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REPORT OF THE WORKING GROUP ON FISHERIES ACOUSTICS SCIENCE AND TECHNOLOGY (WGFAST)

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Executive summary

The Working Group on Fisheries Acoustic Science and Technology [WGFAST] met at the Crowne Plaza Hotel, Dublin, Ireland from the 23–27 April 2007. Rudy Kloser, Australia was Chair and Tim Ryan, Australia was Rapporteur. There were 73 participants from 20 countries.

Highlights:

Under the auspices of the WGFAST working group, two ICES Cooperative Research Reports were submitted for publication in 2007.

The first titled, "Collection of Acoustic Data from Fishing Vessels" represents the input of experts from 12 countries over a three year study group term and consists of a detailed synthesis of the topic and concludes with thirty-nine principal findings and recommendations (Section 3.1). The transference of the acoustic method from dedicated research platforms to fishing vessels represents a major evolution of the science. Apart from the technical details of using acoustics on industry vessels the report has a chapter detailing cooperative research with industry.

The second publication was titled, "Acoustic seabed classification of marine physical and biological landscapes" (Section 3.2). The 225 page report provides an overview of the major issues and applications in this field and a comprehensive review of the technologies and techniques used to investigate these. Acoustic technology and classification science is rapidly evolving to meet the needs of nations to manage and conserve coastal resources. As such, this report must be seen as representing a snap-shot of the discipline at this point in time. While we anticipate that new developments will occur regularly and that this subject must be revisited in the future, we hope that this document will form a basis of our current understanding and will provide guidelines for the coordination of developments in this field.

The ICES 2008 Symposium of the Ecosystem Approach with Fisheries Acoustics and Complimentary Technologies (SEAFACTS) will be held from 16–20 June, 2008 in Bergen Norway. The Conveners for the meeting are Egil Ona (Norway), Rudy Kloser (Australia), and David Demer (USA). This symposium represents a major opportunity to focus international attention on the use of acoustic and complimentary technologies addressing ICES needs in applying the ecosystem approach to marine management issues.

The following four topics in the Terms of Reference were examined and discussions were distilled to the associated points:

Fish behaviour in response to vessel-and other platform-related stimuli

New experiments were reported from the new NOAA noise reduced vessels which have helped to advance our knowledge of fish avoidance for the important adult walleye pollock stock in the Bering Sea (Section 5.4). Importantly there was no statistical difference between total acoustic biomass measured between the noise reduced vessel and their older conventional vessel. Yet significant behaviour differences were noted between the vessels for fish at depths shallower than 90 m. These studies with noise reduced vessels reported at this meeting and the previous WGFAST meetings (*WGFAST B:05 – Sections 3.13 and 3.20 and WGFAST B:06 – Sections 3.4 and 10.1*) enhance our understanding of fish behaviour and the many other benefits of noise reduced vessels. The Study Group on Fish Avoidance of Research Vessels (SGFARV) will now advance the knowledge of this topic over the next three years (Section 9.3).

Survey techniques for epi-benthic, epi-pelagic, and shallow water species

The focus of ICES is to apply the ecosystem approach to management questions within the marine environment. Importantly acoustics represents a unique tool that can address ecological questions: population dynamics, habitat mapping – substrate classification and spatial-temporal interactions throughout the entire water column (pelagic zone) including key forage species. There is a need to focus our efforts over a range of scales and trophic levels. The focus should be on integration and a multidisciplinary approach to data collection with clearly defined objectives (Section 6.17). Therefore there is a need for the WGFAST to focus on the issues raised in this section in coming years to assist ICES in the goal of applying an ecosystem approach to fisheries management.

Species identification techniques (e.g. acoustic, optical and nets) for multi-species assessments, bycatch reduction, and automated data processing

The session highlighted the necessary moves we need to make in realising objective species classification using probabilistic and deterministic methods (Sections 7.1, 7.11). Of particular interest was the incorporation of spatial and temporal information in the classification method (Sections 7.11). To advance our ability to remotely classify species new technologies (ME70) have been manufactured which allow us to test establish methods through hypothesis testing (Sections 7.5, 7.6). A clear direction of WGFAST will be to improve our methods to reliably measure key trophically important species/species groups within the ecosystem that can be reliably measured with acoustics and provide quantitative metrics with estimates of uncertainty for incorporation into fisheries and ecosystem models.

Target strength modelling and measurement

The challenges to the fisheries acoustics community is to continue to increase our understanding of how fish scatter sound and to use this to reduce issues with target identification, and to also more fully understand target strength variability for species of interest. Continued development of more sophisticated observing equipment (such as autonomous echosounders and optical instruments) is required to address the key issues. Incorporating target strength uncertainty into acoustic biomass estimates was seen as an important part of accommodating and recognising the natural variability in fish target strength.

Recommendations

A complete list of the Recommendations proposed by the WGFAST can be found in Annex 3 and Annex 4 of this report.

1 Terms of Reference

In response to the ICES Resolution of the 92nd Statutory Meeting, the Working Group on Fisheries Acoustics Science and Technology [WGFAST] (Chair: Rudy Kloser, Australia; and Rapporteur: Tim Ryan, Australia) met in Dublin, Ireland from 23–27 April 2007 to:

a) Examine works in the following research areas:
   i) Fish behaviour in response to vessel and other platform related stimuli;
   ii) Survey techniques for epi-benthic, epi-pelagic and shallow water species;
   iii) Species identification techniques (e.g. acoustic, optical and nets) for multispecies assessments, bycatch reduction and automated data processing;
   iv) Target strength modelling and measurement; and

b) Present on:
   i) Final report of SGAFV – The Study Group Collection of Acoustic Data from Fishing Vessels 2003 – 2006 (ICES Cooperative Research Report)
   ii) Final report of SGASC – Acoustic Seabed Classification of Marine Physical and Biological Landscapes (ICES Cooperative Research Report)
   iii) ICES 2008 Symposium on Fisheries Acoustics and Technologies for Investigations of Aquatic Ecosystems.

