pollock) and four frequencies (18, 38, 120, 200 kHz) produced distinct Sv difference clusters and matching class labels. The resulting model-based credible intervals covered trawl-verified point values for all categories. This model-based approach is semi-automated, has

flexible structure, and objectively categorizes data while quantifying model and sample allocation uncertainty.

### 3.2 Summary to session

Several talks focused on comparing *in situ* fish target strength (TS) measurements with model results and tried to draw inference based on comparing scattering model results with the data. The contributions of *in situ* measurements and modelling studies are clearly complementary and both are needed. The question of sample size and representative measurements both for the mean and variance of TS values arose repeatedly. The importance of incidence angle and echosounder frequency, as well as animal behaviour and size, was reiterated, as they all affect target strength. Approaches for disentangling the effects on TS of fish behaviour and acoustic properties were presented, e.g. for deriving fish orientation patterns from the combination of modelled and *in situ* fish TS. The role of errors in TS estimates for errors in fish abundance estimates needs to be considered in the wider context of all error sources, including multispecies issues. It was emphasized that acoustics can offer useful information for stock assessment, ecosystem modelling, monitoring and process studies, despite some uncertainty in the TS values which will persist. In summary, discussing target strength determination approaches and issues in WGFASST allows acousticians and ecologists using acoustics to share their experience of using TS models and *in situ* measurement methods.

Several contributions showed that wideband systems are being used increasingly. Their potential for marine organisms identification and classification was demonstrated for several case studies and using different systems. There is more to come in the area of broadband systems, which raises the need for having relevant frequency response curves widely available. This issue will be further addressed in the proposed study group on target classification methods.

## 4 Applications of acoustic methods to characterize ecosystems

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### 4.1 Contributions to the session

#### **Comparison of counting with video plankton recorder to acoustic measurements of euphausiids**

P. Reynisson, A. Gislason and T. Silva

From August 2011 to August 2012, five surveys were made in an Icelandic fjord in order to monitor and estimate biomass of euphausiids. A local boat was hired for the project and four transducers at frequencies 38, 70, 120 and 200 kHz were mounted on a pole to the side of the boat. All were connected to EK60 transceivers. The area was surveyed systematically each time, mainly during the daylight hours. A Bongo net and a krill trawl were used for biological sampling. A video plankton recorder (VPR) was towed several times each survey to sample data on vertical distribution of euphausiids in the water column, as well as to get density estimates independent of the acoustics. The ultimate goal was to get an estimate of the average target strength of the animals, which then could be applied to the acoustic density measurement. The dominating euphausiids species in the area is *Thysanoessa raschi*. The acoustic response at different frequencies was used to discriminate euphausiids from other organism. Thus the distribution of euphausiids in the area was mapped. In general, the results from the VPR counts and acoustics were coherent, although the preliminary target strength is rather high. One shortcoming of this method for estimating densities of euphausiids is the unknown avoidance of the animals to the VPR.

#### **Multifrequency Acoustics for Monitoring Pelagic Ecosystems: A Canadian Case**

Ian McQuinn and Maxime Dion

The ecosystem approach to fishery management requires monitoring capabilities at all trophic levels, including pelagic organisms. However, in eastern Canada, pelagic organisms have been chronically under-sampled, despite their recognized key role in the functioning of ecosystems. Increasingly, multifrequency acoustic methods are being developed for the classification of pelagic scattering layers such as swimbladdered (capelin, herring) and non-swimbladdered fish (mackerel and sandeel), and krill (*Meganyctiphanes*, *Thysanoessa*), all important forage species. Using simple multifrequency algorithms to systematically classify backscatter collected on large-scale surveys throughout eastern Canada into the dominant species or species groups, indicators useful for ecosystem monitoring are being developed. Although a work in progress, new insights into the dynamics of pelagic biomass have been revealed with more to come.

#### **A multifrequency acoustic index of Barents Sea euphausiid (krill) biomass?**

Patrick Ressler, Padmini Dalpadado, Gavin Macaulay, Nils Olav Handegard

We used multifrequency acoustic backscatter from several recent 'ecosystem surveys' in the Barents Sea to classify acoustic backscatter likely to be from euphausiids (krill). Spatial patterns in euphausiid-like backscatter from 2010, 2011, and 2012 are broadly consistent with the distribution of euphausiids known from the literature and from



other indices derived from net samples. Such acoustic observations could complement existing net capture indices of euphausiid biomass in this system and improve ecosystem monitoring. The high horizontal and vertical resolution of the acoustic data could be exploited for studies of predator–prey interactions. Possible applications for this acoustic index of biomass and what might be done during data collection to improve acoustic observations of euphausiids and similar zooplankton in future surveys will be discussed.

### **Analysis of the acoustic discrimination of krill**

Marian Peña, Lucio Calise and Enrique Nogueira

Acoustic discrimination of different species is often performed by comparison of the frequency response or dB difference of all the available frequencies with respect to the 38 kHz response. For krill species is common to discriminate based exclusively in the difference between the 120 and 38 kHz frequencies. More recent papers warn on the variation of this pair of frequencies difference with length. After a revision of the literature, we investigate the variability of this difference with orientation, physiology, and length, employing the state-of-the-art model for this species, the Stochastic Distorted Wave Born Approximation. Two scenarios of mixed species are simulated (krill and mesopelagic fish, krill and juvenile anchovy), and their discrimination examined with an unsupervised organizing map in order to evaluate the number and frequencies necessities, considering the usual working frequencies.

### **Krill behaviour and biomass**

Martin J. Cox

Here a distance sampling based statistical technique is used to estimate krill biomass and associated confidence intervals. The distance sampling technique used calculates an error budget which includes uncertainty in krill target strength caused by krill behaviour, range dependent detectability of krill swarms, and encounter rate. The error budget may be used as a guide to allocate effort in future surveys in order to reduce variance. Many of the distance sampling analysis techniques employed here have been implemented in an R package, and example graphical output from the package are shown. Finally, the influence of uncertainty in krill biomass estimates on management action is explored.

### **Use of acoustic data for ecosystem monitoring on the west coast of Canada**

Stephane Gauthier

In this presentation I will provide an overview of a pilot project to explore historical acoustic data on the west coast of Canada. This project aims to develop indices of ocean productivity based on acoustic backscatter and to establish potential links with a suite of environmental and oceanographic parameters. The data explored were historically used with single species assessment focus, and are now re-analysed within a broader ecosystem context. As part of this exercise we are also identifying critical data gaps to establish more robust protocols for ecosystem monitoring. This involves, for example, the use of multiple acoustic frequencies and the addition of complementary technologies (e.g. optical sensors) to better identify and partition the various components of the ecosystem. Recent advances on these topics will be discussed, as well as potential ideas to move the project forward.

