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

19–22 April 2016

Vigo, 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

The ICES Working Group on Fisheries Acoustics, Science and Technology (WGFAST) is the only international forum where individuals working in fisheries acoustics can network to discuss ongoing developments in the technique. As such, it is been highly successful, attracting 67 participants in 2016.

Highlights

The major themes addressed during the meeting included:

- Behaviour;
- Applications of acoustic methods to characterize ecosystems;
- Acoustic properties of marine organisms;
- Emerging technologies, methodologies, and protocols (special topic: Biomass estimation: Best practice and guidance).

A separate session was held for each theme, where the participants first presented the latest results of their work, followed by a discussion. The abstracts and discussion summaries are given in the report. The contributions highlighted the wide range of applications of acoustics to characterize a fast growing list of ecosystem characteristics and features. Acoustic methods are being used to assess and develop models of krill distribution, investigate sound-scattering layers, refine our definition and comprehension of pelagic habitats, and help construct a better understanding of oceanic features such as frontal zones. The discussion following the behaviour session identified two potential topics for future research or theme sessions at FAST or ICES ASC meetings: potential effects of sound on aquatic organisms, and additional efforts to quantify fish reactions to sound from vessels. Several presentations highlighted research and increasing applications of acoustic wideband technologies. Wideband systems are expected to replace the current standard narrowband scientific echosounders. To accompany this change, WGFAST is organising in 2016 an ICES Training Course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics'.

1 Administrative details

Working Group name

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

Year of Appointment within the current three-year cycle

3

Reporting year concluding the current three-year cycle

2016

Chair

Verena Trenkel, France

Meeting venue(s) and dates

6–9 May 2014, New Bedford, USA, (66)

29 May 2015, Nantes, France, (43)

19–22 April 2016, Vigo, Spain, (67)

2 Terms of Reference a) – e)

WGFAST terms of reference

ToR	Description	Background	Duration	Expected deliverables
a	Produce a list of papers originating from the community of the WGFAST working group	The WGFAST community produces several papers every year, and an update on recent WGFAST activities that acknowledges ICES is important.	Year 1, 2 and 3	An updated list of references
b	Present recent work within the topics "Applications of acoustic methods to characterize ecosystems", "Acoustic properties of marine organisms", "Behaviour", and "Emerging technologies, methodologies, and protocols".	Create a venue for informing the group members on recent activities and seeking input to furhter developement. An overview of the different contributions will be presented in the annual report.	1,2,3	Report
c	Write a review to showcase the work of WGFAST with particular emphasis on its relevance to the ICES/ACOM strategis plans	After three years a review paper will be written to showcase the work of WGFAST	3 year	Write a review paper showing the WGFAST contribution over the last 3 years
d	Organize international acoustic symposium	Organize the 8th international symposium with working title "Marine Ecosystem Acoustics – observing the ocean interior across scales in support of integrated management"	2015	Symposium and special issue in ICES Journal of Marine Science
e	Organize joint sessions at ICES ASC	Organize joint sessions with survey working groups to foster collaboration regarding the use of acoustics data and cross-fertilization	2 or, 3	Topic session at ICES ASC

Recommendation from WKSUREQ	The possibilities to implement new and more cost efficient technology needs to be addressed, and a joint ToR linking WGECO, as the central ecosystem effects EG, with WGFAST/WGFTFB allowing explicit linkage between technology groups and user groups must be established through SSGIEOM and SCICOM/ACOM, as WGECO is an advisory EG.	2016
Recommendation 1 from WKSCRUT	1. WKSCRUT identified that there are no standard procedures in place for how to deal with bad weather conditions and how to treat the data. There is a need for an improved understanding of effects such as signal loss due to bad weather situations. WKSCRUT recommends that standardized methods to quantify the signal to noise ratio during normal survey operations should be defined and established.	2016
Recommendation 2 from WKSCRUT	2. Expert judgments on the degree of data quality are diverging. The actual decision to interrupt acoustic survey operations due to bad weather so far is based on expert judgment and subjective. WKSCRUT recommends that standardized approaches for the interruption of acoustic survey operations in bad weather should be defined and established.	2016
Recommendation from WKIACTDB	Review the acoustic metadata standard in relation to the proposed database design.	

3 Summary of Work plan

Summary of WGFAST 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 comunity. 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 comunity. Produce a review paper to showcase the developments originating from WGFAST

4 Summary of Achievements of the WG during 3-year term

Publications:

- ICES. 2014. A metadata convention for processed acoustic data from active acoustic systems, SISP 4 TG-AcMeta, ICES WGFAST Topic Group, TG-ACMeta. 40 pp.
- Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R. et. al. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326. 133 pp.
- Trenkel, V.M., Handegard, N.O., Weber, T. C. 2016. Marine Ecosystem Acoustics: a symposium on "Observing the ocean interior in support of integrated management". ICES Journal of Marine Science.

Activities initiated by WGFAST:

- Organization of ICES Symposium on Marine Ecosystem Acoustics - Observing the Ocean interior in support of integrated management'', 25–28 May 2015, Nantes, France; 214 participants from 31 countries
- Special issue on acoustics symposium in ICES Journal of Marine Science
- Joint ASC session with WGISUR[1] 'Ecosystem monitoring in practice' (2015); The session was attended by approximately 50–70 participants. Contributions included 14 (15) talks and 5 posters and addressed three core areas of innovative ecosystem monitoring techniques: (1) novel methods and datasets to be applied/examined when following an ecosystem approach in monitoring; (2) studies recently or currently conducted applying measures to follow a more holistic approach to ecosystem monitoring; (3) new joint survey programs focusing on combining or expanding existing surveys to broaden measurements of ecosystem parameters and e.g. marine strategy framework descriptors in an ecosystem survey.
- ICES ASC session on 'Fisher collected acoustic data (FCAD)' (2016).
- ICES ASC session on 'What is a good pelagic habitat?' (2016).
- ICES Training course proposal on 'Introduction to abundance estimation from fisheries acoustic surveys' (proposed for 2017).
- ICES Training course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics' (Bergen, Norway, December 2016).
- ICES Training course on 'Application of Geostatistics to analyse spatially explicit Survey data in an Ecosystem Approach' (Fontainebleau, France, December 2014).
- ICES workshop on 'Scrutinisation Procedures for Pelagic Ecosystem Surveys' (WKSCRUT) (Hamburg, Germany, September 2015).
- ICES workshop on 'Collecting Quality Underwater Acoustic Data in Inclement Weather' (WKQUAD) (proposed for 2017).

[1] Working Group on Integrating Surveys for the Ecosystem Approach

- Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] and the Working Group on Fisheries Acoustics Science and Technology [WGFAST] (JFATB) chaired by Paul Winger (Canada) and Alex De Robertis (USA) in New Bedford, USA (5 May 2014). The meeting discussed novel research on a broad range of subjects related to technological developments of optical and acoustic techniques in combination with trawl sampling.
- ICES WGFAST Topic Group on 'Calibrating echosounders on fishing vessels' (initiated in 2016).
- ICES WGFAST Topic Group on 'Defining a data format for omni fisheries sonars' (initiated in 2016).
- ICES WGFAST Topic Group (TG-ACMeta) for 'Defining a metadata convention for processed acoustic data from active acoustic systems' (2014-2016).
- ICES Working Group on target classification (WGTC) (2014-2016).
- ICES workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys (WKEVAL) (Copenhagen, Denmark, August 2015).
- Broadband/wideband acoustic methods discussion forum (2015, 2016).

5 Final report on ToRs, workplan and Science Implementation Plan

5.1 Progress and fulfilment by ToR

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

Nineteen manuscripts to appear in special issue on "Marine Ecosystem Acoustics" of the ICES Journal of Marine Science.

5.1.2 ToR b Present recent work in fisheries acoustics

Abstracts for all work presented in 2016 are found in Annex 5.

Applications of acoustic methods to characterize ecosystems

This session highlighted the wide range of applications of acoustics to characterize a fast growing list of ecosystem characteristics and features. Acoustic methods are being used to assess and develop models of krill distribution, investigate sound-scattering layers, refine our definition and comprehension of pelagic habitats (through tools like the Profiling Lagrangian Acoustic, Optical System), and help construct a better understanding of oceanic features such as frontal zones. A wide range of acoustic tools and methods were displayed in this session as well, from the use of conventional commercial echosounders to assess the distribution of key fish species in trap fisheries, multibeam system to assess the distribution of fish assemblages around gas platforms, upward-looking moored echosounder to monitor juvenile salmon migration at sea, and the use of broadband technology to improve fish species and size discrimination with the goals of minimizing overfishing and bycatch. As the community is striving to use acoustics to its full potential in ecosystem assessment, new ways of using and integrating existing data are also being explored. This included for example the use of night-time data in typical daytime anchovy surveys, the use of historical surveys defined for one species (Atlantic herring) to assess another (Bluefin tuna), and comparing biomass estimates derived from different sources such as acoustic and bottom-trawl surveys. The complexity and wealth of information in acoustic data can present analytical challenges, and efforts are being made in testing the ability of models to measure and detect change (an important aspect for environmental assessment and ecological research), and in the development of synthetizing tools for ocean observation and monitoring, through initiative like the Nekton Interactive Monitoring System (NIMS). All of these presentations were great examples of how acoustics has now become an important and valuable tool in ecosystem research, and will continue to expand as new vessels equipped with a suite of broadband, multibeam, and omni-sonar systems (such as the RV Tamgu-21 highlighted by South Korea) will take on the world oceans.

A common challenge to all of these ecological applications is the verification of target animal, the so-called ground-truthing. All sampling tools have biases, and truly integrated ecosystem science need to use a combination of methods and tools. It is generally agreed that several sampling tools independent of each other are desired, but in some cases tools are used to understand and assess the bias and constraints of another tool (an example of this is the combination of optical systems within trawlnets). There is undoubtedly a need for more research into the selectivity and organisms reactions to the various sampling tools used in science, and the development of alter-

native methods when and where conventional tools cannot be use, such as in untrawlable areas.

Mixed aggregations of species remain a particular challenge. Even when sampled with nets using multiple closing codend, some aggregations are composed of several species that are integrated together in samples (e.g. mesopelagic fish communities). This is where progress in broadband/wideband technologies and processing could really make a difference.

Behaviour

One motivation for the behaviour session was the increasing international concern and in some countries, legislation (e.g. Marine Mammal Protection Act) to minimize impacts of sound on aquatic organisms including marine mammals. A lack of available funding to support travel prevented the participation of invited speaker Dr Brandon Southall to inform the WGFAST community on the latest research and legislative activities that potentially constrains use of acoustic technologies in marine waters.

Tuesday morning's behaviour session contained six talks and a series of updates from the FAST chair. Three themes were evident in the collection of presentations: how behaviour potentially influences acoustic-based abundance estimates, how fish behaviour can be characterized using acoustics, and how vessel noise characteristics potentially influences fish behaviour and subsequent acoustic measurements. Two examples from the Wadden Sea and the Bay of Biscay illustrated how temporal changes in behaviour and interactions with the environment, influences the location of fish in the water column and the availability of animals to be measured for distribution characterizations and abundance estimates. Characterization of fish behaviour included descriptions of aggregation formation and potential aural cues used for predator–prey interactions. There were presentations on noise characteristics of a new Australian survey vessel and a review of ICES CRR 209 noise standards relative to current vessel design and manufacturing practices.

The discussion of the behaviour session identified two potential topics for future research or theme sessions at FAST or ICES ASC meetings: potential effects of sound on aquatic organisms, and additional efforts to quantify fish reactions to sound from vessels. There was encouragement to include marine mammal scientists in discussions and research by the fisheries acoustics community. There was also a short discussion on the WGFAST efforts to examine causes of behavioural reactions by fish to vessel noise and the status of the subsequent report (see below).

Following the presentation by H. Knudsen on the need to revisit CRR 209 on vessel noise the group WGFAST acknowledged that new methods for reducing noise have been developed since this publication of this CRR while the most recent works produced by the working group referred more to fish avoidance than to physical possibilities of noise reduction. Therefore, WGFAST encourages H. Knudsen to go ahead in this field and submit a concrete proposal. In order to make the last relevant works of WGFAST easily accessible, the final report of SGFARV (Study group on Fish Avoidance to Research Vessels, 2012) is added as an annex to the present report.

Acoustic properties of marine organisms

The acoustic properties of marine organisms' session contained seven presentations. Two were about organisms for which no estimates of backscatter strength have been previously available. This illustrates that the acoustic method continues to be applied to new species and situations. Three of the presentations provided results that were

significantly different from currently used target-strength measurements. The cause of this was not confirmed but appears likely due to changes in fish tilt angle distributions between the earlier measurements and that of the fish in their surveyed state. This illustrates the important role of fish behaviour in averaged acoustic properties and highlights the need to demonstrate and repeatedly check that acoustic property estimates are appropriate to particular survey situations. Two of the presentations discussed new methods to measure acoustic properties of marine organisms and confirms that improvements and enhancements to the basic, well-proven techniques for measurement of acoustic properties continue to be of value to the community.

The discussion at the end of the session raised several points:

- The increasing use of broadband acoustic signals, and the resulting need to understand and interpret the more complex backscatter is likely to increase the use of acoustic scattering models.
- As with all modelling, validation is important, particularly for the commonly used models which are highly simplified versions of reality.
- The addition of organism parts beyond the gas-filled swimbladder is likely to be a useful enhancement as is the effect of body flexing on the backscatter.
- With high-resolution broadband signals, or large fish (such as tuna), it is important to understand that the point-source assumption may not be valid and that this alter how the results should be interpreted. Broadband can move us from basic backscatter measurements to imaging of the internal structure of organisms.

Emerging Technologies, Methodologies, and Protocols

Sixteen presentations highlighted research and applications of acoustic wideband technologies, alternative platform and deployment capabilities, calibration of sounders and sonars, and collection of acoustic and environmental data on commercial fishing vessels in the Emerging Technologies, Methodologies, and Protocols session. Scientific broadband systems are now commercially available and seven presentations covered a range of topics including definitions and terminology specific to broadband data collection and processing; evaluation and assessment of the broadband Simrad EK80 that will soon replace the current standard scientific echosounder, the Simrad EK60; and target classification and fish size estimation in polar and temperate ecosystems. Alternative deployment strategies were presented to sample fish near the sea surface, monitor selected locations within survey areas with the goal of reducing future survey effort, and integrate optical and acoustic data to improve abundance estimates of reef fish. Calibration protocols for omnidirectional sonar systems and monitoring echosounder performance highlighted the continued need for collecting high quality data. Commercial fisheries vessels are collecting scientific-grade acoustic and environmental data, which are being used to generate potential pelagic habitat maps, and in return these maps help direct fisheries effort and reduce search time.

5.1.3 ToR c Write a review to showcase the work of WGFAST with particular emphasis on its relevance to the ICES/ACOM strategic plans

The following manuscript reviews recent work carried out by WGFAST members and themes presented at the ICES symposium on Marine Ecosystem Acoustics:

Trenkel, V.M., Handegard, N.O., Weber, T.C. 2016. Marine Ecosystem Acoustics: a symposium on "Observing the ocean interior in support of integrated management". ICES Journal of Marine Science, submitted.