WGFAST will report to the Fisheries Technology Committee at the 2007 Annual Science Conference in Helsinki, Finland 17–21 September 2007.

2 Opening the meeting

2.1 FTFB/FAST opening

Paul Connolly, Head of fisheries BIM, Chair of MCAP (ICES) opened the WGFAST and WGFTB meeting welcoming participants from both working groups. In particular, he noted the synergies between both working groups and encouraged participants to take the opportunity during the tea breaks and lunch to explore areas of common interest. He stressed the need for working groups to work together to solve cross disciplinary problems.

2.2 Opening and welcome to FAST by Rudy Kloser

Rudy Kloser acknowledged and thanked Dave Demer as past WGFAST Chair from 2004 to 2006. He also noted all past Chairs and their contribution to the ongoing scientific direction within WGFAST and the completion of a large number of well referenced ICES cooperative reports. Rudy Kloser noted the philosophy for WGFAST to foster strong international science advancement in the area of fisheries acoustics and a forum to focus this science on the emerging issues within ICES and adoption of the ecosystem approach to fisheries management. He recognized retired members of the group – Robert Kieser and Van Holliday who contributed greatly to WGFAST and that this may continue in the future where possible. Rudy Kloser thanked Claire Welling (ICES) and Denise McMullen (CSIRO) for their work in organizing the meeting. Tim Ryan was appointed as Rapporteur. Rudy Kloser thanked presenters and participants for their attendance.

Rudy Kloser highlighted the SGAFV and SGASC ICES CRR reports that have been completed and represented a significant contribution by WGFAST to the ICES community. Bill Karp and John Anderson were thanked for their efforts as Chairs of the SGAFV and SGASC groups respectively and for their hard work in ensuring the reports were completed on time.

2.3 Participants and agenda

A list of the 73 participants from 20 countries appears in Annex 1.

3 Study Group final reports

3.1 Rudy Kloser for Bill Karp. Final report on the work of SGAFV – The Study Group on the Collection of Acoustic Data from Fishing Vessels 2003–2006

In 2003 SGAFV, the Study Group on the Collection of Acoustic Data from Fishing Vessels was established to evaluate the collection of acoustic data from fishing vessels and provide appropriate recommendations. Experts from 12 countries participated in the work of the study group during its three-year term. The SGAFV prepared a written report which will be published as an ICES Cooperative Research Report in mid-2007. The preface of the report consists of a detailed synthesis of the work of the study group and concludes with the thirty-nine principal findings and recommendations of SGAFV. Chapter 1 begins with a general overview of the work of the SGAFV and proceeds to consider the different types of research and monitoring studies that might be conducted from fishing vessels. Chapter 2 provides comprehensive background information on the behaviour of fish in relation to noise radiated by vessels and factors and provides guidance on selection of commercial vessels for acoustic sampling. Chapter 3 discusses the selection, installation and operation of acoustic instruments and equipment for measurement of operational, oceanographic, and meteorological parameters. Operation of acoustic and ancillary instruments at sea, and data collection and management are discussed in Chapter 4. Chapter 5 discusses the importance of biological sampling and recommends alternative biological sampling strategies. Analysis and interpretation of acoustic and ancillary data collected from fishing vessels are addressed in chapter 6. Chapter 7 considers the benefits of cooperative research and offers recommendations for improving the likelihood of success in these types of ventures. An extensive bibliography is provided. In this presentation we review the work of the study group, and summarize the findings and recommendations.

3.2 John T. Anderson, Acoustic Seabed Classification of Marine Physical and Biological Landscapes: ICES Cooperative Research Report

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Recently, ICES undertook a review of acoustic seabed classification science. This review will be published as a Cooperative Research Report in 2007. The aim of our report was to review the state-of-the-art in Acoustic Seabed Classification (ASC). The report provides an overview of the major issues and applications in this field and a comprehensive review of the technologies and techniques used to investigate these. Acoustic technology and classification science is rapidly evolving to meet the needs of nations to manage and conserve coastal resources. As such, this report must be seen as representing a snap-shot of the discipline at this point in time. While we anticipate that new developments will occur regularly and that this subject must be revisited in the future, we hope that this document will form a basis of our current understanding and will provide guidelines for the coordination of developments in this field.

4 ICES 2008 Symposium

4.1 David A. Demer[1], Egil Ona[2], and Rudy Kloser[3]. ICES 2008 Symposium on Fisheries Acoustics and Technologies for Investigations of Aquatic Ecosystems

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Ecosystem-based approaches to fisheries management require consideration of numerous biotic and abiotic factors of the aquatic environment using a variety of sampling equipment and analysis techniques. Data must be efficiently collected and integrated to enhance our understanding of relevant ecological processes and thus facilitate more effective management advice. Acoustical methods remain the primary remote-sensing tools for space-time-observations in the aquatic environment, but they continue to evolve with innovative implementations and augmentation with other mature and new technologies. The 2008 ICES Symposium provides an invaluable opportunity for the international community to take stock of this rapidly evolving field, and thereby progress our knowledge of aquatic ecology, and its utility for improved fisheries management. This will be the sixth acoustics Symposium sponsored by ICES (Bergen, Norway, 1973 and 1982; Seattle, USA, 1987; Aberdeen, Scotland, 1995; and Montpellier, France, 2002). The objective is to review and discuss recent developments in methods and technologies applied to the characterization of marine and freshwater ecosystems for improving the effectiveness of fisheries management. Particular emphasis will be on technologies for measuring numerous aspects of the aquatic environment, and merging these data sets to elucidate functional ecological relationships. Discussions on the contemporary challenges and future directions of these studies will be organized into the following themes: 1) technologies for observing ecological processes on important temporal- and spatial-scales; 2) instrumentation for continuous shipboard sampling of biological components of the sea-surface and the water column; 3) methods for observations of animals residing near a boundary; and 4) passive acoustical observations and assessments.