### **Joint analysis of multifrequency acoustic and hydrobiological data to characterize sound-scattering layers in the Bay of Biscay**

Barbara Remond, Mathieu Doray, Pierre Petitgas, Anne Lebourges-Dhaussy, Laurent Berger

Series of fisheries acoustic pelagic surveys contain unexplored multifrequency data on characteristic planktonic or micronektonic sound-scattering layers (SSLs), with well-organized spatial structures and sometimes high density. Algorithms have been proposed to infer the SSLs coarse taxonomic composition, based on their multifrequency acoustic response. Ground-truthing algorithm results is however required to progress towards effective acoustic mesoscale monitoring of SSLs scatterers. Detailed hydrobiological data were collected in a restricted area of the Bay of Biscay to characterize the size spectrum and abundance of living or non-living particles that may contribute to the SSLs backscatter, simultaneously recorded at 12 frequencies. A classification method was used to cluster water column depth layers with similar acoustical responses. Hypothesis on the composition of the different groups were made based on the mean frequency response. Then, an inversion algorithm (Lebourges-Dhaussy and Ballé-Béganton, 2004) was applied to the acoustic vertical profiles to infer the vertical distribution of planktonic scatterers, based on models of their multifrequency acoustic response. Backscatterers models used in the inversion procedure were chosen based on biological sampling and acoustic clustering results. Finally, hydrobiological samples were used to validate the inversion process results and the hypothesis made on the SSLs composition. The method was applied to data collected with EK60 echosounders at low frequencies (18, 38, 70, 120, 200, 333 kHz) and a TAPS plankton profiler at high frequencies (265, 420, 700, 1100, 1850, 3040 kHz). Results show the presence of gas-bearing organisms at low frequencies, and of copepods and euphausiids at higher frequencies. Turbidity also contributes to the acoustic backscatter in estuarine areas.

### **Towards an understanding of the distribution, biomass and energetics of mid-trophic organisms in the open ocean**

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

The mid-trophic micronekton (small crustaceans, gelatinous, squid and fish) and meso zooplankton of ~2 to 20 cm length are forage for top predators and represent a major component of ocean ecosystems displaying daily vertical migrations. These vertical migrations as observed with acoustics transport primary production at surface waters to depths of ~300 – 1200 m. Variations of these acoustic scattering layers are evident temporally and along latitudinal and longitudinal gradients. Correlations between acoustic scattering patterns and associated covariate data such as ocean colour derived surface production and temperature and oxygen profiles link acoustic scattering diversity to ecological diversity. To directly infer ecological information from these scattering layers such as biomass and energetic exchange between epi and meso pelagic depths and specific highly reflective acoustic groups such as fish with gas bladders is complicated by resonance scattering. Understanding scattering of different acoustic groups is necessary to interpret detail within these scattering layers. We use multifrequency acoustics, optics and nets deployed to 1000 m to determine the composition of layers and how we can convert acoustic backscatter to ecological variables. In particular we explore the biomass from depth stratified net tows between 25° S to 55° S using depth stratified sampling and acoustic backscatter. The

biomass of the micronekton fish component is estimated using acoustic and nets for the Tasman Sea with associated uncertainties and compared to global estimates from nets and models.

### **Combination of acoustic and egg survey methods to understand the process of the long-term fluctuation of *Maurolicus japonicus* in the Japan Sea**

Tadanori Fujino, Hideaki Kidokoro, Tsuneo Goto and Yongjun Tian

In the Japan Sea (JS) a unique species of mesopelagic micronektonic fish; *Maurolicus japonicus*, carries a large biomass and plays an important role in the ecosystem through its diurnal vertical migration. Recently, egg survey data showed abundance of *M. japonicus* increased corresponding the cold to warm thermal shift occurred in the late 1980's, and it was indicated that this species could be useful as a biological indicator to monitor the ecosystem regime shift in the JS. In this study, process of the abundance increase of *M. japonicus* in the late 1980s was examined from analysis of the historical egg data (1979–1991) and acoustic data (2000–2005, 2009). Historical egg data collected at each region of JS showed late 1980s regime shift of *M. japonicus* started between 1988–1989 from the southwest and middle of JS on spring. Acoustic data (2009) showed approximately 75% of the total biomass distributed in the southwest of JS, indicating the large contribution of the southwestern region to the biomass fluctuation of the entire JS. Acoustic data also showed ambient temperature at the adult swimming depth were in a wide range (1–19°C). This may indicate fluctuation of *M. japonicus* was induced by external factor such as prey organism abundance, rather the direct effect of temperature on the fish.

### **Characterizing distributions of meso and bathypelagic nekton along the Mid-Atlantic Ridge**

John K. Horne and Hannah L. Linder

Horizontal and vertical distributions of organisms play a key role in facilitating biological processes, which influence pelagic ecosystem structure and function. This study uses a suite of metrics to characterize water column distributions of meso (1000–1500 m) and bathy (>1500 m) pelagic nekton biomass from Iceland to the Azores along the Mid-Atlantic Ridge. Three regions were characterized and compared: north of the Charlie Gibbs fracture zone (CGFZ; north of 53.15°N), the Charlie Gibbs fracture zone, and south of the Charlie Gibbs fracture zone (south of 48.15°N). Initial observed patterns include diel vertical migrations of layers or layer components spanning hundreds of metres, increased water column occupation and intensity south of the CGFZ, the presence of a 200 m wide second layer below 2000 m wherever bottom depth allowed, and a potential backscatter increase in close proximity to the bottom (i.e. benthic boundary layer). These preliminary observations will be quantified using the suite of distribution metrics.

### **Going pelagic: How abiotic conditions force demersal Baltic cod into open water, and how this affects assessment**

Matthias Schaber, Hans-Harald Hinrichsen, Joachim Gröger

Hydroacoustic measurements were applied to resolve seasonal distribution patterns of adult cod (*Gadus morhua*) in a physically challenging environment of the central Baltic Sea. Sampling was conducted biannually from 2006 to 2009 during the begin-

ning and peak of eastern Baltic cod spawning season on hydroacoustic transects covering the Bornholm Basin. Individual cod were identified using hydroacoustic single-target detection in combination with a fish-tracking algorithm. Distribution patterns of individual cod were related to ambient in-situ environmental conditions to identify possible abiotic driving mechanisms. Results showed a clear effect of salinity and ambient oxygen concentration marking the upper and lower boundaries of favourable cod habitat. Deteriorating oxygen levels in deep layers of the Bornholm Basin during the course of the years investigated led to a seasonal upward movement of cod resulting in an increasingly pelagic distribution of large fractions of the local population. The results presented in this study highlight a significant shortcoming of the assessment survey design established for this species, as the observed shift in (vertical) distribution is not taken into account during the regularly conducted bottom-trawl surveys generating abundance indices, thus introducing a potential bias into a dataserie used to tune the ICES standard stock assessment of this species.