5.1.4 ToR d Organize international acoustic symposium

The ICES Symposium on Marine Ecosystem Acoustics - Observing the Ocean interior in support of integrated management" took place in Nantes, France, 25–28 May 2015. It was attended by 214 participants from 31 countries.

5.1.5 ToR e Organize joint sessions at ICES ASC

- Joint ASC session with WGISUR 'Ecosystem monitoring in practice' (2015). The session was attended by approximately 50-70 participants. Contributions included 14 (15) talks and 5 posters and addressed three core areas of innovative ecosystem monitoring techniques: (1) novel methods and datasets to be applied/examined when following an ecosystem approach in monitoring; (2) studies recently or currently conducted applying measures to follow a more holistic approach to ecosystem monitoring; (3) new joint survey programs focusing on combining or expanding existing surveys to broaden measurements of ecosystem parameters and e.g. marine strategy framework descriptors in an ecosystem survey.
- ICES ASC session on 'Fisher collected acoustic data (FCAD) ' (2016)
- ICES ASC session on 'What is a good pelagic habitat?' (2016)

5.1.6 Other ToRs

Recommendation from WKSUREQ received in 2016

The possibilities to implement new and more cost efficient technology needs to be addressed, and a joint ToR linking WGECO, as the central ecosystem effects EG, with WGFAST/WGFTFB allowing explicit linkage between technology groups and user groups must be established through SSGIEOM and SCICOM/ACOM, as WGECO is an advisory EG.

WGFAST discussed recent technological developments which could be employed to provide cost efficient alternative ways of data collection and analysis. The group drew up a list of promising technological developments and identified potential applications.

Moorings: cost-efficient sampling platform for distant spawning areas when equipped with echosounder, optical sensors, etc. Has been used by WGFAST members.

Autonomous platforms: low cost transect sampling in coastal waters can be carried out using kayaks, sailing boats and small Autonomous Underwater Vehicles (AUVs).

Fishing vessels: fishing vessels have increasingly scientific-grade echosounders installed which can be used to collect acoustic information during ordinary fishing operations and several members of WGFAST have experience in using such data. The issue of calibrating these echosounders is to be tackled by the newly created topic group on Calibrating echosounders on fishing vessels.

Automated data analysis: Fisheries acoustics has gained much experience in automatic data treatment, which has become necessary due to the large amount of data being collected on non-scientific platforms. This makes it possible to offer derived data products at relatively low cost.

Survey design: WGFAST suggests that there is potential to optimize vessel based surveys by making better use of knowledge of habitats and suitable time periods for target species. Including prior knowledge of current spatial distributions of pelagic species might allow to adapt survey transects and avoid surveying areas where the species is (temporarily) absent. A recent example is the international blue whiting survey.

Recommendations from WKSCRUT received in 2016

1. WKSCRUT identified that there are no standard procedures in place for how to deal with bad weather conditions and how to treat the data. There is a need for an improved understanding of effects such as signal loss due to bad weather situations. WKSCRUT recommends that standardized methods to quantify the signal to noise ratio during normal survey operations should be defined and established.

2. Expert judgments on the degree of data quality are diverging. The actual decision to interrupt acoustic survey operations due to bad weather so far is based on expert judgment and subjective. WKSCRUT recommends that standardized approaches for the interruption of acoustic survey operations in bad weather should be defined and established.

In response to these two recommendations, WGFAST proposes to organize a dedicated workshop in 2017. The proposal for the Workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD) is found in Annex 2.

Recommendation from WKIACTDB received in 2016

Review the acoustic metadata standard in relation to the proposed database design.

WGFAST discussed revision of the acoustic metadata standard to make it suitable as basis for the database of acoustic interpreted data to be held by ICES. The revised metadata standard will be published as a new version of the ICES SISP manual 'A metadata convention for processed acoustic data from active acoustic systems'.

Other issues

ISO liaison

ICES now has a Category A liaison to the ISO Underwater Acoustic subcommittee (ISO/TC 43/SC 3). The basic role of all ISO liaisons is to engage stakeholders and build consensus around standards. The liaison gives ICES the ability to:

- Participate in ISO/TC 43/SC 3;
- Appoint experts to the subcommittee;
- Access subcommittee documents;
- Comment, but not vote, on standards developed by the subcommittee.

ISO/TC 43/SC 3 currently has four working groups that are developing standards on the measurement of noise from ships, acoustic terminology, measurement of sound from pile driving, and the calibration of active sonars. The group also participates in a joint working group that is concerned with measuring noise from hulls and propellers.

ICES can also propose new standards, but the development of such depends on interested subcommittee members agreeing to work on the standard.

Creation of Topic group on Defining a data format for omnidirectional fisheries sonars

The motivation behind the creation of this topic group is the increased interest in using fisheries sonar data for scientific purposes, which is available on many fishing vessels, but also for existing and new research vessels. There is currently no standard format used by the different manufacturers, nor an agreed request from the scientific community.

A common format agreed by WGFAST members will facilitate the use of this type of data and will give sonar manufactures and post-processing software developers more effective means to support the scientific use of omni-sonar data. The topic group will be led by Hector Pena (IMR, Norway).

ICES acoustics training course

The organization of an ICES training course on how to plan and analyse a fisheries acoustics survey was discussed and the idea accepted. The target audience are fisheries scientists running surveys using acoustic methods on research vessels or other platforms. The training course will provide an introduction to standard practices for acoustic biomass estimation but also to more recent developments. The course will not be instrument specific but aim at covering the most commonly used systems and software packages. The course will be a combination of theory and hands on experience analysing data samples. The training course will be developed by Paul Fernandes (University of Aberdeen, UK) and John Horne (University of Washington, USA).

5.2 Science highlights

The 7th Symposium on fisheries acoustics and technology for aquatic ecosystem investigations was organized by WGFAST in 2015 under the heading 'Marine Ecosystem Acoustics - Observing the Ocean interior in support of integrated management'. The symposium offered the opportunity to take stock of recent progress and the use of acoustics within the ICES acoustics community and beyond. Over the years and as the technology matured, the ICES fisheries acoustics community has evolved to incorporate the application of acoustics for characterizing fish, their ecosystems, and their management, in addition to continued technical developments (Figure 5.2.1).

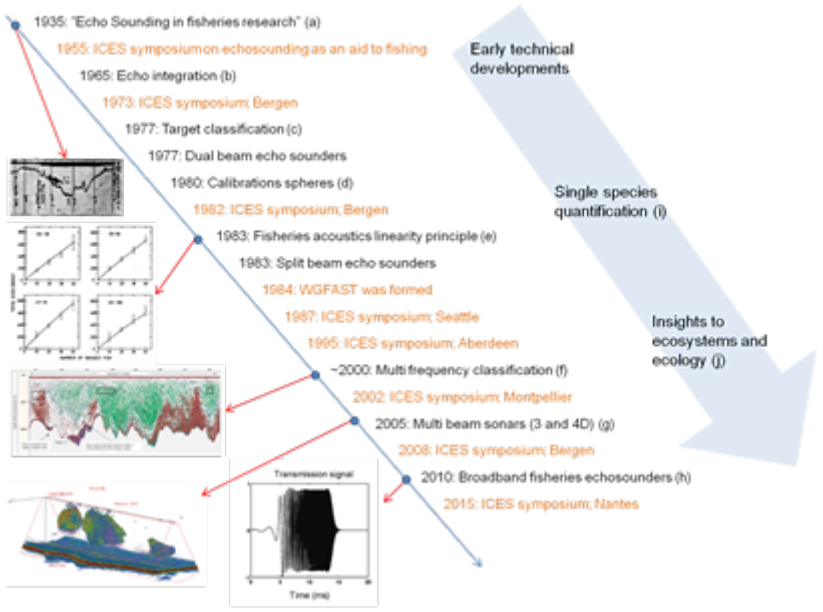


Figure 5.2.1. Time line for the development of the marine ecosystem acoustics. The right part of the figure depicts the general trend, important milestones in the development of fisheries acoustics are shown on the left hand side with an emphasis on the uptake of technologies by the general fisheries community. (a) Sund (1935) (b) Dragesund and Olsen (1965); (c) Holliday (1977); (d) Foote *et al.* (1987); (e) Foote (1983); (f) Brierley *et al.* (1998) Kloser *et al.* (2002); Korneliussen and Ona (2003); (g) Trenkel *et al.* (2008); (h) Stanton *et al.* (2010) (i) MacLennan (1990); Simmonds and MacLennan (2005) (j) Benoit-Bird and Lawson (2016).

A detailed view of changes in focus of the ICES fisheries acoustics community can be obtained by comparing the topics of talks and posters presented in 2015 with those of three previous ICES acoustic symposia (2008, 2002, and 1987). For this, we analysed the list of the 25 most common words in the abstracts (titles only for 1987) of each symposium (Figure 5.2.2). The words (roots) process and characteris* appeared in 2015 and ecosystem in 2008 demonstrating an increasing application of acoustics to ecological studies at the wider ecosystem scale, though species applications continue to be important since 2002. The 1987 symposium was characterized by studies of behaviour and river related issues, while in 2015 the marine environment dominated. Fisheries applications have become numerous since 2008. Focusing on the 10 words that were common to the abstracts of all four symposia, abundance estimation of fish schools and their distribution in the sea using surveys were recurrent themes, as were measurement of acoustic targets. Multivariate analysis of the 50 most common words found in the abstracts (titles) of the four symposia revealed an overall temporal trajectory of symposia contributions towards more species-oriented studies and more emphasis on ecosystem and management aspects with increasing focus on zooplankton/krill, assessment, management, spatial aspects and distributions.

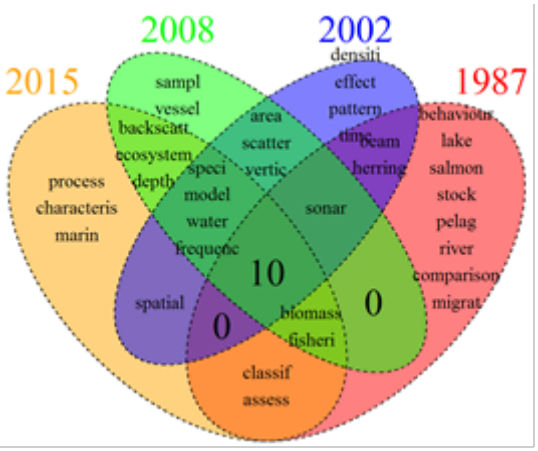


Figure 5.2.2. Text mining of the abstracts of four recent ICES acoustic symposia (titles only for 1987). Visualization of the 25 most frequent words using a Venn diagram. The ten words (roots) common to all symposia are: abund, distribut, estim, fish, measur, school, sea, survey, system, and target.

Analysing the structure of the research community that participated in the 2015 symposium 14 groups of co-authors were identified (Figure 5.2.3). Remarkably, only 7% of contributions had a single author (isolated dots in Figure 5.2.3), demonstrating the high degree of collaboration within the acoustic community forged over many years and indicating a state of maturity of the field. Two large meta-communities emerged from the analysis. The first meta-community consisted of three groups of Asian authors (salmon, pink and red groups in Figure 5.2.3). The core of the second meta-community (centre of graph) was formed by seven groups with authors from the traditional ICES acoustics community in Europe, America, Australia, and New Zealand.

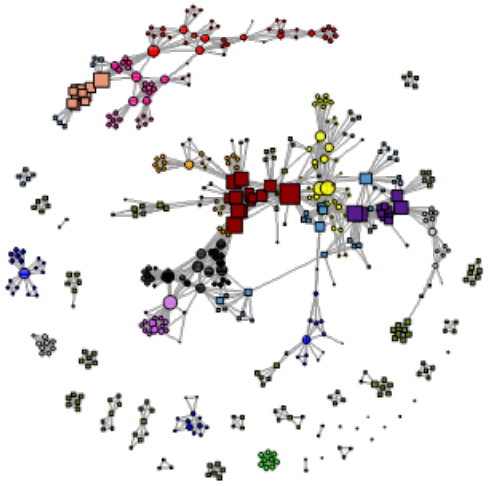


Figure 5.2.3. Network of 2015 acoustic symposium co-authorships (talks and posters). Each vertex represents a contributor. The colours indicate cluster membership. The size of each vertex is proportional (on log-scale) to the number of co-authors.

6 Cooperation

Cooperation with other WG

In 2014, a joint meeting (JFTAB) took place with the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB) back to back with the WGFAST meeting in New Bedford, USA.

Cooperation with Advisory structures

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

Cooperation with other IGOs

In 2015, a member of WGFAST took part in the meeting of the ISO Underwater Acoustic subcommittee (ISO/TC 43/SC 3) for which ICES has a category A liaison.

7 Summary of Working Group self-evaluation and conclusions

In addition to discussing recent advances and applications of fisheries acoustics, WGFAST has produced best practice guidelines and launched initiatives to share knowledge and best practice. Full details can be found in the self-evaluation report.

ICES WGFAST is the only international forum where individuals can network to discuss ongoing developments in fisheries acoustics. As such, it has been highly successful, attracting over 60 participants in 2014 and 2016, and over 200 participants for the ICES acoustics symposium organized in 2015. A measure of WGFAST success is the wide participation beyond the ICES community: regular participants include those from Australia, New Zealand, and the west coast of the USA and Canada. Without this WG, the fisheries acousticians in each member and observer state will be more isolated and have to rely on sporadic international conferences which do not have fisheries (and marine resource related) applications at heart: this would be a major loss to the ICES community and would jeopardize the quality of associated surveys and the relevant underwater acoustics research worldwide. WGFAST is therefore proposing to continue as an ICES working group.

Annex 1. WGFAST List of participants

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Annex 2. Recommendations

RECOMMENDATION	ADRESSED TO
1. WGFAST recommends to verify and if necessary include in survey manuals for acoustic surveys (SISPs) details on minimum data quality for acoustic and trawl data collection on research or hired vessels participating in surveys. For acoustic data this includes the list of echosounder frequencies, etc. For trawl data this includes the type of trawl and the auxilliary data to be collected.	WGIPS, WGACEGG, WGBIFS
2. Organize workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD)	WGFAST, ACOM, SCICOM
3. Propose training course on Introduction to abundance estimation from fisheries acoustic surveys.	WGFAST, SCICOM, Training

Annex 3. Workshop proposals and WGFAST terms of reference

WKQUAD

The **Workshop on Collecting Quality Underwater Acoustic Data in Inclement Weather (WKQUAD),** chaired by Matthias Schaber (DE) and Mike Jech (USA), will meet for 3 days (31/3-2/4/2017) in conjunction with WGFAST in 2017 to:

a) Review current knowledge and experience on the impact of weather conditions on acoustic data collected with a variety of single and multibeam, narrow and wideband echosounders and sonars operating at common acoustic frequencies used in fisheries acoustics on research vessels;

b) Develop standard procedures and methods for identifying unsuitable survey conditions, i.e. situations that are considered too degraded to continue collecting acoustic data;

c) Propose methods for dealing with degraded data;

d) Test and compare the proposed procedures and methods for selected datasets (to be made available before the workshop);

e) Provide recommendations based on b) and c) to ICES acoustic survey planning groups so that they can update the relevant SISP manuals.

WGQUAD will report by June 30 2017 for the attention of WGFAST, WGIPS, WGBIFS, WGACEGG, ACOM and SCICOM.