4.2 Subgroup discussion

The main group was split into 6 subgroups to discuss the themes and topics of the symposium and to report on the organisation of theme sessions and invited speakers including:

- What topics will you be talking to at the symposium?
- In what areas should we target invited speakers and what should be the scope of the talk.
- Which topics should be addressed in plenary?
- Which topics could be addressed in parallel sessions; and which topics should definitely not compete?

The general consensus of the group was that parallel sessions should be avoided if at all possible but if they had to happen, careful attention should be paid to which sessions run in parallel. The timing conflict between the animal behaviour and target strength sessions at the Montpelier 2003 was noted by most groups as an example of sessions that should not be run in parallel. All groups provided good feedback about invited speakers and topics that will be used by the symposium organisation committee.

5 Topic 1: Fish behaviour in response to vessel and other platform related stimuli

5.1 Dick Wood[1], Bureau Veritas: Underwater Noise Issues associated with the latest NERC Research Vessel, RRS "James Cook"

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The latest oceanographic research vessel, RRS "James Cook" has been developed with a low underwater radiated noise (URN) signature. This paper describes some of the design measures adopted in the development of this vessel along with underwater noise signature. A comparison is also made between this vessel and other recent noise reduced vessels to demonstrate the high degree of compatibility between their URN signatures. Comparison is also made between these recent vessels and older (noisier) research vessels and discusses the main differences in the design process.

Probably one of the most important issues, not addressed in the ICES limit set forward in ICES CRR 209, is the relevance of radiated tones to fish scaring activities. This paper compares some of the tonal characteristics that arise during ranging and compares these with the mean spectrum levels derived from 1/3rd octave band measurements (the ICES measurement protocol).

5.2 Bjarne Stage[1], Karl Johan Stæhr[1], and Bo Lundgren[1]. Planned experiments on vessel noise measurements and fish reactions to noise

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Measurements of noise from research vessels have traditionally been made in special military measurement ranges, which are relatively costly to use. The Danish Navy has recently contracted a private company to produce a relatively simple measurement buoy-system with hydrophone and GPS that can be deployed in the open sea from the vessel to be measured. We will describe the plans to record the vessel noise with the buoy-system and to later study the reactions of captive fish to this recorded noise in the large fish tanks available in the North Sea Centre.

5.3 Yvan Simard[1,2], and Richard Lepage[1]. Small- and meso-scale noise conditions experienced by demersal fish in Gulf of St. Lawrence

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A 5-month time-series of noise conditions in the demersal zone in the Gulf of St. Lawrence was recorded during the fishing season from mid-May to mid October 2005. The recordings were made with a calibrated AURAL autonomous hydrophone placed at an altitude of 5 m over a 292-m deep bottom. The instrument was set to record 16-bit *.wav files in the 1-kHz low-frequency band. The continuous time-series was sampled at 6-h intervals to get the power spectrum density (PSD) in the [10-1000 Hz] band, third octave and broadband rms level series. Shipping noise from St. Lawrence's major continental seaway was the dominant noise source. Every ship transiting in the area increased noise levels by 10-30 dB for ~10-50 min. Lloyds mirror interference patterns were often present around the closest point of approach, which generated high-frequency variability in narrow-band noise levels. The PSD series was weighted by the audiogram of cod to get an estimate of the short-term noise conditions

experienced by this demersal fish around a transiting ship and mean conditions during the fishing and intense traffic season.

5.4 Alex De Robertis[1], Vidar Hjellvik[2], Neal Williamson[1], Christopher D. Wilson[1]. Inter-vessel comparison of acoustic backscatter recorded by a noise-reduced and a conventional research vessel

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Acoustic backscatter estimates of walleye pollock (*Theragra chalcogramma*) based on measurements using the conventional NOAA research vessel, *Miller Freeman* (MF) were compared to estimates from the newly constructed, noise-reduced NOAA vessel, *Oscar Dyson* (OD) during an inter-vessel comparison (IVC) experiment conducted in the eastern Bering Sea (EBS) during 3-13 July 2006. The experimental design required that the vessels travelled side-by-side at a separation distance of 0.5 nmi (side-by-side transects), and at other times the vessels followed each other at a distance of 1 nmi along short transects (follow-the-leader transects). The IVC experiment was conducted in conjunction with the EBS biennial acoustic-trawl stock assessment survey for walleye pollock, and the design provided minimal impacts to completing the survey with the conventional vessel while allowing collection of the IVC data.