### **Hydrography, stock structure and habitat definition of the South Pacific jack mackerel**

J r mie Habasque, Herv  Demarcq, Anibal Aliaga, Alexis Chaigneau, Fran ois Gerlotto, Arnaud Bertrand

South Pacific jack mackerel (*Trachurus murphyi*) is a heavily exploited species characterized by a broad distribution in the South Pacific. The population has dramatically decreased during the last decades because of both overfishing and, quite likely, less favourable environmental conditions. The need for relevant management procedure is critical ([www.southpacificrfmo.org](http://www.southpacificrfmo.org)). Several hypotheses on stock structure are currently proposed including single population, patchy population and metapopulation. In the present study we aim at determining the environmental and hydrographical/biogeochemical conditions impacting the shape of the 3D habitat of the Jack mackerel that may drive the distribution, composition and structure of the population, both in space and time. To define the habitat and study its variability we selected a series of parameters. Classical parameters such as temperature and productivity are used to delimit the area of distribution and determine the most favourable areas. In addition we take into account the presence of an oxygen minimum zone (OMZ) which appears to be a key feature structuring the habitat. We test the hypothesis according to which jack mackerel population increases when the range of productive waters extends in the South Pacific convergence zone and when the OMZ deepens enough to allow access to the rich coastal Peruvian waters. The study is based on available/published information from different sources (satellite, scientific survey, fishing vessel capture and acoustic data). Habitat volume estimation using observations tools -as environmental satellite, oceanographic data and catches- is highly improved by using acoustic information from scientific surveys and vessels of opportunity. Preliminary results presented here seem to validate the proposed hypothesis.

### **Characterizing small pelagic populations habitat in the Mediterranean Sea**

M. Giannoulaki, M. Iglesias, P. Tugores, M. Pyrounaki, I. Leonori, F. Campanella, A. Bonanno, B. Patti, J. L. Bigot, A. De Felice, V. Ti ina, G. Basilone, A. Machias, S. Somarakis, V. Valavanis

Mediterranean Sea is a highly diverse ecosystem but less well studied compared to large upwelling systems. Within the current work the habitat of small pelagic fish populations in the Mediterranean (i.e. anchovy, sardine, horse mackerel, Mediterranean horse mackerel, chub mackerel and Atlantic mackerel) was characterized combining historic survey data (i.e. acoustic, ichthyoplankton, bottom and pelagic trawl surveys) from different seasons and different parts of the Mediterranean Sea (e.g. Spanish Mediterranean Waters, Gulf of Lions, Adriatic Sea, Strait of Sicily and Aegean Sea) along with satellite environmental and bathymetry data through the application of habitat modelling techniques. Selected models were evaluated based on areas not included in model construction and used to assess environmental relationships. In a subsequent step, they were used to produce habitat suitability maps for the entire Mediterranean basin over the period 2000–2010 addressing different life stages (i.e. adults, juveniles and eggs) of the target species depending on data availability, and using the same spatial resolution. Based on the annual maps, habitat persistency maps were produced using GIS techniques taking into account for each grid cell the occurrence of high probability for suitable conditions as well as the temporal variability of this probability. The degree of overlapping between the persistent nurseries/spawning habitat areas of the target species was estimated and discussed in respect to the Mediterranean Sea features. In a further step, the extent of the suitable habitat area in an annual basis was evaluated as an indicator for changes in species abundance.

#### **Acoustics show how high frequency physical features structure the oceanscape and shape the distribution of zooplankton and fish**

Arnaud Bertrand, Daniel Grados, François Colas, Alexis Chaigneau, Ramiro Castillo, Ronan Fablet

Surface submesoscale physical structures are an essential part of oceanic turbulence and drive organisms' distribution. Yet the ocean landscape at scales smaller than  $O(1\text{km})$  remains largely unexplored. Here we use a unique dataset acquired off Peru with simultaneous acoustic information on the depth of the upper oxygen minimum zone, a proxy of the physical structuring of the upper ocean layer, and on the biomasses of macrozooplankton and pelagic fish. When comparing these data with high resolution ocean simulations, similar features emerge at scales  $>O(1\text{ km})$ . However, when using observation at higher resolution, a «new world» emerges. The field becomes dramatically dominated by physical features with a characteristic scale of  $O(200\text{ m})$  that are much more intense than the observed features at larger scales. These submesoscale structures determine organisms' distribution. Indeed they embed half of the biomass of macrozooplankton and of their main predators, the forage fish. Thus, the submesoscale dynamics largely structures the physical fields (e.g. oxycline) and planktonic particles organize passively in this space. Then, biological interactions such as predator-key relationships transmit this spatial structuring along the trophic chain.

#### **4.2 Summary of session**

The presentations in this session illustrated that acoustics information is now widely and routinely used in conjunction with environmental observations, but also various *in situ* sample data to investigate spatial patterns and their properties of pelagic ecosystems. The investigations presented covered a wide range of spatial scales, illustrating for instance the role of submesoscale features in overall ecosystem structuring.

Oxygen structures occur in a large variety of ecosystems that are affected by permanent or temporal anoxia. Oxygen (estimated by acoustics or by classical methods) is now routinely used as a crucial environmental forcing factor defining, among others, potential habitats.

Several presentations used the dB-difference method or some variants of it in different ecosystems around the world to separate krill from fish but also different zooplankton species. Simulation results indicated the sensitivity of this approach to local conditions and the relevance of "local tuning" of model parameters. Bubble layers and/or layers of gas-bearing organisms seem to be a common occurrence across ecosystems and were observed in many different systems. Attempts to identify their composition have failed so far, despite several attempts to fish on them or observe them by video. Clearly these unidentified bubble layers pose a challenge for the use of acoustics as they might mask the detection of organisms of interest. A joint effort seems warranted to address this challenge.

Acoustics provide both quantitative and qualitative information on exploited and unexploited ecosystem components, including the biotope. Further, they provide relevant information to define both benthic and pelagic habitats.

Several indices relevant to the functioning of ecosystems are already available, and it is important to promote the results to relevant ICES working groups.

The session confirmed that data availability is important. WGFAST recommends to widely disseminating processed acoustic data to the ecological community. The use of the data by others (so with new ideas) is a way to extend and promote the use of acoustic data. The data should be relatively fine scale, and it should be possible to sum across categories, to reconstruct the total raw backscatter.

## 5 Behaviour

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### 5.1 Contributions to the session

#### **Spatial dynamics and shoal behaviour of juvenile anchovy (*Engraulis encrasicolus*) in the Bay of Biscay**

Guillermo Boyra, Enrique Nogueira and Marian Peña

In the year 2009, two consecutive acoustic surveys targeting juvenile anchovy were carried out with a delay of about three weeks in the Bay of Biscay. In total, about 45 sampling days under stable meteorological and hydrographical conditions between early September and mid-October, made possible to monitor the changes on spatial distribution and shoal aggregation patterns of this species. In the first survey, juveniles were seen spread over a large area on the oceanic and slope waters, while in the second one, three weeks later, the spatial distribution moved towards the coast but without entering the continental shelf, thus compressing into a narrower band parallel with the shelf break. Also, the vertical distribution was seen to change by increasing its mean depth. On the other hand other behavioural changes were also observed. The shoal aggregation patterns changed from diffuse and small near-surface aggregations to increasingly denser and larger schools that appeared more reactive to the vessels. Towards the end of the sampled period, anchovy juveniles and adults were found mixed together in some locations of the outer French shelf.