Supporting information

Priority	Acoustic surveys provide crucial information for the stock assessment of pelagic species and the wider pelagic ecosystem. Consequently, these activities are considered to have a very high priority.
Scientific justification	Term of Reference a) to e) The acoustic equipment being used for acoustic surveys is becoming more diverse, making the issue of how to deal with the impact of inclement weather conditions on the quality of the collected acoustic data more complex. Only a group of both acoustic experts and data users can be expected to define standards and best practice procedures.
Resource requirements	The monitoring and research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	Members of WGFAST (25-30 participants expected) and guests.
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are linkages to both SCICOM and ACOM.
Linkages to other committees or groups	There are linkages to all groups currently planning acoustic surveys or using acoustic survey data like WGIPS, WGACEGG, WGBIFS.
Linkages to other organizations	The work of this group is of international interest to all countries carrying ou acoustic biomass estimation surveys.

JFTAB

The **Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour** [WGFTFB] and the W**orking Group on Fisheries Acoustics Science and Technology** [WGFAST] (**JFTAB**)**,** chaired by Paul Winger (Canada) and Chris Wilson (USA), will meet on April 3 2017 in conjunction with WGFTFB and WGFAST to:

a) Review the observer effect: how platforms and instruments affect the behaviour of aquatic fauna.

b) Review recent progress in image analysis and machine learning techniques for efficient data processing in aquatic research.

JFTAB will report by 30 June 2017 for the attention of WGFAST, WGFTFB, ACOM and SCICOM.

Supporting information

Priority	WGFAST and WGFTFB have joint interests in the effects of observation methods on behaviour of fish and other marine organisms and the use of image analysis methods.
Scientific justification	Term of Reference a) All observation methods and platforms impact fish behaviour and consequently acoustic measurements and fishing gear catch performance. A group of acoustic and fishing technology experts is therefore well suited to discuss progress in the field from different perspectives. Term of Reference b) Optical imaging methods are increasinlgy used as auxiliary methods in various fields, including fisheries acoustic and gear technology studies. Both groups of experts can benefit from sharing their diversity in collecting and analysing optical data.
Resource requirements	The monitoring and research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	Members of WGFTFB and WGFAST and guests (120 participants expected).
Secretariat facilities	None.
Financial	No financial implications.
Linkages to advisory committees	There are linkages to both SCICOM and ACOM.
Linkages to other committees or groups	There are linkages to all groups collecting or using data from acoustics, optic or fishing gears.
Linkages to other organizations	The work of this group is of international interest to all countries conducting surveys.

WGFAST

The **Working Group on Fisheries, Acoustics, Science and Technology (WGFAST)**, chaired by Richard O'Driscoll, New Zealand, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2017	4-7 April 2017	Nelson, New Zealand	Interim report by 30 June 2017 to SSGIEOM	New chair from 2017
Year 2018	to be decided		Interim report by 30 June 2018 to SSGXXX	
Year 2019	to be decided		Final report by 30 June 2019 to SSGXXX	

ToR descriptor

ToR	Description	Background	Science Plan topics addressed	Duration	Expected Deliverables
a	Collate information on acoustic related research and surveys by Country represented in WGFAST.	a) Science Requirements b) Advisory Requirements	27	3	Filled in template for WGFAST report
b	Present recent work within the topics "Applications of acoustic methods to characterize ecosystems", "Acoustic properties of marine organisms", "Behaviour", and "Emerging technologies, methodologies, and protocols".	Create a venue for informing the group members on recent activities and seeking input to further development. An overview of the different contributions will be presented in the annual report	1, 11, 13, 27, 28	1, 2, 3	Report
c	Organize training session on use of acoustics for biomass estimation	Introductory course on use of acoustic for abundance estimation, including survey design and data analysis	31	1	ICES training course
d	Provide guideance for calibrat-	Fishing vessels increasingly collect	31	1 or 2	Report

	ing echosounders on fishing vessels (topic group)	acoustic data. To allow quantitative use of these data, suitable calibration procedures for fishing conditions are needed.			
e	Organize joint sessions at ICES ASC		31	2 or 3	Topic session at ICES ASC

Summary of the Work Plan

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

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	Stock assessment groups using acoustic abundance indices.
Linkages to other committees or groups	The work in this group is closely aligned with complementary work in the FTFB Working Group. The work is of direct relevance to the survey planning groups within SSGIEOM 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 Managament Organization and the American Fisheries Society.

Annex 3. WGFAST MA self-evaluation

1) Working Group name.

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

2) Year of appointment.

2014

3) Current Chair.

Verena Trenkel, France

4) Venues, dates and number of participants per meeting.

6–9 May 2014, New Bedford, USA, 66 participants

29 May 2015, Nantes, France, 43 participants

19–22 April 2016, Vigo, Spain, 67 participants

WG Evaluation

5) If applicable, please indicate the research priorities (and sub priorities) of the Science Plan to which the WG make a significant contribution.

11. Develop methods to quantify multiple direct and indirect impacts from fisheries, as well as from mineral extraction, energy generation, aquaculture practices, and other anthropogenic activities, and estimate the vulnerability of marine ecosystems to these impacts.

27. Identify knowledge and methodological monitoring gaps, and develop strategies to fill these gaps.

28. Promote new technologies and opportunities for observation and monitoring, and assess their capabilities in the ICES context.

31. Ensure the development of best practices through establishment of guidelines and quality standards for: (a) surveys and other sampling and data collection systems; (b) external peer reviews of data collection programmes; and (c) training and capacity-building opportunities for monitoring activities.

6) In bullet form, list the main outcomes and achievements of the WG since their last evaluation. Outcomes including publications, advisory products, modelling outputs, methodological developments, etc. *

Publications:

- ICES. 2014. A metadata convention for processed acoustic data from active acoustic systems, SISP 4 TG-AcMeta, ICES WGFAST Topic Group, TG-ACMeta. 40 pp.
- Demer, D. A., Berger, L., Bernasconi, M., Bethke, E., Boswell, K., Chu, D., Domokos, R. et. al. 2015. Calibration of acoustic instruments. ICES Cooperative Research Report No. 326. 133 pp.
- Trenkel, V.M., Handegard, N.O., Weber, T. C. 2016. Marine Ecosystem Acoustics: a symposium on "Observing the ocean interior in support of integrated management". ICES Journal of Marine Science.

Activities initiated by WGFAST:

- Organization of ICES Symposium on Marine Ecosystem Acoustics - Observing the Ocean interior in support of integrated management", 25-28 May 2015, Nantes, France; 214 participants from 31 countries
- Special issue on acoustics symposium in ICES Journal of Marine Science
- Joint ASC session with WGISUR 'Ecosystem monitoring in practice' (2015) ; The session was attended by approximately 50-70 participants. Contributions included 14 (15) talks and 5 posters and addressed three core areas of innovative ecosystem monitoring techniques: (1) novel methods and datasets to be applied/examined when following an ecosystem approach in monitoring; (2) studies recently or currently conducted applying measures to follow a more holistic approach to ecosystem monitoring; (3) new joint survey programs focusing on combining or expanding existing surveys to broaden measurements of ecosystem parameters and e.g. marine strategy framework descriptors in an ecosystem survey.
- ICES ASC session on 'Fisher collected acoustic data (FCAD) ' (2016)
- ICES ASC session on 'What is a good pelagic habitat?' (2016)
- ICES Training course proposal on 'Introduction to abundance estimation from fisheries acoustic surveys' (proposed for 2017)
- ICES Training course on 'Principles and Methods of Broadband/Wideband Technologies: Application to fisheries acoustics' (Bergen, Norway, December 2016)
- ICES Training course on 'Application of Geostatistics to analyse spatially explicit Survey data in an Ecosystem Approach' (Fontainebleau, France, December 2014)
- ICES workshop on 'Scrutinisation Procedures for Pelagic Ecosystem Surveys' (WKSCRUT) (Hamburg, Germany, September 2015)
- ICES workshop on 'Collecting Quality Underwater Acoustic Data in Inclement Weather' (WKQUAD) (proposed for 2017)
- Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] and the Working Group on Fisheries Acoustics Science and Technology [WGFAST] (JFATB) chaired by Paul Winger (Canada) and Alex De Robertis (USA) in New Bedford, USA (5 May 2014). The meeting discussed novel research on a broad range of subjects related to technological developments of optical and acoustic techniques in combination with trawl sampling.
- ICES WGFAST Topic Group on 'Calibrating echosounders on fishing vessels' (initiated in 2016)
- ICES WGFAST Topic Group on 'Defining a data format for omni fisheries sonars' (initiated in 2016)
- ICES WGFAST Topic Group (TG-ACMeta) for 'Defining a metadata convention for processed acoustic data from active acoustic systems' (2014-2016).
- ICES Working Group on target classification (WGTC) (2014-2016)

- ICES workshop on evaluating current national acoustic abundance estimation methods for HERAS surveys (WKEVAL) (Copenhagen, Dankmark, August 2015)
- Broadband/wideband acoustic methods discussion forum (2015, 2016)

7) Has the WG contributed to Advisory needs? If so, please list when, to whom, and what was the essence of the advice.

Yes, indirectly

8) Please list any specific outreach activities of the WG outside the ICES network (unless listed in question 6). For example, EC projects directly emanating from the WG discussions, representation of the WG in meetings of outside organizations, contributions to other agencies' activities.

Included in 6. Highlights:

- Organization of ICES Symposium on Marine Ecosystem Acoustics - Observing the Ocean interior in support of integrated management", 25-28 May 2015, Nantes, France
- Informal collaboration with Acoustical Society of America at New Bedford meeting in 2014
- Participating in SPRFMO scientific committee meeting in 2015
- Participating in ISO underwater subcommittee meeting on behalf of ICES (2015)

9) Please indicate what difficulties, if any, have been encountered in achieving the workplan.

None

Future plans

10) Does the group think that a continuation of the WG beyond its current term is required? (If yes, please list the reasons)

Yes.

Fisheries acoustics is an international field of applied science which requires an interdisciplinary approach bringing together expertise in biology, engineering, and physics. The field provides techniques to detect fish and other underwater resources, and to quantify their abundance and distribution[2]. As such it is a vital component for the accurate resource assessment which is required for effective management. Increasingly the technique is being directed to a broader range of applications (e.g. studies of abundance, distribution and behaviour of fish around offshore energy sites; and in broader ecological studies of e.g. predator prey interactions). The specialised expertise required is highly dispersed, because most nations provide resources for only one or two locations with one or two individuals working in any of the aforementioned fields.

[2] Simmonds, E.J. & MacLennan, D.N. (2005). Fisheries acoustics: theory and practice. 2nd edition. Blackwell Publishing, Oxford, 456 pp.

ICES WGFAST is the only international forum where such individuals can network to discuss ongoing developments in the technique. As such it has been highly successful, regularly attracting over 50 participants annually over a long time period (since 1984)[3]. A measure of WGFAST success is the wide participation beyond the ICES community: regular participants include those from Australia, New Zealand and the west coast of the USA and Canada. Without this WG, the fisheries acousticians in each member and observer state will be more isolated and have to rely on sporadic international conferences which do not have fisheries (and marine resource related) applications at heart: this would be a major loss to the ICES community and would jeopardize the quality of associated surveys and the relevant underwater acoustics research worldwide.

11) If you are not requesting an extension, does the group consider that a new WG is required to further develop the science previously addressed by the existing WG.

(*If you answered YES to question 10 or 11, it is expected that a new Category 2 draft resolution will be submitted through the relevant SSG Chair or Secretariat*.)

12) What additional expertise would improve the ability of the new (or in case of renewal, existing) WG to fulfil its ToR?

Participation from experts on the impacts of echosounders and sonars on marine organisms, in particular marine mammals, would allow the group to progress in this area.

13) Which conclusions/or knowledge acquired of the WG do you think should be used in the Advisory process, if not already used? (please be specific)

WGFAST contributions to improving acoustic surveys, defining acoustic data formats, and best practice for acoustic abundance estimation already in use.

3 Fernandes, P.G., Gerlotto, F., Holliday, D.V., Nakken, O. & Simmonds, E.J. (2002). Acoustic applications in fisheries science: the ICES contribution. ICES Marine Science Symposia 215: 483-492.

Annex 5. Meeting Agenda

	TUESDAY April 19 2016	Session
5-9:00	House keeping	
0-9:20	WGFAST opening	
0-9:40	Nictimeral and schooling behaviour of blue whiting in the Cantabrian Sea ***Pablo Carrera***	**Behaviour** Chair: John Horne
0-10:00	Abundance and tidal behaviour of pelagic fish in the gateway to the Wadden Sea Bram Couperus, Sven Gastauer, Sascha M. M. Fässler, Ingrid Tulp, Henk W. van der Veer, ***Jan Jaap Poos***	
00-10:20	Spatial dynamics of juvenile anchovy in the Bay of Biscay ***Guillermo Boyra, Marian Peña, Unai Cotano, Xabier Irigoien, Anna Rubio and Enrique Nogueira***	
20-10:40	Measurements of Underwater Noise from the RV Investigator ***Alec Duncan, Rudy Kloser, Matthew Sherlock***	
40-11:10	**COFFEE BREAK**	
10-11:30	Do top predators cue on sound production by mesopelagic prey? ***David A. Demer, Simone Baumann-Pickering, David M. Checkley***	
30-11:50	ICES CRR 209 "Underwater Noise of Research Vessels, Review and Recommendations" – is it time for revision? ***Hans Petter Knudsen, Per W. Nieuwejaar***	
50-12:20	**Discussion**	
20-12:30	*Update on WGFAST TORs progress* ***Verena Trenkel***	**WGFAST business**
30-12:40	Report from ICES ASC 2015 session on *Ecosystem monitoring in practice* ***Sven Gastauer***	
40-14:00	**LUNCH BREAK**	
00-14:20	Minimum demands for a research vessel to be used for scientific acoustic surveys ***Verena Trenkel***	
20-14:30	TOR Request for guidance on procedures in bad weather conditions ***Verena Trenkel, Sven Gastauer***	
30-14:50	Quality assurance of acoustic data products from multiple vessels in a range of sea states ***Tim Ryan, Rudy Kloser, Ryan Downie and Gordon Keith***	
50-15:30	Other related initiatives (SONA，?)，workshop proposal, discussion ***Sophie Fielding, Verena Trenkel***	
15-15:30	ICES acoustic data base and update of meta-data standard in response to TOR 'Review the acoustic metadata standard in relation to the proposed database design' ***Nils Olav Handegard, Tim Ryan***	
30-16:00	***TEA BREAK***	
00-17:00	Potential initiatives related to wideband acoustics following discussion in 2015 ***Marian Peña, Ben Scoulding, Mike Jech***	
00-18:00	Subgroup meetings	
30-	**Visit to European Fisheries Control Agency**	