Overall, no differences were detected in vessel avoidance, which would impact echo integration results of adult pollock. However, analysis of pollock depth distributions from both vessels suggested that for fish at depths less than 90 m, there was a comparatively larger diving response to OD, where the reaction occurred primarily after vessel passage. Because the change in vertical distribution appeared to occur after the fish had been detected by the echosounder, the reaction should not influence echo integration measurements. These results indicate that use of OD rather than MF is unlikely to bias the Bering Sea acoustic-trawl survey time series due to differences in vessel avoidance for adult walleye pollock. More IVC work is planned and underway to determine whether these results are typical for juvenile as well as adult walleye pollock in other situations and under different environmental conditions.

5.5 Vasilis Trygonis and Stratis Georgakarakos, Investigation of school speed measurement errors by simulation

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A fish school's horizontal position when it is measured by multibeam omnidirectional sonar includes an uncertainty due to the beam geometry. Behavioural studies based on horizontal speed measurements of swimming schools are affected by this uncertainty since speed estimates, especially the so-called "instantaneous speed", are biased. The aim of this study is to investigate the order of this uncertainty, its relationships with the sonar operation and finally to test algorithms for its reduction. The study is based on a simulation procedure, where ideal targets move in similar patterns to real tuna schools observed by an SP90 SIMRAD long range omnidirectional sonar. From the simulated experiments it is suggested that the following three factors can significantly affect the speed measurement errors: the mean swimming speed of the school, the distance to the transducer and the number of the observation pings. The real and simulated schools can be tracked by applying the Multibeam Sonar Tracer software. The real positions of the simulated schools can be predicted applying certain smoothers on both polar coordinates of the successive position measurements. Prediction performance is not changed significantly by the selected smoothing algorithms, but mainly by the three mentioned factors. Further improvements of the method are discussed.

5.6 Marc Soria, Gaël Potin, Pascal Cotel, Emmanuel Tessier, Laurent Dagorn. Is there a relationship between FAD-associated and free shoals? Lessons from acoustic surveys on small pelagic fish in a network of shallow FADs in Reunion Island

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Small and large pelagic fish are known to aggregate around fish aggregating devices (FADs). One major question in this field is: can fish abundance around FADs be used as a proxy of the total fish abundance in the area? This issue was first addressed through acoustic observations on small pelagic fish in a bay of Reunion island (Western Indian Ocean). Twenty artificial structures such as moored buoys, artificial reefs, aquaculture cages, submarine shipwreck or fishing FADS, are scattered in the bay from 15 m to 50 m depth. We conducted 28 acoustic surveys during new moon periods from February 2003 to August 2006 in order to (1) characterize the effects of FADs on small pelagic fish distributions, (2) study if there is any relationship between the abundance of FAD-associated and non FAD-associated (free) shoals. The frequency histogram of the distance between fish shoals and the nearest FAD revealed a 150 m FAD influence on the distribution of shoals. This distance was applied to distinguish FAD-associated shoals (< 150 m) from free shoals (> 150 m). For these two types of shoal and for each survey, shoal densities (number of shoals by nautical miles) and acoustic and morphological descriptors were then computed. FAD-associated shoal densities were significantly related to free shoal densities, suggesting correlative evidence between both. However, the regression performed on acoustic and morphological descriptors did not show clear relationship. The potential of using densities of shoals around FADs as a proxy for total density in the area is discussed.

5.7 Egil Ona[1], Ingvald Svellingen and Ronald Pedersen. Vessel avoidance by herring during rough weather conditions

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Vessel avoidance may in particular surveys of pelagic fish cause seriously biased estimates of abundance. Most of the experiments for quantifying the effects of vessel-induced behaviour reported have been done in good weather conditions, and consequently under fairly low background noise levels. Wind and waves on the sea surface creates an elevated background noise level, particularly in the low frequency part of the spectrum where the fish ear is most sensitive. Also other potential herring senses that may be receptive to pressure or particle acceleration will experience an elevated variability, or noise, at increased sea state. How representative are therefore the results from inshore experiments to real ocean survey situations? The paper presents data collected during the November 2006 wintering herring survey from RV “G.O Sars”. A 38 kHz scientific echo sounder system, operated on batteries from a lander-system was bottom mounted at 1000 meters depth, with the instrument package and transducer floating at 210 m depth. The transducer beam was pointing up towards the surface through herring layers, which migrated from 250 m depth during daytime to 50 metres depth during nigh time. The results from 16 vessel passages over the lander are reported in this paper and discussed.

5.8 Panel session on Topic 1: "Fish behaviour in response to vessel and other platform related stimuli" led by Francois Gerlotto and Egil Ona

Synthesis of Francois Gerlotto's summary:

The session was interesting as it covers questions from within the study group. Firstly, what is a silent vessel? We know this is a complex answer for fish, they do not respond the same way to similar stimulus. When we consider the acoustics of a scaring vessel we must continue to understand what is the signal emitted by the vessel. Work presented by Bo Lundren (5.2) highlighted how difficult it is to do work in a tank situation. A complex challenge and experiments have to be done, but must be done with care. How will these results translate to the real world? The presentation by Yvan Simard (5.3) showed that many vessels in the sea are likely to affect the behaviour and learning of fish. We can have a very wide observation field (10's km) so we can follow accurately how the fish will respond to the stimulus. Chris (5.4) presented an unexpected outcome, with the response of fish being stronger to the noise quieted vessel. It highlights how it is not only the strength of the signal that is the only factor in fish response. Vasilis's Trygonis's (5.5) work on simulating avoidance described the possibility to model and simulate fish movements which will help discriminate in a complex observation where the key uncertainties lie. Marc Soria (5.6) showed how there are complicated factors in the sea such as FADs that affect fish distribution. Finally Egil Ona's presentation (5.7) showed how we are moving towards an ecosystems based avoidance measurement.