#### **Effect of abundance on spatial strategies of the Chilean Jack mackerel as observed through acoustic surveys**

Francois Gerlotto and Jose Cordova

The Chilean Jack Mackerel *Trachurus murphyi* is susceptible to huge variations in its overall biomass, and the fisheries in the South Pacific Ocean varied from 5 million tons to less than 500 000 tons per year. These changes in abundance impact the way the fish occupy the space at various scales, from the complete Ocean to the variations in school shapes. This species represents an important source of proteins and incomes for several countries, and it is studied since the early 2000 by the South Pacific Regional Fisheries Management Organization ([www.southpacificrfmo.org](http://www.southpacificrfmo.org)). Among the conclusions of this Organization, the need of a good knowledge of the population structure and spatial strategy related to environmental conditions was defined as essential to a correct assessment of this stock. This paper presents some analysis applying Petitgas' index of occupation of space on acoustic data from surveys in Chile and Peru. Our preliminary results show that depending on its overall abundance the fish seems to change several times its strategy from a constant density on a varying space to a constant space occupied with variable densities. The impact of such behaviour in the population structure is discussed.

#### **Studying blue whiting spatial distribution patterns using acoustics derived and other information**

Verena Trenkel

Blue whiting (*Micromesistius poutassou*) is an important prey species in the Northeast Atlantic due to its large stock size and wide geographic distribution. The stock has

undergone large variations which have led to changes in spatial distribution patterns. Results from studying spatial patterns on the spawning grounds to the west off the British Isles in relation to oceanographic conditions, in particular the strength of the Subpolar Gyre, and on the feeding grounds in the Bay of Biscay will be presented.

### **Near-surface behavior observed by airborne lidar**

James Churnside, David Demer

The complementary technology of airborne lidar can be valuable in observing behaviour near the surface, where acoustic techniques can be affected by the presence of the vessel. Two recent examples are presented. The first example suggests that vessel avoidance by Pacific sardine (*Sardinops sagax*) can be different during the day than at night. The depths of 15 schools were measured by lidar and echosounder. There was no significant difference between the depths measured by the two techniques during the day or between the depths measured by lidar during the day and at night. Depths measured by the echosounder at night, however, were significantly greater than the corresponding lidar measurements, suggesting that sardines might be diving to avoid the vessel at night, but not during the day. The second example suggests that moon jellyfish (*Aurelia* spp.) can form hollow aggregations at the surface. The depths of the bottom of these aggregations were significantly correlated with the depths of the shallow mixed layer. The horizontal extent was too large to be explained by Langmuir circulation. A simple, agent-based behavioural model reproduced the general pattern using the assumption that individuals turned to avoid turbulence at the surface and at the pycnocline.

### **Collective behaviour of penned herring: Observing the collective behaviour and investigating the effect of various sound stimuli**

Nils Olav Handegard, Kevin Boswell, Alex DeRobertis, Guillaume Rieucan, Lise Doksaeter Sivle, and Lars Stien

Here we report the preliminary results of an experiment conducted in 2012 where various stimuli were presented to schooling herring (*clupea harengus*) in a net pen. We played back vessel noises, various tones, killer whale calls as well as simulated a predator encounter by pulling a predator-shaped model through the school. Two underwater loudspeakers were used, and the emitted stimuli range from 10 Hz to 2 kHz. The sound field inside the pen was measured using two vertical hydrophone arrays and two calibrated hydrophones. Various properties of the collective responses in herring were measured by using a suite of techniques, including cameras, echosounders and multi beam sonar. Overall, there was very little reaction to sounds at the levels presented, except for the predator model that consistently elicited behavioural evasive reactions. The propagation speed of the behavioural response, a prerequisite for information transfer of potential treats within schools, was of the same strength as similar experiments in tanks. However, the collective response was dampened more than anticipated indicating weaker amplification of the response than observed *in situ*. This may be caused by changes in fish state. Biological parameters were measured showing an increase in levels of cortisol, glucose and lactate when exposed to killer whale playback, indicating physiological stress due to the predator sound.



## **Underwater sound measurements of a free-running research vessel from a standard naval range and a new buoy system**

Héctor Peña, Jan Tore Øvredal and Bjørn Totland

Adverse consequences in natural fish behaviour to underwater sound produced by research vessels have been a concern to the fisheries acoustics community for several decades. Most of the available noise measurements for research vessels have been carried out using standard naval facilities, following protocols determined by under-sea warfare requirements. The measurements from these facilities provided to a high standard, however they have disadvantages such as; limited availability, no mobility, and in most cases elevated costs. To avoid these, a buoy system equipped with 3 Ethernet hydrophones, GPS, and radio communication was adapted for standardized sound measurements. The buoy system, together with the Norwegian naval acoustic range in Heggernes, were used to measure the underwater sound of free-running RV “Håkon Mosby” following the American National Standard ANSI/ASA S12.64-2009 grad b. Results showed good agreement in overall sound level and frequency-dependent variation between the two systems for most of the frequency range between 8 Hz to 16 kHz. Lower sound levels were observed in the buoy system in the lower frequency range (4-8 Hz), compared to the naval range, which could be attributed to a suboptimal calibration for that frequency range.

### **5.2 Summary of session**

The behavioural studies presented in this session can be grouped according to three broad objectives: 1) obtain information to ensure that acoustic results are unbiased or for understanding potential sources of bias; 2) study individual fish behaviour to gain new insights in behavioural ecology or information which can be used to optimize survey designs; 3) study population behaviour, in particular large-scale spatial and temporal distribution patterns. The information needed for an ecosystem approach to management relates to all three objectives.

An example of a method aimed at removing the observation bias due to fish behaviour (vertical avoidance) was presented. It compared the result of different observation methods (Lidar and vessel based echosounders) to estimate relative bias. Vessels may have an impact on the fish behaviour, and this issue has renewed interest due to the increased use of vessel of opportunities which vary substantially in noise levels and therefore have the potential to induce variable fish avoidance behaviour. A portable instrument for measuring vessel noise was presented and is likely to help understand the extent of this problem.

Acoustics can help to carry out more fundamental research on fish behaviour. An example of this was presented for school behaviour of herring. The objective was to investigate the mechanisms of internal school behaviour. Among the points touched upon in the discussion was the issue of the natural state of fish vs. those being used in mesocosm and laboratory experiments. It was pointed out that acoustics offer a way to observe fish behaviour *in situ*, and can help bridge the gap between laboratory based results and *in situ* observations.

The population behaviour studies looked at issues like spawning distributions and their relationship with environmental conditions and population density and structure, primarily using statistical analysis methods. This approach is linked with the previous session on ‘Applications of acoustic methods to characterize ecosystem’. Both are complementary approaches to the same general question. The population

behaviour perspective offers a way to introduce behaviour into the analysis and study of ecosystem processes and changes. WGFAS<sup>T</sup> encourages these types of studies and expects to see more of them in future.

## 6 Emerging technologies, methodologies, and protocols

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### 6.1 Contributions to the session

#### **Scattering directivity of herring: what can we learn from the comparison of in situ and simulated target strengths distributions from multibeam and multifrequency echosounders?**

Laurent Berger, Mathieu Doray and Naig Le Bouffant

Multibeam echosounders provide a larger sampling volume and a finer resolution compared to classical monobeam echosounders. These features are expected to improve the precision of acoustic-based fish biomass estimates. However, fish are known to be directional scatterers and are observed under different angles with multibeam systems. Specific combinations of beam steering angles and oriented fish swimming directions are thought to possibly increase the fish Target Strength (TS) measurements variance. We have compared in situ and simulated TS distributions at different angles and frequency to assess the influence of fish scattering directivity and orientation on in-situ TS measurements. The TS simulation model took into account fish pitch, yaw and angular position in the beams. Results show similar TS distributions for all frequencies and angles, and a relatively flat mean TS response as a function of beam steering angles. The model outputs that fitted best the in situ data however reveal a complex fish orientation response that suggests avoidance behaviour to the survey vessel.