	WEDNESDAY April 20 2016	Session
0-9:00	House keeping	Emerging technologies, methodologies & protocols Chair: Mike Jech
0-9:20	Applications of broadband/wideband acoustic technologies to quantitative fisheries acoustic surveys: data acquisition, calibration, and data processing ***Dezhang Chu, Rebecca Thomas, Sandy Parker-Stetter***	
0-9:40	Remote fish species and size discrimination using wideband echosounders ***Alessandro Antona, Karel Keesman, Sascha Fässler, Ben Scoulding***	
0-10:00	Scotia Sea krill-ecosystem study: New experiences with wideband acoustics on the RRS James Clark Ross ***S Fielding, T Dornan, P Enderlein, O Godo, J Horne, R Kubilius, C Reiss, G Stowasser, J Watkins***	
00-10:20	Attempts at sizing mackerel with broadband acoustics ***Paul Fernandes, Kaj Dworski, Tim Stanton, Cynthia Sellers, Phil Copland, Alan Fenwick***	
20-10:40	Species discrimination using wideband acoustic backscattering measurements from a basin-wide acoustic-trawl survey of the Gulf of Alaska ***Chris Bassett, Chris Wilson, Alex De Robertis***	
40-11:10	**COFFEE BREAK**	
10-11:30	Comparing echo integration results from the Simrad EK60 and EK80 ***Gavin Macaulay***	
30-11:50	Measurements of Underwater Noise from the RV Investigator ***Alec Duncan, Rudy Kloser, Matthew Sherlock***	
50-12:10	Can a bottom-moored echosounder array provide a survey-comparable index of abundance? ***Alex De Robertis, Robert Levine, Chris Wilson***	
10-12:30	Development of optical - acoustic methods for the assessment of reef fish in untrawlable habitats ***Campanella Fabio, Taylor J. Christopher, Somerton David, Campbell Matthew, Boswell Kevin, Jacques Dale, Murawski Steve, Grasty Sarah, Ebert Erik, Wakefield Waldo, Lembke Chad***	
30-14:00	**LUNCH BREAK**	
00-14:20	ADVANCED SIZING OF FISH IN HORIZONTAL ACOUSTIC RECORDS ***I. Koliada, J. Kubecka, H. Belk***	Emerging technologies, methodologies & protocols Chair: Mike Jech
20-14:40	Fisheries and fishers' acoustic data. 1. Collecting acoustic data from fishing vessels: methods, metrics and indicators. ***F. Gerlotto, M. Gutierrez, C. Vasquez, S. Peraltilla, A. Aliaga, R. Bernales***	
40-15:00	Fisheries and fishers' acoustic data. 2. Establishment of fishery and acoustic information system through the use of fishing vessel data ***R. Bernales***	
00-15:20	Fishing Industry Acoustics: towards better species recognition and the application of acoustic data from pelagic freezer-trawlers ***Martin Pastoors, Sascha Fässler, Ben Scoulding, Thomas Brunel, Benoit Quesson, Jeroen van de Sande, Maurits Huisman, Sytse Ybema, Rob Pronk, Eric Roeleveld, Yngve Heggelund***	
20-15:40	Practical calibration of ship-mounted omni fisheries sonars ***Gavin Macaulay, Sindre Vatnehol, Hector Peña, Atle Totland, Egil Ona***	
40-16:10	***TEA BREAK***	
10-16:30	Using the ringdown zone as an inter-calibration monitoring tool ***Adam Dunford, Yoann Ladroit, Richard O'Driscoll***	
30-16:50	Proposal for an industry acoustic survey on spawning aggregations of VIa-VIIbc herring ***Martin Pastoors, Sascha Fässler, Susan Lussau, Edward Farrell, Ian Gatt, Sean O'Donoghue, Gerard van Balsfoort, Verena Ohms***	
50-17:30	***Discussion*** ***Response to TOR Implementing new and more cost efficient technology***	
30-18:00	Report from SPRFMO initiative on Calibrating echosounders on fishing vessels and discussion on creating a topic group on Calibrating echosounders on fishing vessels ***François Gerlotto, Adam Dunford***	***WGFAST busin***
30-	**Reception by the mayor at the Quiñones de León castle**	

	THURSDAY April 21 2016	Session
8:50-9:00	House keeping	
9:00-9:20	Investigation of two North Pacific frontal zones and their effects on the composition and biomass of micronekton using multi-frequency acoustics ***Réka Domokos***	Applications of acoustic methods to characterize ecosystems Chair : Stéphane Gauthier
9:20-9:40	Acoustic estimation of the nycthemeral variability, of pelagic ichthyofauna and plankton abundance in the Bay of Biscay. ***Sobradillo B., Santos M., Urlarte A., Boyra G***	
9:40-10:00	Euphausiid Biomass in the Georges Bank/Gulf of Maine Region from 1999-2012 ***Michael Jech, Gareth Lawson, Michael Lowe***	
10:00-10:20	Assessing Models to Detect Change in Acoustic Data for Ecosystem Characterization ***Hannah Linder, John Horne***	
10:20-10:40	Combined use of mobile surveys with DIDSON and moored autonomous echosounders to study juvenile salmon migration at sea in the North Pacific. ***Stéphane Gauthier, Shanl Rousseau***	
10:40-11:10	**COFFEE BREAK**	
11:10-11:30	The distribution of key species in the NDSF (Western Australia) ***Sven Gastauer, Miles Parsons***	
11:30-11:50	ARTIFICIAL HABITAT MAPPING IN ADRIATIC SEA ***A. Gaetani, A.N.Tassetti, P. Polidori, S. Leoni, G.Fabi***	
11:50-12:10	First trial of multibeam echosounder ME70 and EK80 on R/V Tamgu-21 ***Myounghee Kang, Junseong Park, Kangseok Hwang, Hyung-kee Cha, Junghwa Choi, Hyungbeen Lee, Jeong-Hoon Lee***	
12:10-12:30	New insights into pelagic habitat with combined vessel acoustics, nets and a Profiling Lagrangian Acoustic, Optical System (PLAOS) ***Rudy Kloser, Tim Ryan, Arti Verma, Matt Sherlock, Adrian Flynn, Caroline Sutton, Ryan Downie and Lisa Gershwin***	
12:30-14:00	**LUNCH BREAK**	
14:00-14:20	*Fish identification of Atlantic Mackerel using the fisheries echo-sounder* ***Rika Shirai, Jérôme Dubuis, Yuriko Ohnishi, Shinji Ogawa***	
14:20-14:40	*Herring Acoustic Surveys: The search for Atlantic Bluefin tuna in the Gulf of St Lawrence.* ***Gary D. Melvin, Jenna Munden and Monica Finley***	
14:40-15:00	Acoustic sampling volume effect on shadowing of fluid like organisms by resonant gas bearing organisms ***Arthur Blanluet, Mathieu Doray***	
15:00-15:20	Comparison of biomass estimates from acoustics and trawl surveys for pelagic species ***V. Trenkel***	
15:20-15:40	Modelling krill distribution in eastern Canadian waters using statistical habitat models based on acoustic data: a climatological approach ***Stéphane Plourde, Ian H. McQuinn, Caroline Lehoux and Marie-Noëlle Bourassa***	
15:40-16:00	Exploiting acoustic measurements for ocean observing, environmental monitoring, and ecological applications ***John Horne, Ross Hytnen, Sharl Matzner, Adam Maxwell, Kenneth Ham***	
16:00-16:20	**TEA BREAK**	
16:20-16:50	***Discussion***	
16:50-18:00	Self-evaluation of WGFAST, new ToRs, new chair, next meeting, ...	WGFAST
20:00-	**Banquet**	

	FRIDAY April 22 2016	Session
0-9:00	House keeping	
0-9:20	Variability in Atlantic mackerel target strength and its effects on acoustic abundance estimates *Ben Scoulding, David MacLennann Sascha Fassler, Paul Fernandes*	Acoustic properties of marine organisms Chair: Gavin Macaulayl
0-9:40	Ping to ping variations in the frequency dependent target strength of single targets using a broadband echosounder (EK80) *Arti Verma, Alec Duncan, Rudy Kloser*	
0-10:00	When algae sound fishy *Anne Lebourges-Dhaussy, Gildas Roudaut, Adilma Montenegro, Arnaud Bertrand*	
00-10:20	Biscay anchovy controlled in-situ target strengths measurements *Mathieu Doray, Laurent Berger, Naig Le Bouffant, Jean Yves Coail, Jean Philippe Vacherot, Pierre Petitgas*	
20-10:40	Biscay anchovy and sardine target strength modelling *Laurent Berger, Mathieu Doray, Xavier de la Bernardie, Elisabeth Lys, Pierre Marinière, Pierre Petitgas*	
40-11:10	**COFFEE BREAK**	
10-11:30	TS measurements of bluefin tuna (*Thunnus thynnus*) in sea cages *Vicent Puig, Patricia Ordoñez, Isabel Perez, Fernando de la Gandara, Vicent Estruch, Lucio Calise, Víctor Espinosa*	
30-11:50	Estimation of TS and acoustic discrimination of tuna around FADs Guillermo Boyra, Gala Moreno and Igor Sancristobal	
50-12:30	*Discussion*	
30-14:00	**LUNCH BREAK**	
00-14:10	WGTC update *Rolf Korneliussen*	WGFAST business
10-14:20	Creation of topic group for defining data format for sonar *Hector Pena et al.*	
20-14:40	Update from ISO underwater acoustics sub-committee *Gavin Macaulay*	
40-14:50	Training course on Introduction to running an acoustic survey *Paul Fernandes et al.*	
50-16:00	Other initiatives and business	
00	*Meeting closure*	

Annex 6. Abstracts of contributions

Behaviour

Nictimeral and schooling behaviour of blue whiting in the Cantabrian Sea

Pablo Carrera

Abundance and tidal behaviour of pelagic fish in the gateway to the Wadden Sea

Bram Couperus, Sven Gastauer, Sascha M. M. Fässler, Ingrid Tulp, Henk W. van der Veer, Jan Jaap Poos

The shallow coast of the Netherlands is an important habitat for small pelagic fish. They form one of the major links between plankton and the higher trophic levels. Predatory fish, sea mammals and birds rely on small pelagic fish as a major food source. Currently, monitoring of fish in the Dutch coastal zone mainly focuses on demersal species, using bottom trawls and fykes. Four hydroacoustic surveys were carried out in May and October 2010/2011 in the Marsdiep area, a relatively deep tidal inlet in the western Wadden Sea, to quantify abundances of pelagic fish. The aims of this study were to (1) describe temporal and vertical variation in fish distribution and school dimensions in relation to tide, and (2) estimate biomass of pelagic fish and their proportion to total fish biomass. The biomass of pelagic fish in the Marsdiep area ranged between 23 and 411 kg/ha. These were mainly sprat, but also young herring, anchovy and pilchard. The fish was scattered in small schools with volumes smaller than 5m3 and concentrated in the top 10m below the surface. There was a clear effect of tidal cycle on school volume and fish abundance, with larger densities and larger schools at high tide compared to low tide. In May, sandeel contributed substantially to the pelagic assemblage, whereas in October sandeel was absent in the trawl catches, most likely because they stayed buried in the seabed from late summer to spring. The presence of pilchard and anchovy confirmed their re-establishment in the Southern North Sea and Wadden Sea. The abundance of pelagic fish exceeded the biomass of demersal fish in the western Wadden Sea by an order of magnitude. This finding is relevant to ecosystem studies. The fact that this study suggests that small pelagics outnumber demersal species to such a large extent calls for a rethinking of the allocation of monitoring effort in the Dutch coastal zone.

Spatial dynamics of juvenile anchovy in the Bay of Biscay

Guillermo Boyra, Marian Peña, Unai Cotano, Xabier Irigoien, Anna Rubio and Enrique Nogueira

In autumn 2009, the implementation of two successive acoustic surveys targeting juvenile anchovy (*Engraulis encrasicolus*) in the Bay of Biscay allowed us to monitor the changes in the spatial distribution and aggregation patterns of juveniles of this species during 45 days under fairly stable meteorological conditions. Juvenile anchovy changed its biological condition and behaviour in a different manner in two distinct areas. In the Spanish sector the juveniles migrated 20 nautical miles towards the coast, but they remained off-the-shelf and near the surface during the whole surveyed period. As the coastward advance compressed them against the shelf break, their area of distribution decreased, their density increased and the juveniles spread in fewer but heavier shoals. In the French sector the juveniles migrated also from slope waters toward the coast at similar velocity, but they crossed the shelf break into the continental shelf, where they increased significantly their mean depth until grad-

ually adopting the typical nyctemeral migrations of adult anchovy. The mean length of the juveniles that adopted the nyctemeral migrations was significantly higher than that of the juveniles remaining at the surface, suggesting that body size is relevant to accomplish this change. The stronger temperature gradients between shelf and oceanic waters in the Spanish sector, favored by a narrow shelf, may have acted as a barrier influencing the distinct observed spatial patterns in the two areas.

Measurements of Underwater Noise from the RV Investigator

Alec Duncan, Rudy Kloser, Matthew Sherlock

Australia's Marine National Facility has recently taken delivery of a new, $126 million, multi-purpose blue-water marine research vessel, RV Investigator. The ship is equipped with an extensive suite of active acoustic instrumentation that include an omnidirectional sonar, three multibeam echosounders, six split-beam scientific echosounders , two acoustic Doppler current profilers and a sub-bottom profiler. Permanently installed seismic compressors also prepare the ship to undertake geophysical survey missions. The ship has been designed to maximize the performance of these systems through innovative hull design to minimize air bubble entrainment under the acoustic transducers, and by reducing the underwater sound radiated from the ship through an innovative propulsion system, coupled with advanced isolation of vibration from the primary power generation machinery.

This paper discusses some recent underwater noise measurements that were carried out in southern Tasmanian waters following Det Norske Veritas (DNV) guidelines in order to determine baseline underwater noise signatures for the vessel, and to characterize the noise performance of the various acoustic instruments. The baseline measurements obtained are compared to the ship's design criteria of DNV Silent-R and the expected background wind and thermal noise. The potential variability of vessel noise spectra obtained when following DNV noise measurement guidelines are also discussed.

Anoxic conditions over the bottom: Can they affect small pelagic fish schools behavior and morphology?

Konstantinos Tsagarakis, Maria Myrto Pyrounaki, Athanassios Machias, Marianna Giannoulaki

Variability of the characteristics of fish schools is known to be species dependent but it is also affected by the size of individuals and life stage. Within the framework of this study, we analysed acoustic data from fish schools (mainly constituted by anchovy juveniles and sardine adults) collected during daytime from two areas of the Central Mediterranean Sea with similar bathymetry but differences in oxygen concentration: (a) Amvrakikos Gulf, a closed basin which presents an extended anoxic layer and (b) well oxygenated, shallow coastal waters of the eastern Ionian Sea. A suite of school descriptors (i.e. positional, energetic, morphometric) was estimated in order to identify differences in the two areas. ANOVA test results showed significant area differences in almost all examined school descriptors. Specifically, in the area presenting extended anoxic layer over the bottom, schools' occurrence was limited to the upper part of the water column, being around 13 m depth on average and well above the seabed (i.e. minimum school altitude 20 mvs.5 m, respectively). Moreover, at the same area small pelagic fish schools were smaller, presenting more circular forms and higher backscattered strength. The increased number of schools within the narrow depth zone seems to impose changes in schools morphometry. In addition,

interannual variability of certain school descriptors was encountered within Amvrakikos Gulf especially in school area, length, perimeter and the backscattered strength. This is most likely due to differences in the extent of the anoxic zone among years as well in the relevant species composition.

Do top predators cue on sound production by mesopelagic prey?