Synthesis by Egil Ona:

Dick Wood (Section 5.1) demonstrated that the industry can manufacture noise reduced vessels within the CRR 209 specification. He raised the issue of how the noise spectrum measured from vessels should be averaged. If single tones within the spectrum are important, they will be lost when using 1/3 octave averaging. Also Wood questioned the infrasound end of the spectrum, "How important is it from 20 Hz and below?" Experience has shown it is extremely difficult to meet CRR209 specifications for this part of the spectrum due to propeller blade frequencies. Is it necessary to have an amendment of the recommendations in CRR209 in this spectrum region? Do we know enough on fish hearing at these frequencies? These are important issues that will need to be dealt with in the new study group in close contact with other research groups (e.g. Olav Sand's group at University of Oslo).

Systems for in situ noise ranging with portable equipment were presented by Bo Lundgren (5.2), where he is also planning sound playback experiments in aquariums. Comments on the difficulties in playback experiments, wavelengths, reflections, and habituation etc. came from the audience.

Long-term recordings of small and meso-scale noise in the Gulf of St. Lawrence was presented by Yvan Simard (5.3). He showed that demersal fish in this area are often exposed to vessel noise, both from trawling and from merchant vessels passing. As the cod can sense the presence of a vessel at several kilometres, the sound levels are seldom above its reaction threshold. However, the reaction is probably dependent on the general background noise level, varying with weather conditions, the sound propagation conditions, and also on whether the fish have adapted to vessel noise or not. This supports the findings on herring, where year-to-year variability in avoidance reaction is quite large.

An excellent well-analysed comparison between a conventional research vessel and a noise-reduced vessel was presented by Chris Wilson (5.4). They used parallel echo recordings of walleye pollock as the target species with no systematic difference reported. However, observation of a lower density on the conventional vessel, when sailing behind the noise-reduced vessel may indicate that the perturbation of the walleye pollock was larger by the

noise-reduced vessel than by the old vessel. This is similar to the observations made for herring, and it is therefore worthwhile to further discuss why the new vessel or propeller designs create a larger total perturbation than the older vessel or propellers. The largest perturbation seems to occur during or directly after propeller passage, and is therefore too late to create differences in the acoustic registration on the echo sounders, as these are often mounted in the centre of the vessel, or further forward. The obvious parameters to study in this area are vessel size, shape of hull, pressure waves, propeller design and signals from the low-noise propeller, or basically that the total "signal" from these vessels are new, and "unknown" to the fish.

Sonar school detection, and tracking errors was the topic in Vasilis Trygonis presentation (5.5), basically showing that the internal tracking algorithms in commercial fishery sonar can be drastically improved. The background for the study was tracking of schools in relation to FAD's. These results are highly relevant for this topic when using sonar for evaluating school avoidance and also when using sonar for studying interactions between schools and its predators. Further work in this area was strongly supported by the audience.

In a second FAD related talk, a paper by Marc Soria (5.6) used acoustic surveys to investigate if there was a connection between free schools (more than 150 m away from a FAD) and schools aggregated at the FAD. A connection was found related to the number of schools and differences in morphological parameters. An investigation on whether the FAD altered the general behaviour of the schools and if FAD density estimates could be used as a proxy abundance index was discussed. There was also a discussion from the audience on the active stimuli in attracting fish to the FAD, and if noise generated by the FAD was important. In this study the active use of sound as attractant had not been tested.

The last presentation under this topic was by E. Ona (5.7), showing an investigation on vessel avoidance on herring in rough weather conditions. Using a standard setup, no avoidance was seen on wintering herring at 40 – 80 m depth. Wind speeds during the experiments were 30 – 35 knots with wave heights of 5 – 7 meters. The authors concluded that the background noise level or the variation in pressure due to waves could mask the vessel noise or pressure wave, and thereby reduce the reaction distance for herring. This contrasts with previous avoidance measurements inside fjord systems in at reasonable sheltered conditions where marked avoidance was observed. It was therefore demonstrated that the inside fjord observations are not necessarily representative for herring reactions in open sea surveys.

The investment in expensive silent research vessel was questioned, and will be in the future, based on some of the new findings. It was discussed that without these new noise reduced vessels follow the CRR 209 report we would not be able to advance our understanding of fish behaviour. Also it was demonstrated that the received noise level on the echo sounder and sonar systems has improved by more than 20 dB for some of the vessels, now enabling accurate deep water measurements of small targets like orange roughy, mesopelagic fish and zooplankton. Other, non-biological targets have also been measured in very deep water, not seen by conventional vessels.

The presenters and panel session Chairs (Egil Ona (Norway) and Francois Gerlotto (France)) were thanked for their contribution to this important topic with the information gained during this session to be used within the Study Group on Fish Avoidance of Research Vessels (SGFARV, Chair Francois Gerlotto). The terms of reference of the study group will explore when and why fish avoid research vessels and:

i) Elucidate and expand the list of the possible physical stimuli produced by research vessels (platform related stimuli - PRS) that could elicit avoidance reactions in survey-targeted species;

ii) Produce a literature review to improve our understanding of fish hearing and their reaction to stimuli;

iii) Generate a list of required items to be monitored and measured on research vessels, wider than just noise related;

iv) Produce a review of methods for measuring avoidance to aid in the design and development of new methods to independently monitor fish reaction to PRS;

v) Design explicit experiments to further examine the causes of fish reactions to PRS; and

vi) Produce an ICES Cooperative Research Report.

In particular the Chair thanked the researchers at IMR (Norway) and NMFS (USA) for carrying out the detailed experiments that have helped the ICES community improve our understanding of fish avoidance that will lead to better management of pelagic fish resources.