#### **Improved morphological fish school characterization using simulations of multibeam sonar data**

Arne Johannes Holmin, Rolf Korneliussen, Dag Tjøstheim

A new method for segmentation of multibeam sonar data of fish schools has been developed and compared to the existing segmentation method used by the post-processing system LSSS (Large Scale Survey System). The new method was found to provide estimates of the total volume, total target strength, and mean volume backscattering strength that were generally more accurate than those obtained by LSSS, for simulated MS70 data of 240 fish schools of various shapes, sizes, packing densities, and depths. The new segmentation method takes a Bayesian approach in which the probability that a volume element (voxel) contains the school is estimated based on the observed data and estimated noise.

#### **Improved methods for data processing from omnidirectional fisheries sonar for studying pelagic fish schools**

Héctor Peña

Omnidirectional fisheries sonar is a valuable tool when observing pelagic schooling fish, especially when they are schooling close to the sea surface, in the echosounder acoustic blind zone. However, current omnidirectional sonars are not designed for scientific purposes, and several technical and methodological challenges need to be addressed for this purpose. The amount and focus of the efforts will depend in the objectives of the analysis, rather than observing many school during acoustic surveying or detailed inspections of individual schools. The processing system for omnidi-

rectional fisheries sonar (PROFOS) is the software developed for processing fisheries sonar data, as a module of the LSSS system. Improvements in calibration, sonar data handling and school scrutinizing, will be presented. Also, planned ex-situ experiments on schools in net cages and field trials using research and commercial vessels will be discussed.

### **Operational use of MS70**

Rolf Korneliussen

The Simrad MS70 quantitative multibeam sonar covers 3 spatial dimensions in each ping, and is intended to be used together with other acoustic equipment to cover the water volume around a ship. The Large Scale Survey System LSSS is designed for handling all acoustic data, including data from MS70, to optimal quality within available time (2h for 24h data) with one of the purposes being abundance estimation of marine organisms. Efficient use of MS70 on operational cruises has been hampered for several different reasons, the last being the ability of LSSS to reliably detect and process very large amounts of schools within available time. The ability to detect and process large amounts of schools close to the surface within available time will be demonstrated, and results of using MS70 data will be compared to results of using other acoustic equipment.

### **Detecting presence-absence of bluefin tuna by automated analysis of long-range sonars in fishing vessels**

Jon Uranga Aizpurua, Guillermo Boyra, Haritz Harrizabalaga, Maria Carmen Hernandez

This study presents a new methodology for automated analysis in tuna long-range sonar signals. This approach attempts to solve the problem of sonar image processing. The study is focused at bluefin tuna (*Tunnus thynnus*) of the Bay of Biscay. In this process, for each sonar image we obtain measurable regions to analyse where each region is described by a set of characteristics. Through the help of experts, each region is identified into a class and a database is created by supervised learning. Thus, a classification model is performed. The final aim of this process is to maximize the estimation of tuna in regard to the real values, and to propose a new index of abundance, based on the automatic estimation of sonar images.

### **Calibration trials on a omni-directional fishery sonar with the split-beam method**

Sindre Vatnehol, Atle Totland and Egil Ona

A preliminary method for calibrating a 64 beam omnidirectional fishery sonar with the split-beam method is presented. The backscattered sound waves from a WC 64 mm diameter calibration sphere on each element in cylindrical sonar transducers are collected using the Simrad SX90 omni-directional sonar. Using simple beamforming techniques, it is possible to use split-beam method to detect the position of the sphere inside each beam, and to calculate the target strength of the sphere at the acoustic axis in each beam. These methods are compared with the sphere position data collected with a new, motorized sonar calibration rig. Challenges due to the sonar position on the vessel hull and possible multipath problems are discussed.

## **Acoustics in fisheries assessment and research: Past, Present and Future**

Gary D. Melvin

Acoustics have played a critical role in research and assessment of pelagic (primarily) and demersal fish for more than half a decade. During this period there have been numerous developments in hardware, changes in survey design, and software enhancements to improve qualitative and quantitative analysis of backscatter data. The primary application of acoustics continues to be the estimation of biomass of pelagic marine fish as either a relative or absolute index of abundance for input into analytical stock assessment models. Although over the last several decades the scope of applications has broadened to fish tracking and seabed classification for single/split-beam systems. Multibeam sonars have added another dimension to observations from a qualitative and behavioural aspect, but the use of these systems in the quantitative application can only be described as being in its infancy. This report provides a general overview of the historical importance of acoustic in fisheries biology, where we are today, and some speculation of where we are going in the not too distant future.

## **Biomass estimation of a deep-water fish at a higher frequency reduces uncertainty**

Tim E. Ryan; Rudy J. Kloser

The use of deeply towed bodies to acoustically survey the commercially important fish, orange roughy (OR), *Hoplostethus atlanticus*, is well established. This approach reduces range dependant errors and weather effects that can significantly bias vessel-based surveys. Importantly, deeply towing allows the use of both lower and range-limited higher frequencies enabling multifrequency methods which can effectively discriminate OR. Acoustic biomass estimates have to date been based on 38 kHz, largely as a legacy of vessel-based surveys that require a long-range frequency. Accordingly research on the key parameter of OR target strength (ORTS) has focused on this frequency. Recently however, a net-attached acoustic-optical system has been used to obtain robust in-situ ORTS measurements at 120 kHz supported by visual verification of species and measures of fish orientation. This has enabled estimates of OR biomass to be made at 120 kHz for the first time. When compared to 38 kHz, this frequency doubles the signal originating from OR and is ~10 times less sensitive to the presence of small gas-bladder species. Biomass estimates can now be compared between both frequencies and provide an absolute estimate of biomass with lower sources of uncertainty. Importantly there is good agreement between biomass estimate at both 38 kHz and 120 kHz that reduces sources of unquantified uncertainty in previous estimates of OR TS at 38 kHz.

## **Comparisons of acoustic and trawl-based Atlantic herring population estimates in the Gulf of Maine**

J. Michael Jech and Victoria Price

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 con-

tinuously with Simrad EK500 and EK60 echosounders operating at 12 or 18, 38, and 120 kHz. Comparisons of biological data show similarities in length–frequency, age, and sex distributions but differences in maturity stages among bottom trawl and midwater trawl catches. Differences in maturity stages suggest differences in survey timing relative to spawning, whereas similarities in other biological variables suggest consistency in fish on/near the bottom and in the midwater. 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.

### **Hydroacoustic information system for fisheries resource research**

Sergey M. Goncharov, Alexander V. Polyakov, Sergey B. Popov, Viacheslav A. Bizikov

A lot of hydroacoustic survey data of many fish species were collected over the years. These data should be organized and shouldn't cause doubt as to their authenticity. The survey data and all steps of their calculation should be clear as well as they should comply with common methods. For these aims VNIRO has developed the hydroacoustic information system which includes the database of the hydroacoustic survey data collected in marine and freshwater areas and GIS «ChartMaster» used for mapping of resource data and estimation of aquatic living resources.