David A. Demer, Simone Baumann-Pickering, David M. Checkley

Deep-scattering layer (DSL) organisms, comprising a variety of mesopelagic fish, and squids, siphonophores, crustaceans, and other invertebrates, are preferred prey for numerous large marine predators, e.g. cetaceans, seabirds, and fish. Some of the DSL species migrate from depth during daylight to feed near the surface at night, transitioning during dusk and dawn. We investigated if any DSL organisms create sound, particularly during the crepuscular periods. Over several nights in summer 2015, underwater sound was recorded in the San Diego Trough using a high-frequency acoustic recording package (HARP, 10 Hz to 100 kHz), suspended from a drifting surface float. Acoustic backscatter from the DSL was monitored nearby using a calibrated multiple-frequency (38, 70, 120, and 200 kHz) split-beam echosounder (Simrad EK60) on a small boat. DSL organisms produced sound, between 300 and 1000 Hz, and the received levels were highest when the animals migrated past the recorder during ascent and descent.

The DSL is globally present, so the observed acoustic phenomenon, if also ubiquitous, has wide-reaching implications. Sound travels farther than light or chemicals and thus can be sensed at greater distances by predators, prey, and mates. If sound is a characteristic feature of pelagic ecosystems, it likely plays a role in predator–prey relationships and overall ecosystem dynamics.

ICES CRR 209 "Underwater Noise of Research Vessels, Review and Recommendations" – is it time for revision?

Hans Petter Knudsen, Per W. Nieuwejaar

The ICES CRR 209 has become a de facto standard through the past 20 years. Many research vessels worldwide have been built in compliance with this recommendation. The means for noise reduction recommended was true in 1995, but there has been a great development in technology since then. The costs associated with building in accordance with the recommendations are considerable higher compared with "conventional" propulsion systems. Research shipping communities have raised questions about cost/benefit, and they have called for a more nuanced recommendation that does not necessarily point out one concept for noise reduction as the only possible. The impact of allowing 3, 5 and 10 dB higher levels in the lower frequency range is discussed. Some institutions have modified the "ICES curve" below 25 Hz, what is the impact of that? This presentation points out some factors that indicate that it will be possible to build research vessels with modern technology and lower cost without necessarily degrading the collected acoustic data noticeably.

Special session "Bad weather conditions"

Quality assurance of acoustic data products from multiple vessels in a range of sea states

Tim Ryan, Rudy Kloser, Ryan Downie and Gordon Keith

Acoustic data quality can vary enormously between vessels. It is typically determined by a complex interplay of sea state, vessel design, its operation (speed and heading in

relation to swell) and external sources of interference. Often there are multiple types of noise and attenuation. Each source of data degradation require specific strategies to either prevent or, less optimally, address in post-processing. To that end we apply a sequence of filters designed to eliminate the major sources of noise and attenuation to produce publically available quality controlled data products from a fleet of vessels-of-opportunity. These products may be used for a variety of purposes where the level of data quality needed may depend on the application. We use the percentage of data rejected in processing, background signal-to-noise and (when available) vessel motion as indicators of quality. The effectiveness of these indicators are applied to a number of vessels to test how they perform for automated processing. We recognize the need to further develop metrics that can describe the quality and utility of the data. To that end we look forward to the WGFAST discussion of this topic.

Emerging technologies, methodologies, and protocols

Applications of broadband/wideband acoustic technologies to quantitative fisheries acoustic surveys: data acquisition, calibration, and data processing

Dezhang Chu, Rebecca Thomas, Sandy Parker-Stetter

Northwest Fisheries Science Center, 2725 Montlake Blvd. E, Seattle, WA 98112, USA

Recent advances in fisheries acoustics on broadband/wideband technologies, especially the availability of the Simard EK80 wideband echosounders, have made the quantitative acoustic measurements become reality. However, unique features related to inherent characteristics of broadband signals result in many different operational and data processing considerations as compared to those for the narrowband echosounder systems. Simple adaptation of the methods applicable to the narrowband echosounder systems, such as EK60 systems, may not be appropriate even with replacing the on-axis gain and equivalent beam angle with the corresponding frequency-dependent quantities. In this presentation, special concerns on the Simrad EK80 echosounders will be analysed, including the shape of the transmitted pulse, calibration, and data processing techniques. The field data collected with EK80 echosounders during both 2015 Joint US and Canada hake and trawl acoustic survey (Sake 2015) and the 2016 winter hake survey will also be presented and analysed.

Remote fish species and size discrimination using wideband echosounders

Alessandro Antona, Karel Keesman, Sascha Fässler, Ben Scoulding

Exploring the frequency domain has been highlighted as offering the most potential towards the successful identification of targets at sea. So far, multifrequency acoustic measurements have indeed shown potential in this respect. However, when species have similar morphology, pointwise information across the spectrum is often insufficient to deliver effective discrimination. Consequently, many fish species which co-occur in the same regions cannot be distinguished remotely. The development of wideband echosounders, which transmit and receive over a broad frequency band, can provide continuous backscatter information, making it easier to distinguish between species. Nevertheless, a major limitation to these methods is the need for large amounts of "ground-truthed" acoustic data for training fully data-based classification algorithms, which currently represent the only available option. To cope with this problem, we have developed a novel model-based approach, which has been tested on wideband data collected during the Dutch component of North Sea herring acoustic survey in 2015, using a Simrad EK80 broadband echosounder operating at six carrying frequencies delivering the frequency range 16-450 kHz. Three acoustically

similar species of fish were investigated; sprat *Sprattus sprattus* (mean length (ML) = 12.5 cm), Norway pout *Trisopterus esmarkii* (ML = 14 cm), and two size classes of herring *Clupea harengus* (MLs = 17 and 23 cm), using broadband TS scattering models developed using COMSOL Multiphysics software. Subsequent discrimination between these species was done using a least-squares minimization function. The classification rates were lastly compared to those obtained with the most commonly used data-based algorithms. Preliminary results indicate that broadband acoustics show enhanced potential in the discrimination of these pelagic species, compared to previously described multifrequency approaches.

Scotia Sea krill–ecosystem study: New experiences with wideband acoustics on the RRS James Clark Ross

S Fielding, T Dornan, P Enderlein, O Godo, J Horne, R Kubilius, C Reiss, G Stowasser, J Watkins

A multinational investigation of the krill-based ecosystem around the South Orkney Islands (east of the Antarctic Peninsula) was undertaken in January 2016. The key aims were to investigate oceanographic and biological factors influencing spatial variability of krill abundance and distribution, and krill-predator interactions. Time and space scales investigated spanned both the individual krill schools and the South Orkney Island region.

The RRS James Clark Ross is equipped with 3 Wide Band Transceivers (WBTs) and 3 EK60 GPTs operating at 38, 70 and 120 kHz. The 70 and 120 kHz WBTs and GPTs were calibrated in Scotia Bay (South Orkney Islands) at the start of the cruise. The EK80 was used whereas the ship was fishing for both krill and fish targets, otherwise the EK60 was used for biomass and distributions surveys. In addition two WideBand Autonomous Transceivers (WBATS) were deployed, one on an upward looking mooring at 200 m and the other lowered on a CTD frame to provide vertical TS and integration profiles. An attempt to calibrate the WBATs was also undertaken in Scotia Bay.

We present some initial findings and discuss our experiences with the new instruments.

Comparing echo integration results from the Simrad EK60 and EK80

Gavin Macaulay

Using a new model of scientific echosounder requires careful verification that existing and new systems give similar results for echo integration and target-strength measurements. Verification of analysis software output is also necessary. In preparation for the delivery of two new research vessels to Norway's Institute of Marine Research (which will have only Simrad EK80 echosounders), an EK60/EK80 echo integration comparison experiment was conducted. Acoustic data were collected in November 2015 from G.O. Sars in the North Sea. An EK60 and EK80 were connected to the same transducer and pinged alternately using a transceiver switching arrangement and data recorded for at least 18 km of ship travel. This was repeated for all six available transducers (18, 38, 70, 120, 200, and 333 kHz) over a range of mark types (light, medium, and strong backscatter). Data were collected both when the EK80 was operating in single-frequency mode (hence a CW-CW comparison) and chirp mode (a CW-FM comparison). We present and discuss the results of the comparison. The CW-CW analysis demonstrates the comparability of the EK80 when used in place of an EK60 for conventional single-frequency backscatter measure-

ments. The FM signal theoretically gives an improved signal-to-noise ratio, giving for a greater operating range, but for echo integration introduces increased uncertainty in the backscatter to biomass conversion.

Fish finding with autonomous surface vehicles for the pelagic fisheries

Geir Pedersen, Rune Hauge, David Peddie, Gaute Ø. Lied, Inge K. Eliassen, Tom Kjøde, Yngve Heggelund

The pelagic fisheries use large resources to find pelagic fish every year. User-friendly and low-cost autonomous systems for fish detection can represent a cost and environmentally friendly approach, reducing vessel time needed for fish finding and potentially securing better catches in species and size. Several long-endurance surface vehicles are on the marked and being used for scientific applications, these technologies are so far underutilized by the fishing industry. Through an industry funded research project we test the concept using Sailbouys fitted with a low-cost echosounder. Custom software is developed for on-board echosounder data processing. If schools are detected information, including the buoys position and echograms, are transmitted to vessels and shore, where the fishers can evaluate the information. We also investigate how these new types of vessels can be used in an optimal way for the industry. The concept and fish finding system is tested in nearshore and offshore field trials.

Can a bottom–moored echosounder array provide a survey–comparable index of abundance?

Alex De Robertis, Robert Levine, Chris Wilson

When fish repeatedly occupy localized areas (e.g. spawning grounds), moored echosounders may produce comparable abundance indices to those from shipboard surveys. Moored acoustic measurements can also provide insights into the behavior of spawning fish. The primary uncertainty in the moored echosounder approach is the spatial-representativeness of long-term observations from a single location, which will depend on the behaviors of the fish. Three trawl-resistant moorings instrumented with a new 70 kHz split-beam echosounder (WBAT: Wide Band Autonomous Transceiver) were deployed in Shelikof Strait, in the Gulf of Alaska from February to May 2015. Repeated acoustic surveys at two spatial scales were conducted to 1) estimate the spatial representativeness or effective foot print of the mooring, and 2) compare abundance estimates from the moorings to those from repeated ship surveys. The mooring observations were highly correlated with ship observations over a much broader area, suggesting that the moorings can be used to determine abundance over a much larger area than the sampling volume of the beam. Analysis of acoustic data from an annual survey of spawning walleye pollock in Alaska were used to predict that 3-5 moored echosounders can provide an index of pollock abundance comparable to that produced by the survey. Thus, it is feasible to design a relatively sparse mooring array capable of providing abundance information and other aspects of fish behavior in this environment.

Development of optical – acoustic methods for the assessment of reef fish in untrawlable habitats

Campanella Fabio, Taylor J. Christopher, Somerton David, Campbell Matthew, Boswell Kevin, Jacques Dale, Murawski Steve, Grasty Sarah, Ebert Erik, Wakefield Waldo, Lembke Chad

Many commercially and ecologically important fish species inhabit high-relief coral or rocky reef habitats making difficult the application of traditional assessment methods. The untrawlable habitats limit the use of trawl and nets for extractive sampling for either population assessments or ground-truthing for fisheries acoustic surveys. Optical measurements (scuba dives, manned and unmanned vehicle) have been the most common methods used to study these environments but they are not able alone to provide absolute abundance estimates and the amount of uncertainty and bias can be considerable. We combined the use of acoustic and optical methods and tested the operability of this approach in a rocky reef area in the northeastern Gulf of Mexico (Florida Middle Grounds). We conducted multifrequency fishery acoustic surveys using split-beam echsounders (SBES) concurrently with a stationary stereo cameras (MOUSS - Modular Optical Underwater Sampling System) deployed along the acoustic transects. Species-specific acoustic density estimates of the priority species/groups are provided. Potential sources of bias and the uncertainty of the estimates are presented and discussed.

Attempts at sizing mackerel with broadband acoustics

Paul Fernandes, Kaj Dworski, Tim Stanton, Cynthia Sellers, Phil Copland, Alan Fenwick

Atlantic mackerel are a small pelagic fish which undergo vast migrations and school in huge numbers. The Northeast Atlantic stock is the biggest and most valuable single species fishery in Europe, worth over US$1.5 billion per annnum. From January 2015, under the EU's new "Landings obligation", European fleets in this fishery are no longer allowed to discard fish: i.e. they cannot throw fish back to sea once they have been caught. Mackerel fetches higher prices for larger fish, so fishers need to avoid catching smaller fish, to maintain profitability and to comply with the landings obligation. Previously, small fish would have been discarded – which in this fishery is known as "slippage", because it was done en masse. Using simple scattering models to compare large to small fish, small mackerel have a different broadband scattering spectrum, with a transition point from Rayleigh to geometric scattering that is at a higher frequency than larger fish. We deployed an Edgetech broadband sonar in the North Sea in October 2015 to determine the broadband spectra of mackerel schools. Poor weather and an unusually late arrival of fish in the surveyed area meant that we were only able to verify the size composition of one school. We estimated the size of fish in this school to be 20 cm from the acoustic data, whereas catches indicated that the fish were 33 cm. We also had issues with equivalent levels of the various broadband channels we used. We discuss these issues and potential solutions and present steps for going forwards to try and reach the goal of remote fish sizing using broadband acoustics.

Species discrimination using wideband acoustic backscattering measurements from a basin-wide acoustic-trawl survey of the Gulf of Alaska

Chris Bassett, Chris Wilson, Alex De Robertis

Broadband echosounders have the potential to increase the efficiency of fisheries surveys by improving species discrimination using the frequency response of the biological scatterers. Measurements were collected with 18-, 38-, 70-, and 120 kHz Simrad wideband transceivers, which span the range from 15-160 kHz, during a large-scale survey of the Gulf of Alaska from June to August 2015. Frequency spectra are presented of volume backscatter from aggregations as well as target strengths for several species commonly observed optically and in trawls during the survey. The

preliminary results are mixed with regard to species discrimination. Spectra from morphologically similar animals (e.g. similarly sized fish with swimbladders) remain difficult to distinguish. However, mixed assemblages of dissimilar taxa as well as an unsampled (i.e. no trawl/optics ground-truth samples) scattering layer encountered periodically throughout the surveyed area, exhibited resonance near 18 kHz. These latter two scattering types were easily identified with broadband techniques but not with narrowband echosounders.

Development of optical – acoustic methods for the assessment of reef fish in untrawlable habitats

Campanella Fabio, Taylor J. Christopher, Somerton David, Campbell Matthew, Boswell Kevin, Jacques Dale, Murawski Steve, Grasty Sarah, Ebert Erik, Wakefield Waldo, Lembke Chad

Advanced sizing of fish in horizontal acoustic records

I Koliada, J. Kubecka, H. Belk

The importance of hydroacoustics for the study of fish density, biomass and behaviour in shallow inland waters is widely recognized. However, unbiased conversion from acoustic parameters, such as target strength (TS) to the parameters familiar to fisheries biologists, such as length and weight, is still not a routine procedure. The largest source of variation in relationships between body size descriptors and TS. Missing aspect information limits future progress of horizontal acoustic surveys and thus their application in surface waters around the world. The main goal of this work is to strengthen present mobile horizontal hydroacoustic surveys by new methodology to identify fish aspect. Measurements were performed in Rímov Reservoir (Czech Republic, deep, stratified, meso-eutrophic) was using a Simrad EK60 split-beam echosounder. Unlike present approaches, the new methodology uses the TS of the same fish from several transducers with different pan. It is able to estimate size of every recorded fish and the patterns of fish orientation in pelagic areas of lentic water bodies. This approach can increase considerably the accuracy of hydroacoustic biomass estimation and will promote the use of this robust and fish friendly approach.