6 Topic 2: Survey techniques for epi-benthic and shallow water species – the ecosystem approach

6.1 Joseph D. Warren[1] and David A. Demer[2]. "Small vessel surveys of krill populations near Livingston Island"

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Acoustic surveys of krill abundance and distribution near Livingston Island were conducted from a small research vessel during the austral summer during six field seasons from 2000 to 2007. The surveys were conducted by a two person team using a 6 m inflatable vessel equipped with a 120 kHz echosounder (first three field seasons) or a 38 and 200 kHz echosounder (last three field seasons). Net tow data from a nearby research vessel, video camera observations, and multiple-frequency discrimination techniques were used to identify the acoustic targets as Antarctic krill (*E. superba*). Scattering data were converted to estimates of krill biomass for each survey such that the different field years could be compared with each other and from measurements of krill abundance conducted by the US Antarctic Marine Living Resources (AMLR) program's annual survey of krill stocks in the Scotian Sea. Krill abundance in the nearshore waters was consistently higher than the offshore area surveyed by the AMLR program.

6.2 Ronan Fablet[1], Carla Scalabrin[1], Jacques Massé[2], Pierre Cauchy[1]. Can we learn acoustics-based school classification models from multi-specific trawl catches?

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A variety of fish species identification techniques from echosounder data, especially using fish school characteristics, have been attempted. In all cases, training classification models is a key stage. This training issue is generally solved for within a supervised framework which assumes that a set of labelled data (i.e. known correspondences between an acoustic school and a fish species) is available. Such dataset is however often not available, especially for pluri-specific communities, for which only associations between an assemblage of fish schools and trawl catches can be exploited. Training classification models for such datasets requires developing new algorithms relying on the knowledge, at the level of the echogram, either of the presence/absence or of the relative biomass proportion of a given species. Two types of probabilistic classification models are investigated, namely discriminant and generative models. These models provide a straightforward mean for evaluating relative species biomass proportions within echograms.

The proposed approach is evaluated on a dataset of echograms of fish schools acquired in the Bay of Biscay from a 38 kHz single beam echosounder and MOVIES+ software. To perform a quantitative evaluation of the proposed training schemes, multispecific datasets are randomly synthesized from a set of labelled fish schools comprising four species, anchovy, sardine, horse mackerel and blue whiting. School descriptors include bathymetric, morphological and energetic descriptors. This evaluation demonstrates that relevant classification performances can be reached and the analysis of the variances and biases of the associated species biomass estimates is discussed.

6.3 John Simmonds, Mariano Gutierrez, Andres Chipolini, Francois Gerlotto and Arnaud Bertrand

Progress in evaluation of acoustic surveys for Peruvian anchovetta is presented. The work is still in progress, but substantive results have already been achieved. An analysis of time-series of 49 surveys examining some of the major sources of variance through bootstrap is presented, spatial variability in average abundance, and average variance due to acoustic data collection and fishing for length data are combined and considered taken separately. Strong evidence of a mean variance relationship is found and the implications considered. The results from the analysis of survey data are compared with a small number of examples of geostatistical conditional simulations showing how variance from the simulation compares with variance from analysis of the survey data. Some preliminary implications for survey design are presented

6.4 Taina Honkalehto, Patrick Ressler, Rick Towler, Christopher Wilson "Using acoustic data collected by commercial fishing vessels to develop an annual index of abundance for walleye pollock (Theragra chalcogramma) in the eastern Bering Sea"

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Walleye pollock (*Theragra chalcogramma*) are an important component of the eastern Bering Sea (EBS) marine ecosystem and support one of the largest single species commercial fisheries in the world. The EBS pollock population consists of both a midwater and demersal component, which are each monitored by different NOAA assessment surveys – a *biennial* acoustic-trawl (AT) survey conducted aboard a NOAA vessel, which targets the midwater component, and an *annual* bottom trawl (BT) survey conducted aboard two chartered commercial vessels, which targets the demersal component. Annual rather than biennial information on the midwater component of the population would be extremely useful in managing the stock, particularly if the information could be obtained at a relatively modest cost. Thus, the goal of this project is to formulate an *annual* index of abundance for the EBS midwater pollock component, based on acoustic data collected from the commercial vessels used during the BT survey.

This presentation will report on progress made toward the project goal. Formal sampling protocols (http://www.afsc.noaa.gov/RACE/midwater/avo/FVA_protocols.pdf) have been developed to assure that good-quality, quantitative acoustic data were collected from the chartered commercial vessels during the summer 2006 BT survey – the first comprehensive field season. Results of a retrospective study of recent AT surveys have been used to determine the best procedures for classifying pollock backscatter from the BT survey vessels. Customized software was developed and tested to semi-automatically process large volumes of these acoustic data. Lastly, comparative results of the summer 2006 midwater pollock abundance estimates, based on the summer 2006 AT survey (the "gold-standard") and the BT survey, will be presented to evaluate the potential value of the BT survey index in predicting midwater pollock abundance.