The database has two levels structure based on DBMS PostgreSQL. At the low level of the database the primary data are stored. The primary data are an array of digitized echo signals ("raw" data) recorded during of the hydroacoustic survey. At the top level - the results of processing.

Updating, viewing and editing of data into the database are performed by special program AcousticDB. The data in the database are organized in such a way that it is easy to evaluate the quality of the equipment calibration and data processing from "raw" signals to calculations of fish surface density.

The problems of short and long-term forecasting of fish stocks in areas of fisheries can be solved with the help of the hydroacoustic information system. Having data on fish biomass distribution for prior periods its change can be predicted in near or long-term future. The accuracy of such forecasts will be higher if more data (data on habitat, food resources, fish mortality factors, etc.) are used in the analysis.

### **Comparing echosounder fish estimates collected simultaneously along three parallel transects lines in a German lake**

Frank Reier Knudsen, Simrad, Horten, Norway Marc Bodo Schmidt, LFV Hydroacoustic Cooperation, Münster, Germany

Echosounder fish survey planning involves spreading out transect lines in a parallel or zigzag pattern to satisfy a statistical coverage requirement. The aim of the present study was to test if echosounder fish estimates are dependent transect line placement in a high fish density German lake.

The survey was conducted in the mesotrophic Bigge reservoir in Germany during daytime in December 2012. The surface area of the reservoir is 7 km<sup>2</sup> with a mean and maximum depth of 20 m and 50 m, respectively. The fish stock is dominated by pelagic vendace (*Coregonus albula*) in high densities. Acoustic data acquisition was conducted along three parallel transects simultaneously using the Simrad EK15 echosounder operating at 200 kHz and with a beam width of 26 degrees. Three calibrated transducers were mounted side by side (athwartship) with 5 m spacing on a floating rig towed 20 m behind a small boat powered by an outboard engine.

Analysis was carried out based on elementary sampling units (ESU) with a defined length of 300 m in six depth layers. Area backscattering values were calculated for each ESU and depth layer. Further, fish densities were calculated by TS/Sv. No statistical difference could be found between the three parallel transects, so in a high fish density lake acoustic estimates are independent of where a transect is placed as long as normal survey planning is otherwise followed.

### **First insights from echosounder data collected on commercial vessels during different fisheries throughout an annual cycle**

Sascha M.M. Fässler, Sven Gastauer, Dirk Burggraaf, and Thomas Brunel

Pelagic trawlers make extensive use of acoustic equipment during their fishing operations. The data recorded from them could potentially provide important information such as precise localized fish densities, extent of stock distribution, and migration. We investigated the possibility of collecting acoustic data during normal fishing trips of Dutch pelagic freezer trawlers, and the potential of these data to estimate fish stock biomass. Data collection trials were realized in 2012 during blue whiting fishing west of the British Isles in spring, during the herring and sprat fishing season in summer in the North Sea, and during trips targeting horse mackerel in the English Channel and Celtic Sea in autumn. Echosounders were calibrated and data logged on external hard drives. This allowed use of the collected and post-processed data for abundance estimates along the path covered by the vessels. The usefulness of the data collected for calculating stock abundance indices was investigated using a fisheries simulator – a tool modelling the behaviour of a commercial fleet fishing on a spatially distributed resource. Simulation results suggest that the accuracy of such indices appear insufficient for very densely aggregated species such as blue whiting but show more potential for more evenly distributed species such as herring.

### **Understanding fishers' echosounder buoys. A behavioural approach to improve remote characterization of fish aggregations around fads**

Lopez Jon, Gala Moreno, Guillermo Boyra, Laurent Dagorn

Thousands of drifting fish aggregating devices (drifting FADs) are employed worldwide in the tropical tuna purse-seiner fishery. Drifting FADs are actively monitored by satellite linked buoys and an increasing proportion of them are equipped with echosounders which provide fishers with accurate geolocation information and rough estimates of total biomass. Current fishers' echosounder buoys assume the

presence of just one tuna species (skipjack; *Katsuwonus pelamis*) for the process of converting acoustic backscatter into tuna biomass, thus biasing the interpretation of the collected acoustic data and reducing biomass estimation accuracy. The aim of this study was to improve biomass estimates of fishers' echosounder buoys so that scientist can use this data source as observatory tools to study pelagic ecosystems. 27 observations collecting echosounder buoys' acoustic data together with real catches made by purse-seiners at the same drifting FADs were analysed. We investigate 3 different methods combining vertical fish behaviour of the different species present at FADs and regional catch statistics to solve remote target classification. Recorded manufacturers' biomass estimation error was very variable. Maximum errors went from 300% overestimation to 100% underestimation. In addition, the study suggests that on average only 25% of the school present under the drifting FAD is sampled by the echosounder buoy. We finally propose a method using vertical behaviour of fish at drifting FADs, and TS of mixed aggregations as the best approach to convert acoustic backscatter from fishers' echosounder buoys into biologically relevant measures, making the data useful to scientists working in pelagic ecosystems.

### **Low Power Multi-frequency Sonar for Long-Term Observations of Volume Backscatter**

David Lemon, Gary Borstad, Leslie Brown and Paul Johnston

Long time-series of continuous data from moored acoustic instruments offer a low-cost method to study ecosystem changes by monitoring the behaviour and abundance of fish and zooplankton in the ocean and lakes. Calibrated sonars with several frequencies allow some information about species composition and abundance to be deduced from acoustic backscatter data. This presentation describes an improved low power, battery-operated sonar with up to four frequencies capable of autonomously collecting data at high temporal and spatial resolution for periods of several months. The procedures used to calibrate the instrument are described. Bottom-mounted deployment introduces additional factors in the instrument calibration, these being the effects of pressure and temperature on the transducer sensitivity. Some results of preliminary laboratory investigation into these effects will be presented. To illustrate the potential of long-term observations from moored sonars, data from two installations in Saanich Inlet, British Columbia, are discussed. The effects of seasonal and year-to-year variations are shown in a several-month segment of a six-year time-series collected by a 200 kHz sonar mounted on the VENUS cabled observatory, with the data organized as depth-time 'cubes' to facilitate handling of such long time-series. Data from a recent nearby deployment of a multiple-frequency instrument (125, 200, 460 and 770 kHz) shows an example of the additional information that can be obtained from simultaneous measurements at several frequencies.

## **6.2 Summary of session**

Studies presented during this session demonstrated that the use of new technologies continues to expand, and that significant progress is made in data analysis methods. In particular, advances in the low energy budgeting of the current generation of autonomous instruments opens up possibilities for a more widespread deployment of these sensors. The expanding use of multibeam and omnidirectional sonars shows that the community is gaining familiarity with the new generation of instruments and their information content. Presentations showed that calibrating these sonars is becoming more accessible and refined and more progress is expected in this area. Sev-



eral talks illustrated new methods for extracting information on school morphology and dynamics from multibeam sonar data and fish orientation from multibeam echosounder data using advanced statistical methods or the comparison of simulation models with data.