Fisheries and fishers' acoustic data. 1. Collecting acoustic data from fishing vessels: methods, metrics and indicators.

F. Gerlotto, M. Gutierrez, C. Vasquez, S. Peraltilla, A. Aliaga, R. Bernales

The use of acoustic data collected aboard fishing vessels is nowadays considered as an efficient source of information allowing more precise analyses of the exploited fish stock dynamics. Nevertheless, two major questions have still to be documented. The first one is developing methodologies that can provide usable data. This requires a series of adaptation of the calibration procedure and that of statistical methods for data collected in a non-conventional way. The second is defining the indicators that this set of data can produce, collecting and elaborating the metrics that these indicators can give. A series of example and analyses are given on these two points taking the industrial pelagic fisheries in Peru as an example.

Fisheries and fishers' acoustic data. 2. Establishment of fishery and acoustic information system through the use of fishing vessel data

R. Bernales

Acoustic data from fishing vessels can be used from two points of view: by adding new and original information to the usual data collected by the research vessels, which aims to improve the models of dynamics of population and help to manage the stock; and by exploiting the data directly by the fishing companies in order to manage their own activities. These two methods are complementary and should help to elaborate a real ecosystem approach to fisheries. The paper presents results and consideration taking the Peruvian industrial pelagic fisheries as an example.

Fishing Industry Acoustics: towards better species recognition and the application of acoustic data from pelagic freezer–trawlers

Martin Pastoors, Sascha Fässler, Ben Scoulding, Thomas Brunel, Benoit Quesson, Jeroen van de Sande, Maurits Huisman, Sytse Ybema, Rob Pronk, Eric Roeleveld, Yngve Heggelund

The Pelagic Freezer-trawler Association (PFA) has been actively collaborating with scientific researchers from IMARES and TNO and commercial partners from Sustainovate and CMR, to achieve two main objectives: 1) better species recognition of fish in the water and 2) application of acoustic data collected on fishing vessels for research and management. Here we will report on the results obtained so far.

Species recognition is aimed at further improving the selectivity of the fishery by generating information on the pelagic species in front of, or under the vessel. This is expected to influence the decision to fish or not to fish, which is an important determinant of selectivity in pelagic fisheries. To obtain information on the species composition, we have been exploring three different methodologies: forward-looking sonars, multifrequency echosounders and broadband echosounders. All methodologies have been tested on operational fishing vessels. The results of the three methodologies will be presented and compared.

The collection of opportunistic acoustic data on fishing vessels has been initiated in 2012 and focused on the process of calibrating commercial vessels and the potential analysis of the data that was collected. During the project, that was finalized at the end of 2015, 9 calibrations were carried out on commercial vessels, mostly with assistance of scientific staff, but in some cases also carried out by the crew. Acoustic data were collected on 374 fishing days during the fisheries for blue whiting and herring. The project has successfully demonstrated the potential for implementing routine acoustic data collection and processing protocols on pelagic freezer-trawlers. Currently, the data processing sequence is still heavily affected by time constraints. Implementation of automation procedures for preprocessing of data is urgently required. The intention is to continue acoustic data collection on a number of pelagic freezer-trawlers during 2016 and beyond.

Practical calibration of ship–mounted omni fisheries sonars

Gavin Macaulay, Sindre Vatnehol, Hector Peña, Atle Totland, Egil Ona

Conventional ship-mounted vertically-oriented echosounders are poor at detecting organisms that are close the sea surface. Fisheries sonars can however ensonify near-surface water and are a useful tool to cover the waters that are unavailable to echosounders. If such sonars can be reliably calibrated they can be used to provide quantitative acoustic estimates of pelagic aggregations. However, for sonar systems that have not been designed as scientific and research instruments, the quantification and verification of the stability of the system performance is of heightened importance, and should include knowledge of how parameters such as the shape and gain of the

beams vary with system and operational configurations. We present a practical methodology for absolute calibration of fisheries sonar when mounted on a ship, illustrate the achievable calibration accuracies and precision, and demonstrate their stability over time and for a range of operating parameters. This work forms an essential prerequisite to the routine use of such sonars for quantitative echo-integration surveys

Using the ringdown zone as an inter-calibration monitoring tool

A. Dunford, Yoann Ladroit and Richard O'Driscoll

Acoustic calibrations are rightly recongnised as the means for confirming transducer operation and allowing quantitative analysis. Howver there is a need for methods of monitoring the echosonder in between calibration to ensure the data collected is worth analysing. The 'ringdown zone', that is the first few sample in each ping, for Simrad echosounders shows promise in this regard. This talk will present some preliminary results on the acoustic ringdown zone in the hope of encourgaging discussion on this important topic.

Proposal for an industry acoustic survey on spawning aggregations of VIa-VIIbc herring

Martin Pastoors, Sascha Fässler, Susan Lussau, Edward Farrell, Ian Gatt, Sean O'Donoghue, Gerard van Balsfoort, Verena Ohms

During the ICES benchmark workshop on herring west of the British Isles, the assessments of herring stock in ICES areas VIa North and VIa South-VIIbc were merged into one combined assessment. This is intended as a temporary fix because it is not possible to segregate the stocks in commercial catches or surveys. ICES has recommended a zero catch in 2016 for the combined stock and the development of a rebuilding plan.

As part of a future rebuilding plan, the Pelagic Advisory Council has proposed to carry out an acoustic survey with fishing vessels on spawning aggregations of VIa-VIIbc herring during the summer of 2016 and the winter 2016-2017. Data on the separate spawning components could provide an important addition to the overall knowledge base and thereby improve the assessment of the two stocks. The collection of acoustic data from commercial vessels has been discussed for a long time already but dedicated surveys conducted by fishing vessels in EU waters are still very limited.

Here we will present the proposed survey plan and we will be looking for potential recommendations and involvement of WGFAST in the review of the survey approach and interpretation of the data.

Applications of acoustic methods to characterize ecosystems

Investigation of two North Pacific frontal zones and their effects on the composition and biomass of micronekton using multifrequency acoustics

Réka Domokos

The North Pacific Subtropical Frontal Zone is an dynamic boundary region between waters of the cool, productive North Pacific Subarctic Gyre and the warmer, oligotrophic, North Pacific Subtropical Gyre, providing a migratory route and foraging ground for highly migratory species, including the economically important albacore and swordfish. The position of this region is marked by the temperature-based Subtropical Front (STF) and the productivity-based Transition Zone Chlorophyll Front

(TZCF). In this work, active multifrequency acoustics aided by trawl samples and in situ oceanographic data were used to study the effects of these fronts on the biomass and composition of micronekton, the assumed "missing link" between increased productivity and aggregation of top predators. Preliminary results indicate that the position of TZCF varied from that of the STF from about 0-4.5 degrees to the north, with the STF exhibiting smaller interannual and mesoscale variability than the TZCF. The position of the STF coincided with a peak in the shallow (SSL) and deep (DSL) scattering layers' strengths, differences in relative strengths between frequencies, and latitudinal changes in vertical backscatter profiles. Nighttime backscatter from the SSL was markedly higher to the south of the STF than to the north, while the strength of the DSL was higher to the north both day and night-times.

Acoustic estimation of the nycthemeral variability, of pelagic ichthyofauna and plankton abundance in the Bay of Biscay.

Sobradillo B., Santos M., Uriarte A., Boyra G

Anchovy (*Engraulis encrasicolus*) is one of the main commercial species in the Bay of Biscay. Anchovy biomass estimation is calculated annually from two different surveys, an acoustic survey and a survey based on the Daily Egg Production Method (DEPM). The objective of this project was the development of a methodology for acoustic estimation of abundance of Bay of Biscay anchovy and sardine using the acoustic data collected in the DEPM survey. These data differ from the typical acoustic data for abundance estimation in several aspects, being the most important one that they were collected 24 hours a day. Therefore, about half of the acoustic data were collected during the night, when schooling aggregations disappear and fish disperse increasing the difficulty of discriminating them from the plankton. Therefore, for the species discrimination, in addition to the typical pelagic trawls, a mask based on the different frequency response of different organisms was configured and applied to separate acoustic echoes in three coarse taxonomic groups: fish (with and without swimbladder), "fluid-like" plankton (euphausiids, copepods, salps, siphonophores without gas inclusion and other large crustacean zooplankton) and others (mainly fish larvae and gelatinous and gas-bearing siphonophores). The work was based on the data of year 2012. Although this is a work in progress and the methodology is far from being completed and validated, the results obtained were promising and consistent with the Bay of Biscay anchovy biomass assessment in 2012.

Euphausiid Biomass in the Georges Bank/Gulf of Maine Region from 1999–2012

Michael Jech, Gareth Lawson, Michael Lowe

Estimates of euphausiid abundance and biomass in the Georges Bank region of the Gulf of Maine were derived from annual acoustic/midwater trawl surveys during the autumn Atlantic herring (*Clupea harengus*) spawning season from 1999 through 2012. Acoustic data were collected continuously with Simrad EK500 and EK60 echosounders operating at 18, 38, and 120 kHz, and although dedicated zooplankton net tows were not conducted, euphausiids were often incidentally captured during midwater trawling operations (0.625 cm knotless mesh codend liner). Four different methods were used to classify euphausiids from the acoustic data: multifrequency single beam imaging (MFSBI, Wall et al., accepted to ICES JMS), sv(120 kHz)-s-v(38 kHz) ("dB differencing"), Z-score (De Robertis et al., CJFAS, 2010), and the multifrequency index (MFI) of Trenkel and Berger (EcoIndictors, 2013). Scattering model predictions of euphausiid target strength and biological metrics were used to scale acoustic data to abundance and biomass for each classification method. Biomass estimates were com-

pared among classification methods and also compared to depth-stratified quantitative net samples available in the survey region for 2010 and to estimates of euphausiid consumption by Atlantic herring to evaluate whether the acoustically-derived biomass estimates were commensurate with historical biomass estimates as well as the estimated trophic requirement. Assessment of classification methods and the role of euphausiids in the Georges Bank/Gulf of Maine foodweb are discussed.

Assessing Models to Detect Change in Acoustic Data for Ecosystem Characterization

Hannah Linder, John Horne

Characterizing pattern and detecting change in marine ecosystems is a common feature of ocean observing, environmental assessment, ecological research, and complying with monitoring regulations. Evaluating change includes an assessment of baseline conditions, and ongoing monitoring to determine if conditions change relative to the baseline. A six step approach: review current practices, identify candidate models, fit models to a baselinet, simulate scenarios of change, evaluate model fit to simulated data, and produce recommendations, was used to evaluate and recommend analytic models used to characterize and detect change. A 120 kHz dataset from a proposed tidal turbine site at Admiralty Inlet, Puget Sound, Washington was used to conduct the model evaluation. Evaluated models included: linear regression, time-series, and nonparametric models. Model fit diagnostics Root-Mean-Square-Error and Mean-Absolute-Scaled-Error were used to measure accuracy of model predicted values. A power analyses evaluated the ability of each model to measure and detect change from baseline conditions. Results of this evaluation will be used to generate guidelines on model choice for detecting change in environmental monitoring data. The creation of standard guidelines for model selection allows comparison between time periods, before and after any event, or among site locations.

Combined use of mobile surveys with DIDSON and moored autonomous echosounders to study juvenile salmon migration at sea in the North Pacific.

Stéphane Gauthier, Shani Rousseau

Most juvenile salmon from the Strait of Georgia in British Columbia pass through the Discovery Islands and Johnstone Strait during their migration to the Northern Pacific. As part of a large collaborative program we are using purse-seine and trawl methods, along with hydroacoustic trials, to determine the distribution and the duration of juvenile salmon residency in the Discovery Islands and Johnstone Strait. These areas are however characterized by narrow channels and very high current velocities which limit net-based sampling to relatively short periods of the tidal cycle. We use mobile surveys using a DIDSON to assess surface distribution of fish at various distance from the shoreline, as well as autonomous multifrequency moored echosounders (ASL Acoustic Zooplankton and Fish Profilers) to assess the behaviour and relative passage rates of salmon at strategic sites within the area. Two of the sampling sites are located close to Atlantic salmon fish farms in order to assess the potential interactions with wild fish. The purse-seine and trawl surveys efforts performed as part of the existing sampling program, supplemented by additional beach seining, directly complement this acoustic data by providing information on species composition and stock structure.

The distribution of key species in the NDSF (Western Australia)

Sven Gastauer, Miles Parsons

The NDSF is a trap fishery in Northwestern Australia. The fishery is characterized as a demersal trap fishery, extending over a vast area, which would traditionally require time and cost-expensive dedicated scientific surveys to gain insights into the distribution of key resources. Taking advantage of Simrad ES70 echosounders mounted on a commercial vessel facilitates gaining insights into distributional patterns of key species. All recording were taken during normal commercial fishing operations. As no dedicated fishing information was available, nor could the commercially caught fish be measured during the standard fishing trips, special tools were developed to deduce species-length information from the traps, through optical GoPro recordings. Additionally, preliminary observations were made to gain insights into trap avoidance pattern through opportunistically collected video recordings at depth while traps were in situ. In addition to the extraction of acoustic fish backscatter, backscatter from other key components such as fluid-like organisms and seabed characteristics have been extracted from echograms. The combination of these findings with catch information and linking resulting patterns with auxiliary environmental information aids habitat classification and the description of the distribution of key species. To further enhance target classification capabilities, target strength models of some of the main species found within the fishery are currently being generated, either based on experimental ex-situ measurements or in-situ recordings in combination with physiological information of the species in question, gained through computational tomography scans.

Artificial habitat mapping in Adriatic Sea

A. Gaetani, A.N.Tassetti, P. Polidori, S. Leoni, G.Fabi

The hydroacoustic technology is an efficient tool to study the sea environment: the most recent advancement in artificial habitat mapping involves acoustic systems to investigate fish abundance, distribution and behavior in specific areas. Along with a detailed high-coverage bathymetric mapping of the seabed, the high-frequency Multibeam Echosounder (MBES) offers the potential of detecting fine-scale distribution of fish aggregation, combining its ability to detect at the same time the seabed and the water column. Surveying fish schools distribution around artificial structures, MBES allows to evaluate how their presence modifies the biological natural habitat overtime in fish attraction and abundance.

In the last years, artificial habitat mapping experiences have been carried out by CNR-ISMAR in the Adriatic sea: fish assemblages aggregating at offshore gas platforms have been systematically monitored employing different kinds of methodologies to understand ecosystem process.

This work focuses on a case study: the spatial fish assemblages distribution has been investigated around a three legs gas extraction platform founded at 80 meters of depth in the central Adriatic sea, 30 miles far from the coast of Ancona.

Different surveys have been carried out around the gas platform since the end of installation:

- Hydroacustic investigations, every month on a squared area (1,5 Km per side) with a specific planning
- Experimental fishing captures with trammelnets increasing distance from the structure
- Underwater video camera between platform legs.