6.5 Richard L. O'Driscoll. Mesopelagic backscatter in the Ross Sea, Antarctica

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Acoustic data from New Zealand longline vessels participating in the exploratory fishery for toothfish were used to study the distribution of mesopelagic prey species in the Ross Sea. Total acoustic backscatter in the upper 1000 m and the variety of mark types decreased from north to south. Common marks north of 67° S included a surface layer at less than 50 m depth, schools and layers centred on about 200 m and 400 m depth, and a diffuse deep scattering layer centred at 750 m depth. South of 70º S, average acoustic density was much lower and most of the backscatter was from schools and layers shallower than 100 m. Near bottom marks were associated with areas shallower than 1000 m on the Ross Sea shelf edge. In general, the amount of backscatter observed in the Ross Sea was much lower than that observed in shelf areas off New Zealand. Little direct information is available on the species composition of different mark types in the Ross Sea. However, different marks exhibited different acoustic responses across the three frequencies examined which provided some clues about the likely identity of the key scatterers. Marks shallower than 100 m depth were stronger on 120 kHz than on 38 kHz, and weak on 12 kHz. This type of acoustic response is typical of krill or other large zooplankton. Schools and layers at 200–400 m depth showed a more consistent response across all three frequencies and may have been associated with small fish. This study identified key areas and mark types for further research, including directed sampling, and showed how fishing vessels could be used to opportunistically collect acoustic data for ecosystem studies

6.6 Tim. E. Ryan, Rudy. J. Kloser. Advances and challenges with deep-towed bodies. A review of recent experiences.

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Deeply towed body systems have been used in Australia over the last 15 years to provide quantitative biomass estimates of a commercial fish species, orange roughy (*Hoplostethus atlanticus*). During this time many technical advances have been made. These include geolocation of both vessel and towed body, platform motion monitoring, transducer design, digitisation of the signal within the towed body, signal transmission and system control via optic fibre as well as moving from single to multiple frequencies. This talk will present CSIRO's most recent deep towed body system, MUFTI-2, with the aim of demonstrating the impact of these technical advances in practice. The technical advances are compelling, potentially providing far superior precision and accuracy. However integrating the quantitative results from new systems with well established time-series (vessel mounted acoustics and older towed body systems) is challenging. Calibration is the key but careful review of major assumptions (both old and new) is essential.

6.7 John T. Anderson[1], Candace Rose-Taylor[2], Christopher Lang[1], and Matthew Wilson[3]. Acoustic seabed classification and mapping of capelin spawning beds and migration corridors using single and multibeam acoustic systems

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Demersal capelin (*Mallotus villosus*) spawning sites were discovered recently in 28 to 33 meters of water several kilometres from shore using observational techniques. Acoustic surveys using a BioSonics DT-X 120 kHz dual beam system were done on seven spawning sites and one non-spawning location. Unsupervised seabed classification (QTC IMPACT^{TM}) produced three acoustic classes for six of the spawning locations, one class at the remaining site and two classes at the non-spawning location. Supervised classification of the spawning locations was based on a training data set that consisted of four categories: fine sand, gravel, cobble/boulder and macroalgae. For 1 km^2 areas centred around each of the spawning sites the proportion of the seabed identified as suitable capelin spawning habitat ranged from 25 to 61% and averaged 42%. This indicates that a significant proportion of the seabed may provide suitable offshore capelin spawning habitat in coastal Newfoundland. We concluded that the seabed structure that surrounds the spawning sites is highly variable in surficial sediment and bathymetric structure. Currently, a Simrad EM710 multibeam system is being used to map the seabed geo-morphology as well as capelin spawning migrations into the spawning locations. Seabed imagery is being generated at one to two meters spatial resolution. Capelin spawning migration in 2005 was characterized initially by small, rapidly moving schools migrating in mid-water below the thermocline. As the migration period progressed large schools migrated into the spawning area increasing in volume by an order of magnitude over a five day period. We evaluate the usefulness of these acoustic techniques in capelin ecological and behavioural research

6.8 Ruben Patel, Compression of single pings from the EK60 Scientific echo sounder

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Transmitting acoustic data trough slow communication links requires data compression. In this case we intend to transmit data trough an acoustic underwater link from an Autonomous Underwater vehicle (AUV) to a research vessel. Since there is no handshaking we are not guaranteed that pings are actually transmitted. This transmission protocol forces us to compress each ping individually. In this context we have analyzed different compression algorithms and strategies to find the one witch works best in this regime. The chosen is to make a controlled data reduction and then compress data before transmission

6.9 Kohji Iida[1], Yong Tang[2], Tohru Mukai[1], and Yasushi Nishimori[3]. Measurement of fish school volume by multi-beam sonar

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A multi-beam sonar provides information on the shape and movements of a fish school using a beam scan, and cruise or turning scans in wide area. It enables to measure not only the volume of a fish school, but also the abundance of fish school. Conversely, the disadvantages of sonar are that it has a narrow dynamic range, there is little research on using the 3-dimensional average target strength (T_S) to estimate fish abundance by measuring echo integration, it is influenced by reverberation of the sea surface and bottom, and sound waves are refracted when they pass through water layers at different temperatures.

To overcome these problems, we combined quantitative echo sounder and GIS technology, and used a high-performance multi-beam sonar to measure fish schools and the sea bottom quantitatively. Our ultimate goal is to develop the next generation of quantitative sonar.

6.10 Hector Pena, Atle Totland and Lene Vestrheim. Real time scientific acoustic data collection from the office

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The system allows the remote control of a dedicated PC onboard a commercial fishing boat using a satellite connection with the required authorization along all the firewalls involved from the vessel to IMR. In this PC are installed the software to run the scientific echo sounder ER60 with 5 frequencies and the high frequency multibeam fishery sonar (Simrad SH80), with a scientific output. This configuration allows a remote control of all the main operational parameters for data collection for both echo sounder and sonar together with the capability to start and stop the storage of raw data in external hard drives onboard the vessel. Also, additional data collection was implemented; navigation information from the electronic navigation chart (with movies storing capabilities), and the display of the closed circuit television installed onboard. To analyze the stored data, the external hard drives are retrieved from the vessel, once arrived to port.