The comparison and cross-correlation of different instruments and observation methods, e.g. trawl and multi-sensor data not only contributes to increasing our confidence as to what we are seeing and measuring acoustically, but also increases our knowledge of how to interpret it. Presentations showed how comparing data from different frequencies has contributed to better understanding of bias and to increased precision of acoustic abundance estimates.

The use of acoustic data collected on fishing vessels for studying questions such as the relative spatial distribution, schooling dynamics and localized densities of commercial fish as well as fleet behaviour was illustrated with several examples. The results showed that these data can be used to estimate the relative amount of time spent searching or fishing, and to investigate what kind of density information fishers base fishing decisions on. Another presentation illustrated how sonar screen images collected on fishing vessels can be used to extract presence-absence information on tuna. A study showed how satellite linked buoys equipped with echosounders used on drifting FADs to actively monitor the tropical tuna fishery can be used as an observatory tool to study pelagic ecosystems.

A recurrent theme was the calibration of sonars and sounders from fishing vessels, autonomous buoys, etc. The challenge is to develop standard, rapid, simple and robust calibration methods, i.e. ideally a "self calibration" methodology. Another area where progress is needed is in the compression of large amounts of data in real time to be transmitted remotely, e.g. for autonomous sensors.

Although more routine use of autonomous systems is expected, particular thought must be directed towards the challenge of where and when to deploy them for optimal efficiency and relevance. Similarly, when using acoustics to study components of the ecosystem other than fish, e.g. jellyfish and micronekton, there is a lack of sampling effort to validate the backscatter. This issue also relates to habitat characterization. Critical habitat definition for specific species, e.g. endangered sea turtles requires large-scale habitat mapping appropriate to acoustic methodologies, which may include validated target classification of, e.g. their jellyfish prey.

## **7 Reports and updates from associated groups and organizations**

### **7.1 Update from SCICOM**

Nils Olav Handegard, Chair of the SCICOM Steering Group on Ecosystem Surveys, Science and Technology (SSGESST), informed the working group about the structure of ICES and the working groups role in the larger picture. He stressed the importance of WGFAST to maintain and develop the core knowledge base for performing acoustic-trawl surveys. The indices from these surveys are core products and will remain so. While maintaining this role, he also emphasized that within the ecosystem approach to fisheries management, the data requirements goes beyond the traditional single species abundance indices. Information about core processes and information across trophic levels are information that many SCICOM expert groups need, and WGFAST is in a key position to develop this. He stressed that the group needs to pay close attention to these needs and build relations other working groups to move the field forward. He also informed the WG about the new SCICOM science plan currently being developed, and explained how WGFAST will fit into the new structure. In conclusion, he stressed that WGFAST is part of the Science committee and explained the importance of doing quality science, and, if appropriate, it would be desirable for ICES if WGFAST is acknowledged in publications stemming from the community.

### **7.2 Study Group on Calibration of Acoustic Equipment**

The ICES Study Group on Calibration of Acoustic Instruments in Fisheries Science (SGCal) convened its third meeting at AZTI Tecnalia in Pasaia, Spain on Saturday 20 April 2013. David Demer (USA) was Chair and Rapporteur. The Chair thanked the host, Guillermo Boyra (Spain), and Claire Welling (ICES) for supporting the SGCal.

Eleven scientists from eight nations participated. The agenda, according to the terms of reference, included presentations on calibration-related developments and was focused on reviewing draft chapters of a new Cooperative Research Report (CRR) on the calibrations of acoustic instruments.

The Chair recalled that the SGCal met first in San Diego in spring 2010; second in Reykjavik, Iceland in 2011; and was granted a one-year extension in 2012. This third meeting marked the end of the group's third year. Therefore, the SGCal will endeavour to complete and submit a final report and draft of the CRR prior to the 2014 meeting of the ICES Working Group on Fisheries Acoustics Science and Technology, in New Bedford, Massachusetts, USA. The following timeline was adopted:

30 June 2013 – Authors update draft chapters

15 August 2013 – Chair merges chapters, reduces redundancy, identifies issues, adds cross-references, and solicits reviews

30 September 2013 – Reviewers provide comments

31 October 2013 – Authors update draft chapters

31 December 2013 – Refinements made to draft CRR

April 2014 – Chair submits final SGCal report and CRR to ICES

Chair will present a final report to the WGFAST in New Bedford, Massachusetts, USA during 5–9 May 2014.

### 7.3 Topic Group on metadata standards

The purpose of TG-AcMeta is 'To describe a metadata convention that details the attribute fields necessary to describe processed water column acoustic volume backscatter data obtained from active acoustic systems'. TG-ACMeta commenced activities in Jan 2011 through e-mail correspondence between the fifteen participants. In April 2011 a group of participants met in Reykjavik Iceland to progress the topic. A second meeting was held in Brest, France in April 2012. The working document produced by TG-ACMeta that describes the metadata convention was reviewed in February 2013 by a Jens Rasmussen, a metadata expert from Marlab in the UK. TG-ACMeta met once more with 10 participants in San Sebastian on 15 April 2013 where the recent review was discussed and changes implemented to the working document. The working document is now well advanced but with some post meeting items to be implemented. A version 1.0 of the metadata document is scheduled to be finalized by September 2013 in time for the ICES ASC.

### 7.4 Engagement with SPRFMO

François Gerlotto reported on engagement of WGFASST with the South Pacific Regional Fisheries Management Organization (SPRFMO). No work was carried out in 2012 awaiting the official creation of SPRFMO which happened in January 2013. Now that the organization has officially been created work will resume. A working group on monitoring using acoustic data has been created and will next meet in October in San Diego.

### 7.5 New topic group on acoustic multi-frequency target classification (TOR d)

The topic group under the coordination of Rolf Korneliussen prepared an outline for an ICES cooperative research report with the following content:

- 1 ) What is a target?
- 2 ) What is target classification?
- 3 ) Steps in target classification (excluding bottom classification)
- 4 ) Analysis approaches
- 5 ) Methods of verification

The group is now looking to get more contributions before preparing terms of references (responsible Rolf Korneliussen) which will be circulated among WGFASST members before mid-June prior to sending them to SCICOM for consideration in September 2013.

### 7.6 Pre-meeting workshop on EchoR analysis routines in R

EchoR is an open source suite of R code for handling preprocessed fisheries acoustics data collected during scientific surveys, and for computing several standard ec(h)osystem indicators based on these data. For each fish species the following indicators are calculated:

- Biomass estimates per elementary sampling distance unit (ESDU);
- Biomass-at-length estimates per ESDU;
- Biomass-at-age estimates per ESDU;
- Biomass estimates per post-stratification area.

Methods for acoustic fish biomass assessment implemented in EchoR are described in Simmonds and MacLennan (2005) and Doray *et al.* (2010).