The data of the first year after the installation have been processed: Multibeam outputs (metrical dimensions of fish assemblages, shape, depth, density…), with the results coming from the other observation tools, have made possible to investigate the biological assemblage attracted by artificial structures hypothesizing which species populate the area and their spatial.

Processing MBES bathymetric and water column data, three-dimensional virtual scenes of the artificial habitats have been created, receiving an intuitive-looking depiction of their state and allowing overtime to evaluate their change in terms of dimensional characteristics and depth fish schools' disposition.

These MBES surveys play a leading part in the general multiyear programs carried out by CNR-ISMAR with the aim to assess potential biological changes linked to human activities on and support an ecosystem approach to fisheries management.

First trial of multibeam echosounder ME70 and EK80 on RV Tamgu-21

Myounghee Kang, Junseong Park, Kangseok Hwang, Hyung-kee Cha, Junghwa Choi, Hyungbeen Lee, Jeong-Hoon Lee

The South Korean RV Tamgu-21 was built in late 2015, and have the latest acoustic systems such as Simrad EK80 (18, 38, 70, 120, 200 and 334 kHz), ME70 (70-120 kHz), and SH90 (111.5-115.5 kHz). The main purpose for the new research vessel is to understand the fisheries resources quantitatively and qualitatively in the coastal waters around South Korea as well as exclusive economic zone. The first calibrations for eleven beams of the ME70 and EK80 were conducted. However, the first survey using these systems will be conducted in April of 2016. For targeting aquatic animals around South Korea, effective ways to use these systems and to analyse data from them should be acquired.

New insights into pelagic habitat with combined vessel acoustics, nets and a Profiling Lagrangian Acoustic, Optical System (PLAOS).

Rudy Kloser, Tim Ryan, Arti Verma, Matt Sherlock, Adrian Flynn, Caroline Sutton, Ryan Downie and Lisa Gershwin

As part of a study into the offshore pelagic habitat of the Tasman Sea and Great Australian Bight, nets, optic and acoustic samplers were used from Australia's new research vessel RV Investigator to determine the taxonomy, size, biomass, trophic linkage and energetics of zooplankton and micronekton. Each of these sampling methods have bias and uncertainty that need to be quantified prior to attributing changes within and between regions. In particular for the gelatinous community that covers a wide range of taxonomic and energetic groups that are difficult to sample with nets. To improve vessel mounted acoustic and net sampling methods of macrozooplankton and micronekton a new profiling multifrequency acoustic optical system was used. The systems 1000 m depth profiling method is lagrangian that allows the acoustic and optical data to be linked at varying sampling ranges to explore species-specific optically verified in situ acoustic signatures. As an example the physonect siphonophore that is often damaged in nets can be observed and their acoustic signature and depth distribution estimated. Based on this method it is possible to compare acoustic echo counting and echo integration biomass estimates for a range of taxa. Initial results from a depth stratified comparison of macrozooplankton and micronekton samples from net, optical and acoustic data are compared to vessel based acoustics to highlight advantages and limitations of each method. The future use of these data for ecological indicators and ecosystem models is explored. This study is being

undertaken as part of CSIRO's Oceans and Atmosphere's Pelagic habitat characterization project, Australia's Integrated Marine Observing System bioacoustics program and the Great Australian Bight Research Program, a collaboration between BP, CSIRO, the South Australian Research and Development Institute (SARDI), the University of Adelaide, and Flinders University.

Fish identification of Atlantic Mackerel using the fisheries echosounder

Rika Shiraki, Jérôme Dubuis, Yuriko Ohnishi, Shinji Ogawa

As fishery is switching from 'first come, first served' fishery to sustainable fishery, acoustic survey and evaluation of fish resources not only using quantitative echosounders but also using fisheries echosounders are demanded.

The fish size distribution and the fish species are critical information to support efficient fishery and also to maintain eco-friendly fishery. Such information can be collected by the fisheries echosounders.

We introduce one of the technologies to identify Atlantic Mackerel using the difference of SV (volume backscattering strengths) between 2 frequencies, which can be installed in fisheries echosounders.

Development of fisheries echosounders or sonar considering the regional regulation or each fishing culture should be continuously conducted in order to support both fishers and the marine environment.

Herring Acoustic Surveys: The search for Atlantic Bluefin tuna in the Gulf of St Lawrence.

Gary D. Melvin, Jenna Munden and Monica Finley

Fishery dependent indices of abundance based on catch per unit of effort are known to be problematic over the long term due to changes in the catchability of the target species. However, the development and implementation of a new fishery-independent index of abundance is a long-term commitment, usually costly, and requires a long time period before a useable time-series is available. Here we examine the historical Atlantic herring annual acoustic survey (1993-2014) in the Baie des Chaleur for Bluefin tuna. The survey has been conducted from the same vessel since inception using a consistent survey design and the same hardware. Traditionally, the acoustic data were scrutinized for herring only and all other species removed from the echogram before integration for acoustic backscatter. Re-examination of the raw data files indicates the presence of Bluefin like targets. Individual targets were identified based TS thresholds established from actual Bluefin TS measurements collected with a split-beam transducer of same frequency in the region. The results indicate that the trends in abundance (#/10km) from the Baie des Chaleur acoustic survey follow a similar trajectory as the cpue index of abundance, but without the large interannual variability. Other acoustic datasets may contain similar information that could be used to develop new indices of abundance time-series.

Acoustic sampling volume effect on shadowing of fluid like organisms by resonant gas bearing organisms

Blanluet Arthur, Doray Mathieu

In the Bay of Biscay the presence of gas bearing organisms resonating at fisheries acoustic frequencies commonly hinders the detection of fluid like (FL) organisms whose weak backscatter is shadowed by strong resonant target echoes. In this preliminary work, we try to identify the effect of the acoustic sampling volume on the shad-

owing of zooplankton by resonant organisms. To do so, we compare acoustic data collected on sound-scattering layers (SSLs) with transducers mounted in the ship hull and in a Remote Operated Vehicle (ROV), respectively. The main goal is to test whether reducing the sampling volume by bringing the ROV close to SSLs targets can facilitate the detection of FL organisms, by avoiding the shadowing by resonant organisms.

Comparison of biomass estimates from acoustics and trawl surveys for pelagic species

V. Trenkel

The question whether data from bottom-trawl surveys is informative for population changes of pelagic species comes up recurrently. In this presentation I compare time-trends of acoustic and trawl data derived biomass estimates for a range of small pelagic species in several ecosystems. Overall the results show little correlation between the two on a species-by-species level but more so for the sum of pelagic species.

Modelling krill distribution in eastern Canadian waters using statistical habitat models based on acoustic data: a climatological approach

Stéphane Plourde, Ian H. McQuinn, Caroline Lehoux and Marie-Noëlle Bourassa

The distribution of krill in eastern Canadian waters is of interest to Species at Risk managers as a primary descriptor for the identification of important habitat for the Northwest Atlantic blue whale. Large-scale acoustic surveys have been conducted over the past decade principally in the Gulf of St. Lawrence (GSL), on the Scotian shelf and waters off southern Newfoundland, collecting dual- and multifrequency acoustic data from which krill-classified backscatter has been extracted. Generalized Additive Models (GAM) were constructed to describe the spatial distribution of krill in these areas from a set of static (bathymetry and slope steepness) and satellite-derived dynamics (sea surface temperature, chlorophyll a biomass, sea level height anomalies) environmental correlates, while considering the stochastic nature of krill spatial distribution, to produce a generalized 'food landscape' for blue whales. GAM results suggested that environmental conditions promoting high krill biomass were species-specific and varied with season. Static and dynamic environmental variables were selected in all GAM, indicating that dynamic oceanographic processes were important in controlling krill aggregations and distribution. The GAM were used to predict 'Significant Aggregations of Krill' (SAK), i.e. areas where dense krill aggregations are more likely to occur and therefore provide some predictability for blue whales. SAK in the GSL varied among seasons, but were generally predicted in the known areas of krill aggregation. SAK were also predicted outside the surveyed areas where sampling effort has been limited to nil, suggesting new areas for future research.

Exploiting acoustic measurements for ocean observing, environmental monitoring, and ecological applications

John Horne, Ross Hytnen, Shari Matzner, Adam Maxwell, Kenneth Ham

Increasing demands to monitor marine ecosystems amplifies the need for efficient and effective characterization of organism abundances and distributions. Monitoring, processing, and archiving acoustic data may also be required in near-real time when documenting environmental change or reporting impacts to meet regulatory requirements. The Nekton Interactive Monitoring System (NIMS) is designed to address four challenges of ocean observation and monitoring: animal tracking,

distribution characterization, regulatory thresholds, and data volume reduction. A Kalman filter is used to identify and link candidate targets into tracks. Backscatter measures are characterized using a suite of metrics (Sv, inertia, dispersion, Aggregation Index, evenness, % occupied) to quantify vertical distributions of pelagic organisms. If tracks cross pre-set exclusion ranges or regulatory thresholds of metrics are exceeded, then notifications are sent to trigger operational modification or mitigation. Kongsberg M3 sonar raw data acquisition rates of 11 Mb per second are reduced to 11 Mb per hour data storage, a 4 order of magnitude data savings. NIMS middleware can be deployed autonomously with instrument packages, remotely to telemeter data, network connected for real-time monitoring, or used to process archived data. Example applications include ocean observatories and marine renewable energy environmental monitoring.

Acoustic properties of marine organisms

Variability of Atlantic mackerel target strength and its effects on acoustic abundance estimates

Ben Scoulding, David MacLennann Sascha Fassler, Paul Fernandes

Atlantic mackerel *Scomber scombrus* is a small pelagic, migratory fish which supports valuable commercial fisheries. Fishery-independent mackerel abundance estimates in the Northeast Atlantic are currently based on egg-production surveys every third year, and do not yet consider acoustic data. Echo-integration surveys could provide annual estimates of abundance, with additional scope for studying mackerel distributions throughout the year. However, this requires good knowledge of the mackerel target strength (TS), which is not yet adequate. The present study provides in situ TS values for mackerel from measurements made at sea with split-beam echosounders operating concurrently at 18, 38, 120 and 200 kHz. Empirical results suggest mean TS of -51.22 dB at 18 kHz, -59.83 dB at 38 kHz, -55.51 dB at 120 kHz and -53.43 dB at 200 kHz, for a mean fish length of 33.1 cm. This differs significantly from the values currently assumed in acoustic surveying. Model fits improved the estimates but still overestimated TS at 18 kHz and underestimated it at 38 kHz. The sensitivity of Atlantic mackerel abundance estimates to variations in TS estimates was also investigated using data from a dedicated mackerel acoustic survey around the Shetland Islands in 2014. Total-stock biomass estimates at 38 and 200 kHz were in close agreement with each other. It is recommended that future acoustic surveys in the Northeast Atlantic echo-integrate at 200 kHz using the TS-L function TS=20log(L) -83.88.

Ping to ping variations in the frequency dependent target strength of single targets using a broadband echosounder (EK80)

Arti Verma, Alec Duncan, Rudy Kloser

The recent advent of commercially available broadband echosounder has opened up the possibility of measuring the frequency dependence of the acoustic target strength of micronekton organisms. Broadband acoustic data at centre frequencies of 70 and 120 kHz were collected using a lowered probe during a recent voyage of RV Investigator in the Great Australian Bight with the aim of improving our ability to monitor and classify the pelagic ecosystem. The acoustic signature of two calibration spheres and different classes of scatterers identified as single targets were collected over a 600 m depth range. The system was calibrated through its depth range to explore any amplitude and frequency changes. Single target scatterers were analysed exploring the ping to ping variation in the frequency dependent target strength and allocated to species groups based on net and optic measurements. In particular, the suspected

gas-bladder resonant scatterers and fluid filled targets and their ping to ping variability are compared with basic scattering models. This study is being undertaken as part of the Great Australian Bight Research Program, a collaboration between BP, CSIRO, the South Australian Research and Development Institute (SARDI), the University of Adelaide, and Flinders University.

When algae sound fishy

Anne Lebourges-Dhaussy, Gildas Roudaut, Adilma Montenegro, Arnaud Bertrand

Underwater acoustics is a valuable source for ecological surprises. In October 2015 we performed a scientific cruise off Northeast Brazil onboard the IRD RV Antea. The vessel was equipped with Simrad EK60 operating at 38, 70, 120 and 200 kHz. In a variety of coastal areas we observed individual echoes alike to small fish echoes. Yet, video observations and trawl sampling revealed nothing else than pelagic algae and no fish at all, leading to the hypothesis that the echoes were originated by the algae. Beyond the acoustic aspect, our observations reveal the existence of a neglected pelagic substratum that could play an important role in pelagic ecosystems. Algae, in particular segments of *Sargassum* sp., were drifting within the mix layer and served as a refuge for crabs and fish larvae. Yet to further characterize ecological processes a first step consist in an acoustic characterization of the observed target. We compared TS and Sv multifrequency responses of algae echoes with those originated by gelatinous. Interestingly, for both types of scatters, the TS decreased with frequency but a different pattern was observed on Sv. Indeed the Sv multifrequency response also decreased with frequency in the case of gelatinous while algae Sv picked at 70 kHz. These preliminary observations must be understood, but such differences may allow us for discriminating algae echoes from other scatters.

Biscay Anchovy and Sardine target strength modelling

Laurent Berger, Mathieu Doray, Xavier de la Bernardie, Elisabeth Lys, Pierre Morinière, Pierre Petitgas

Adult Biscay Anchovy and Sardine have been scanned by RX tomography to get detailed 3 dimensional shapes of their swimbladder. The real swimbladder shapes dimensions have been used to parameterize cylinder, bent cylinder, deformed cylinder and prolate ellipsoid swimbladder shape acoustic models. Target Strengths (TS) predicted by the different models as a function of fish length, fish tilt angle and acoustic frequency were compared to select the most accurate and computing time efficient model to predict Biscay Anchovy and Sardine TS. TS values averaged over natural fish tilt angle distributions are proposed at several frequencies for Biscay Anchovy and Sardine.

Biscay Anchovy controlled in-situ target strengths measurements

Mathieu Doray, Laurent Berger, Naig Le Bouffant, Jean Yves Coail, Jean Philippe Vacherot, Pierre Petitgas

Measuring fish target strength (TS) in the wild is challenging as: i) TS largely varies as a function of physical (tilt angle, depth) or physiological fish attributes, ii) the species and size composition of acoustic targets is difficult to assess in near real time. We propose a methodology for controlled in situ TS measurements based on the joint use of a Remotely Operated Vehicle (ROV) 'EROC' with a pelagic trawl fitted with the 'ENROL' codend opening system. EROC can be moved around the fishing trawl and is equipped with a Simrad EK60 70 kHz split-beam echosounder, and a low-light

black and white camera. Pelagic fish are funnelled into the open trawl and their TS is measured with the EROC echosounder in the middle of the net, where the fish swim in small groups towards the trawl mouth, against a strong current. The fish oriented swimming allows for the recording of nearly horizontal fish TS, hence controlling for the large effect of tilt angle on TS variability. Direct optical identification of the fish species composition is conducted with the EROC camera near the open codend. The methodology is used to measure in-situ TS of Biscay *Engraulis encrasicolus* in controlled conditions.