EchoR includes a large number of data quality checks, which aim to improve the reliability of acoustic-based fish biomass estimates, as well as extended plotting capabilities, both for data quality control, and displaying and inspecting results. Tools for comparing biomass estimates obtained with different methods are also available. Spatial indicators summarizing fish population spatial patterns (Woillez *et al.*, 2007), computed based on per ESDU data, are planned to be included in the near future. EchoR source code and documentation, including a tutorial, can be found at:

<https://forge.ifremer.fr/plugins/mediawiki/wiki/echor/index.php/Accueil>

The objective of the EchoR workshop carried out prior to the WGFASST meeting was to introduce the principles and demonstrate the capabilities of the EchoR routines, by producing maps of biomass estimates by species and ESDU. An overview of the fish biomass estimation method using post-stratification was also provided. Further, maps of fish biomass per ESDU were created based on the participants' own acoustic survey data, or using an example dataset.

## 7.7 References

- Doray, M., Massé, J., and Petitgas, P. 2010. Pelagic fish stock assessment by acoustic methods at Ifremer. Rapp. Int. Ifremer DOP/DCN/EMH 10- 02: 1–17.  
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## Annex 1: List of participants

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## Annex 2: Agenda

	Tuesday	Wednesday	Thursday	Friday
08:45	Housekeeping	Housekeeping	Housekeeping	Housekeeping
09:00	FAST opening	Reynisson et al	Handegard	Knudsen and Schmidt
09:20	Idczak and Gorska	McQuinn and Dion	Peña et al	Fässler et al
09:40	Doray and Berger	Ressler et al	Discussion	Lopez et al
10:00	El Ayoubi et al	Peña et al	Berger et al	Lemon et al
10:20	Gastauer et al	Cox	Holmin et al	Discussion
10:40	Coffee	Coffee	Coffee	Coffee
11:00	Coffee	Coffee	Coffee	Coffee
11:20	Ona et al	Gauthier	Peña (sonar)	FAST ToR 2014-2016
11:40	Dunford et al	Remond et al	Korneliusen	FAST ToR 2014-2016
12:00	Macaulay et al (model)	Kloser et al	Aizpurua	Meeting closure
12:20	Kubilius et al	Fujino et al	Vatnehol	
12:40	Lunch	Lunch	Lunch	
13:00	Lunch	Lunch	Lunch	
13:20	Lunch	Lunch	Lunch	
13:40	Lunch	Lunch	Lunch	
14:00	Lawson et al (field applications)	Horne and Linder	Melvin	
14:20	Peña and Nogueira	Schaber et al	Ryan and Kloser	
14:40	Macaluay et al	Habasque et al	Jech and Price	
15:00	Lawson et al (autonomous)	Giannoulaki et al	Sergey et al	
15:20	Coffee	Coffee	Bus to Pasaia Harbour	
15:40	Coffee	Coffee		
16:00	Fraser and Horne	Bertrand et al		
16:20	Discussion	Discussion		
16:40	SGCal; David Demer	Boyra		
17:00	Metadata; Tim Ryan	Gerlotto		
17:20	SICOM Update; Handegard	Trenkel		
17:40	FAST ToR 2014-2016	Churnside and Demer		
18:00	Tapa break			
19:00	Simrad updates	MAREC updates		
	Applications of acoustic methods to characterize ecosystem			
	Acoustic properties of marine organisms			
	Behaviour			
	Emerging technologies, methodologies, and protocols			
	FAST Business			



### Annex 3: Group photograph

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## Annex 4: WGFASST output in 2012–2013

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

### Peer-reviewed publications

- Robertis, Alex De, and Nils Olav Handegard. (2013) "Fish Avoidance of Research Vessels and the Efficacy of Noise-reduced Vessels: a Review." *ICES Journal of Marine Science* 70, no. 1: 34–45. doi:10.1093/icesjms/fss155.
- Fablet, R., Gay, P., Peraltilla, S., Peña, C., Castillo, R., Bertrand, A. 2012. Bags-of-Features for fish school cluster characterization in pelagic ecosystems: application to the discrimination of juvenile and adult anchovy clusters off Peru. *Canadian Journal on Fisheries and Aquatic Sciences*, 69: 1329-1339.
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- Jech, J. M., and F. Stroman. 2012. Aggregative patterns of pre-spawning Atlantic herring on Georges Bank from 1999-2010. *Aquatic Living Resources*, 25: 1–14.
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- O'Driscoll, R. L., Hanchet, S. M., Miller, B. S. 2012. Can acoustic methods be used to monitor grenadier (*Macrouridae*) abundance in the Ross Sea region? *Journal of Ichthyology*, 52: 700–708.
- O'Driscoll, R.L., Oeffner, J., 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.
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- Trenkel, V. M., Berger, L. 2013. An acoustic multi-frequency index to inform on large scale spatial patterns of pelagic ecosystems. *Ecological Indicators*, 30: 72–79.

### Reports

- FAO. 2012. Fishing vessel execution of acoustic surveys of deep-sea species: main issues and way forward. *FAO Fisheries and Aquaculture Circular*. No. 1059. Rome. 91 pp. <http://www.fao.org/docrep/017/i2522e/i2522e.pdf>. Authors: Ross Shotton (Editor), David Boyer, Gary Melvin, Richard O'Driscoll, Graham Patchell, Hector Pena, Ruben Roa, Tim Ryan, Jessica Sanders, Merete Tandstad, Jessica Sanders.
- O'Driscoll, R. L. 2012. Acoustic survey of spawning hoki in Cook Strait during winter 2011. *New Zealand Fisheries Assessment Report 2012/17*. 50 p.
- 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., Dunford, A. J., Fu, D. 2012. Acoustic estimates of southern blue whiting from the Campbell Island Rise, August–September 2011 (TAN1112). New Zealand Fisheries Assessment Report 2012/18 52 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., Dunn, M. R., Ballara, S. L., Horn, P. L. 2012. Trawl survey of hoki and middle depth species on the Chatham Rise, January 2011 (TAN1101). New Zealand Fisheries Assessment Report 2012/10. 98 p.

## Annex 5: WGFASST multi-annual terms of reference (TORs) for the period 2014–2016

The **Working Group on Fisheries Acoustics, Science and Technology** (WGFASST), 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.

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

### ToR descriptors

ToR	Description	Background	Science plan topics addressed	Duration	Expected deliverables
a	Produce a list of papers originating from the community of the WGFASST working group	The WGFASST community produces several papers every year, and an update on recent WGFASST 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 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 WGFASST 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 WGFASST		3 year	Write a review paper showing the WGFASST 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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### Summary of the Work Plan

Year 1	Produce the annual overview of recent developments within the field, including the list of contributions originating from the WGFAST community.
Year 2	Produce the annual overview of recent developments within the field, including the list of contributions originating from the WGFAST community. Organize the ICES international acoustics symposium (alternatively year 3). Organize a joint session at ICES ASC (alternatively year 3)
Year 3	Produce the annual overview of recent developments within the field, including the list of contributions originating from the WGFAST community. Produce a review paper to showcase the developments originating from WGFAST

### 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 WGFTFB 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.

## Annex 6: Recommendations

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<b>Recommendation</b>	<b>Adressed to</b>
1. Review the metadata standard for acoustic data from the acoustic meta data standard topic group.	ICES Data Centre, SSGESST
2. Review suggestion for the next acoustics symposium	SSGESST
3. Review suggestion for ICES Cooperative Research Report on acoustic target classification	PUBCOM