TS measurements of bluefin tuna (*Thunnus thynnus*) in sea cages

Vicent Puig, Patricia Ordoñez, Isabel Perez, Fernando de la Gandara, Vicent Estruch, Lucio Calise, Víctor Espinosa

In this work we discuss the determinant conditions for ex-situ TS measuraments of bluefin tuna (*Thunnus thynnus*) in floating cages, what include partial ensonification, influence of the nearfield of the scatterers and near range errors associated to scientific split-beam echosounders. Despite the expected problems a dorsal target strength TS) to fork length (FL) relationship for bluefin tuna is obtained. Three cages with juvenile tuna born in captivity and another cage with adult tuna were measured at 120 kHz and 200 kHz with two EK-60 SImrad echosoudners. Both split-beam transducers were mounted side by side in a floating platform in the middle of the cage radius and transmitting downwards. Biometric information of the tuna was obtained using a stereoscopic video camera system. Results show strong correlation between TS and FL at both frequencies ($r2 > 0.9$).

Estimation of TS and acoustic discrimination of tuna around FADs

Guillermo Boyra, Gala Moreno and Igor Sancristobal

The objective of this work is to analyse the acoustic response properties of the main species of tuna found in tropical waters from data collected around drifting Fish Aggreggating Devices (FAD). This analysis has a double objective. On one hand the determination of the in situ target strength (TS) allows the conversion of acoustic backscattering to abundance estimations. On the other hand, the comparison of acoustic backscattering at different frequencies provides the acoustic frequency response characteristic of each species, which can be used to distinguish between species based on purely acoustic methods. This could allow the fishers to identify the species without the need to fish.

Annex 7. Summary of acoustic related research and surveys by country

ICES WGFAST survey list

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
USA	NOAA Fisheries - Alaska Fisheries Science Center	Eastern Bering Sea acoustic-trawl survey	Walleye pollock	*Gadus chalcogrammus*	Eastern Bering Sea, Alaska	June-August 2014, 2016	index of abundance at age/length
USA	NOAA Fisheries - Alaska Fisheries Science Center	Summer Gulf of Alaska acoustic-trawl survey	Walleye pollock	*Gadus chalcogrammus*	Gulf of Alaska, Alaska	June-August 2015	index of abundance at age/length
USA	NOAA Fisheries - Alaska Fisheries Science Center	Shumagins/Sanak acoustic-trawl survey	Walleye pollock	*Gadus chalcogrammus*	Shumagin Islands, Sanak Trough, Alaska	February 2014-2016	index of abundance at age/length
USA	NOAA Fisheries - Alaska Fisheries Science Center	Bogoslof acoustic-trawl survey	Walleye pollock	*Gadus chalcogrammus*	Bering Sea near Bogoslof Island, Alaska	February 2014,2016	index of abundance at age/length
USA	NOAA Fisheries - Alaska Fisheries Science Center	Shekilof Strait acoustic-trawl suvey	Walleye pollock	*Gadus chalcogrammus*	Shelikof Strait, Alaska	February 2014,-2016	index of abundance at age/length
USA	NOAA Fisheries - Alaska Fisheries Science Center	Acoustic Vessels of Opportunity, Bering Sea	Walleye pollock	*Gadus chalcogrammus*	Eastern Bering Sea, Alaska	June-August 2014-2016	index of abundance based on backscatter

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
New Zealand	National Institute of Water and Atmospheric Research Limited	Chatham Rise middle depths trawl survey	Hok1, Lin3/4, Hak1/4	Hoki *(Macruronus novaezelandiae)*, ling *(Genypterus blacodes)*, hake *(Merluccius australis)*	Chatham Rise, New Zealand	January 2014, 2016	Index at age, distribution
New Zealand	National Institute of Water and Atmospheric Research Limited	New Zealand-Australia Antarctic Ecosystems		Silverfish *(Pleuragramma antarctica)*, krill *(Euphausia superba)*	Ross Sea, Antarctica	February-March 2015	Index, distribution
New Zealand	National Institute of Water and Atmospheric Research Limited	Chatham Rise orange roughy spawning plume	ORH3B	Orange roughy *(Hoplostethus atlanticus)*	Chatham Rise, New Zealand	June-July 2014	Index, absolute biomass
New Zealand	National Institute of Water and Atmospheric Research Limited	Cook Strait hoki	HOK1	Hoki *(Macruronus novaezelandiae)*	Cook Strait, New Zealand	July-August 2015	Index
New Zealand	National Institute of Water and Atmospheric Research Limited	Bounty southern blue whiting	SBW6B	Southern blue whiting *(Micromesistius australis)*	Bounty Platform, New Zealand	August 2014, 2015, 2016	Index
New Zealand	National Institute of Water and Atmospheric Research	West coast South Island middle depths trawl survey	HOK1, LIN7, HAK7	Hoki *(Macruronus novaezelandiae)*, ling *(Genypterus blacodes)*, hake *(Merluccius austra-*	West coast South Island, New Zealand	August 2016	Index at age, distribution

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
	Limited			*lis)*			
New Zealand	National Institute of Water and Atmospheric Research Limited	Campbell southern blue whiting	SBW6I	Southern blue whiting *(Micromesistius australis)*	Campbell Plateau, New Zealand	August-September 2016	Index at age, distribution
New Zealand	National Institute of Water and Atmospheric Research Limited	Chatham Rise black oreo	BOE3A	Black oreo *(Allocyttus niger)*	Chatham Rise, New Zealand	October 2014	Index
New Zealand	National Institute of Water and Atmospheric Research Limited	Fisheries Oceanography		Lanternfish *(Myctophidae)*	Chatham Rise, New Zealand	August, December 2015	Index, distribution
New Zealand	National Institute of Water and Atmospheric Research Limited	Chatham Rise smooth oreo	SSO4	Smooth oreo *(Pseudocyttus maculatus)*	Chatham Rise, New Zealand	October-November 2016	Index
New Zealand	National Institute of Water and Atmospheric Research Limited	Subantarctic middle depths trawl survey	HOK1, LIN5/6, HAK1	Hoki *(Macruronus novaezelandiae)*, ling *(Genypterus blacodes)*, hake *(Merluccius australis)*	Southern Plateau, New Zealand	November-December 2014, 2016	Index at age, distribution
Australia	Commonwealth Scientific and	N/A	orange roughy, blue grenadier	*Hoplostethus atlanticus*	Southeast Australia, New Zealand	June, July	Biomass estimates, target strength

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
	Industrial Research Organization (CSIRO)						
Spain	Instituto Español De Oceanografia (Spanish Institute Of Oceanography)	PELACUS	sardine, anchovy, mackerel, horse mackerel, blue whiting, boar fish, bogue, chub mackerel	*Sardina pilchardus, Engraulis encrasicolus, Scomber scombrus, Trachurus trachurus, T. mediterraneus, T. picturatus, Micromesistius poutassou, Capros aper, Boops boops, Scomber colias*	9a N, 8c (North Spanish waters)	March-April	NASC/species, Biomass length/age, Sardine and anchovy egg counts from CUFESBiological, physical and chemical oceanographic characterization through continuos and casts records, Surface microplastics, Apical predators
Spain	Instituto Español De Oceanografia (Spanish Institute Of Oceanography)	ECOCADIZ	sardine, anchovy, mackerel, horse mackerel, blue whiting, boar fish, bogue, chub mackerel	*Sardina pilchardus, Engraulis encrasicolus, Scomber scombrus, Trachurus trachurus, T. mediterraneus, T. picturatus, Micromesistius poutassou, Capros aper, Boops boops, Scomber colias*	9a S (Gulf of Cadiz)	August	NASC/species, Biomass length/age, Sardine and anchovy egg counts from CUFESBiological, physical and chemical oceanographic characterization through continuos and casts records, Surface microplastics, Apical predators
Spain	Instituto Español De Oceanografia (Spanish Insti-	ECOCADIZ-RECLUTAS	sardine, anchovy, mackerel, horse mackerel, blue	*Sardina pilchardus, Engraulis encrasicolus, Scomber scombrus, Trachurus trachurus, T.*	9a S (Gulf of Cadiz)	October	NASC/species, Biomass length/age, Biological, physical and chemical ocean-

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
	tute Of Oceanography)		whiting, boar fish, bogue, chub mackerel	*mediterraneus, T. picturatus, Micromesistius poutassou, Capros aper, Boops boops, Scomber colias*			ographic characterization through continuos and casts records, Surface microplastics, Apical predators
Spain	Instituto Español De Oceanografia (Spanish Institute Of Oceanography)	MEDIAS	sardine, anchovy, mackerel, horse mackerel, blue whiting, boar fish, bogue, chub mackerel	*Sardina pilchardus, Engraulis encrasicolus, Scomber scombrus, Trachurus trachurus, T. mediterraneus, T. picturatus, Micromesistius poutassou, Capros aper, Boops boops, Scomber colias*	Spanish Mediterranean waters	July	NASC/species, Biomass length/age, Sardine and anchovy egg counts from CUFESBiological, physical and chemical oceanographic characterization through continuos and casts records, Surface microplastics, Apical predators
Ireland	MI	IBWSS	Blue whiting	*Micromesistius poutassou*	6, 7	Mars-April	Age stratified abundance
Ireland	MI	WESPAS	Herring	*Clupea harengus*	6a, 7b-c, 7g-k	June-July	Age stratified abundance
Ireland	MI	WESPAS	Boarfish	*Capros aper*	6a, 7b-c, 7g-k	June-July	Age stratified abundance
Ireland	MI	WESPAS	horse mackerel	*Trachurus trachurus*	6a, 7b-c, 7g-k	June-July	Age stratified abundance
Ireland	MI	CSHAS	Herring	*Clupea harengus*	7g-j, 7aS	October	Age stratified abundance

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
Ireland	MI	CSHAS	Sprat	*Sprattus sprattus*	7g-j, 7aS	November	Age stratified abundance
Spain	Instituto Español de Oceanografía (IEO)	JUVENA2014	Juvenile anchovy		Bay of Biscay	September	biomass
Spain	Instituto Español de Oceanografía (IEO)	JUVENA2014	mesopelagic species		Bay of Biscay	September	distribution and behaviour
Spain	Instituto Español de Oceanografía (IEO)	JUVENA2015	Juvenile anchovy		Bay of Biscay	September	biomass
Spain	Instituto Español de Oceanografía (IEO)	JUVENA2015	mesopelagic species		Bay of Biscay	September	distribution and behaviour
Spain	Instituto Español de Oceanografía (IEO)	SCAPA0215	mesopelagic species		Bay of Biscay	February	distribution and behaviour
Spain	Instituto Español de Oceanografía (IEO)	SCAPA0415	mesopelagic species		Bay of Biscay	April	distribution and behaviour
Spain	Instituto Español de Oceanografía (IEO)	SCAPA0715	mesopelagic species		Bay of Biscay	July	distribution and behaviour
Spain	Instituto Español de Oceanografía (IEO)	SCAPA1115	mesopelagic species		Bay of Biscay	November	distribution and behaviour

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
Spain	Instituto Español de Oceanografía (IEO)	MAFIA	mesopelagic species		Brasil-Canary islands	April	distribution and behaviour
Spain	Instituto Español de Oceanografía (IEO)	JUVENA2016	Juvenile anchovy		Bay of Biscay	September	biomass
Spain	Instituto Español de Oceanografía (IEO)	JUVENA2016	mesopelagic species		Bay of Biscay	September	distribution and behaviour
Portugal	IPMA	PELAGO	Sardine and Anchovy and other small pelagic species	*Sardina pilchardus; Engraulis encrasicholus*	ICES 9a	April	absolute biomass, absolute numbers, absolute numbers-at-age (or length), distribution
France	Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer)	Pelgas	anchovy, sardine	*Engraulis encrasicolus, Sardina pilchardus*	Bay of Biscay	April-May	index at age
France	Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer)	Pelmed	anchovy, sardine	*Engraulis encrasicolus, Sardina pilchardus*	Gulf of Lions	July	index at age
United States of	Northeast Fisheries Science Center	NONE	NA	NA	NA	NA	NA

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey [month(s)]	date	Output(s)
America	(NEFSC)							

ICES WGFAST Research areas

Country	Institute	Behaviour	Emerging technologies, methodologies and protocols	Acoustic properties of marine organisms	Applications of acoustic methods to characterize ecosystems
USA	NOAA Fisheries - Alaska Fisheries Science Center	Observation of spawning behaviors with bottom-moored echosounders	Applications of bottom-moored echosounders, Acoustics on autonomous vehicles, Survey applications of wideband acoustics , Optical/acoustic surveys including trawl cameras	Krill TS, fish TS, Wideband measurements	moored echosounder time-series, krill abundance index
New Zealand	National Institute of Water and Atmospheric Research Limited	Behaviour of orange roughy on seamounts			
New Zealand	National Institute of Water and Atmospheric Research Limited	In situ tilt angle distribution of southern blue whiting			
New Zealand	National Institute of Water and Atmospheric Research Limited		Calibration of ES60/ES70 echosounders		
New Zealand	National Institute of Water and Atmospheric Research Limited		Comparison of Furuno FCV30 and Simrad EK60 echosounders		
New Zealand	National Institute of Water and Atmospheric Research Limited		Acoustic data collection with moored echosounders		
New Zealand	National Institute of Water and Atmospheric Research Limited		Estimation of uncertainty for acoustic indices in Bayesian assessments		
New Zealand	National Institute of Water and Atmospheric Research Limited			In situ data collection and modelling of target strength of hoki, oreo, orange roughy, southern blue whiting, and associated species	
New Zealand	National Institute of Water and Atmospheric Research Limited				Using acoustics to evaluate and predict abundance of mid-trophic level organisms for ecosystem modelling
Australia	Commonwealth Scientific and Industrial Research Organization (CSIRO)		Development of instrumentation for acoustic and optical observations of deep-sea commercial fish species and water column micronekton		Application of deployed acoustic and optical

Country	Institute	Behaviour	Emerging technologies, methodologies and protocols	Acoustic properties of marine organisms	Applications of acoustic methods to characterize ecosystems
					instrumentation and vessel of opportuntiy data to characterize water column biota
Spain	Instituto Español De Oceanografia (Spanish Institute Of Oceanography)	Nictimeral migration			systematic assessment surveys+ancillary variables
Ireland	MI	X	X		X
Spain	Instituto Español de Oceanografía (IEO)		EK80: first trials and data processing.		
Spain	Instituto Español de Oceanografía (IEO)	Behaviour of mesopelagic species		Acoustic properties of mesopelagic species	
Spain	Instituto Español de Oceanografía (IEO)				Vertical acoustical layers of mesopelagic species day/night
Portugal	IPMA	yes			yes
France	Northeast Fisheries Science Center (NEFSC)	NA	Wideband data acquisition and processing	In situ and ex-situ TS measurements and modelling	Comparison of acoustic derived estimates with bottom trawl derived ones to evaluate applicability of each method
United States of America	Northeast Fisheries Science Center (NEFSC)	NA	Wideband data acquisition and processing	Theoretical models of acoustic backscatter by fish and zooplankton	Investigating trophic relationships among predators (e.g. marine mammals, birds, tuna) and prey (e.g. mesopelagic, zooplankton, forage fish species).

Annex 8. SGFARV Report: Causes and Consequences of Fish Reaction to Fisheries Research Vessels