6.11 Andrew S. Brierley[1], Michael N. Dawson[2], and William G. Sanderson[3]. An acoustic survey of near-surface jellyfish in a tropical marine lake

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The Golden Jellyfish *Mastigias papua etpisoni* population in 'Jellyfish Lake', Palau, is a major tourist attraction, with more than 70,000 people annually visiting to snorkel, and provides a natural ecological experiment. Net-based monitoring studies have revealed very large year-to-year fluctuations in jellyfish abundance. As well as being of major ecological interest, these fluctuations have consequences for Palauan tourist revenue and require to be understood. The abundance fluctuations may be linked to ENSO-related temperature variations: Golden Jellyfish, like corals, contain symbiotic zooxanthellae that may be ejected when the jellyfish hosts are stressed at high temperatures (cf. coral bleaching). Present monitoring, based on repeated vertical hauls of plankton-nets, is labour-intensive, invasive, and can be subject to small sample sizes and high variance when population sizes are large: therefore it would be desirable to establish an automated monitoring programme. We made acoustic observations of jellyfish (at 120 kHz) in an effort to determine if moored acoustic instruments might provide a viable automated monitoring approach. The jellyfish typically occupy the upper 6 meters of the watercolumn (the illuminated epipelagic zone in which the zooxanthellae can photosynthesise), requiring an upward-looking acoustic survey. Here we describe the deployment of the echosounder system, discuss deadzone-related issues arising from sampling organisms in the very-near-surface zone, report the apparent TS of *Mastigias* at 120 kHZ, and present some peculiar (to us at least) observations on the performance of the EK60 at very short pulse lengths and variations in calibration coefficients between pulse lengths.

6.12 Martin J. Cox[1,2], David L. Borchers[2] and Andrew S. Brierley[1] "A statistical framework for biomass estimation using a multi-beam echosounder"

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Much research conducted using multi-beam echosounders has thus far concentrated on exploring the morphology and internal structure of pelagic aggregations in three-dimensions. Using a two-dimensional (radial distance and detection angle) distance sampling statistical framework we hope to provide a technique that could form the basis for biomass estimation based on multi-beam observations. In the first part of the research a detection function and depth distribution from a survey of Antarctic krill (Euphausia superba) at Cape Shirreff, Livingston Island was estimated.

The change in the detectability of pelagic aggregations caused by variation in the across-swath beam sensitivity was incorporated within this model using a hazard rate form. The depth distribution and detection functions for krill, incorporating variation in angular detectability, were jointly estimated, by maximum likelihood. The detection function was modelled as half-normal and the depth distribution function as normal or log-normal. Using these estimates the number of swarms and associated variance estimates were calculated for the Cape Shirreff survey area.

We will discuss the advantages and limitations of the method, and how it might be developed further in future.

6.13 J. Michael Jech. Addressing differences in abundance estimates from acoustic and bottom-trawl surveys: Atlantic herring in the Gulf of Maine

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Acoustic estimates of Atlantic herring (*Clupea harengus*) population abundance in the Gulf of Maine derived from systematic acoustic surveys differ from population abundance trends derived from randomly-stratified bottom-trawl surveys conducted during the autumn spawning season. The trends from both surveys were similar until 2002, when the acoustic survey indicated a substantial decrease whereas the bottom-trawl survey indicated a relatively stable abundance. Differences in sampling methods, areal extent and timing as well as changes in herring spawning behaviour and timing, spatial distribution and environmental factors are potential factors in divergent population trends. Acoustic data (38-kHz Simrad EK500 and EK60) collected during the bottom-trawl surveys are compared to bottom-trawl catch data and data collected during acoustic surveys (12 or 18-, 38- and 120-kHz Simrad EK500) to address these factors. Initial analyses are focused on the vertical distribution, areal extent and temporal changes in herring distribution. Results of these analyses may influence how our herring surveys are conducted and further improve our ability to estimate herring population abundance.

6.14 Marshall Hall[1] and Rudy Kloser[2]. Estimating low frequency sonar detection range of fish near Forestier Peninsula, Tasmania

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An acoustic method that greatly increase the sampling to continental shelf scale using the water column as a wave guide shows great promise (Makris *et al.*, 2006). This low frequency (390 to 440 Hz) method is reported to provide quantitative and qualitative measurements of fish populations at an omnidirectional range of ~25 km. This greatly improves the imaging of previous systems and could provide an independent estimate of large scale fish populations or

immediately provide school location and behaviour information that would greatly assist traditional acoustic assessment methods. An evaluation of this technology and its potential application to specific ecosystem based approaches to fisheries management in the Australian environment is warranted. In the Australian situation this new technology could be applied to a number of fisheries (e.g. Pilchards, SBT and Red Bait) depending on the oceanic and seabed environment. We present the initial analyses of the expected range performance of such a system at a specific site.

6.15 Yvan Simard[1,2], Delphine Benoit[3], Louis Fortier[3], Catherine Bédard[1], and Xavier Mouy[1]. Acoustics, an effective suite of tools to explore the warming Arctic ocean.

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Since the launching of the NSERC NCE Arctic Net multidisciplinary research program in 2004, multifrequency echosounding and long-term series of passive acoustic recordings contribute to study the impact of climate change on Canadian Arctic ecosystem. Examples are presented to show the interest of these effective tools to sound the poorly known Arctic Ocean. During winter 2004, the CCGS Amundsen research icebreaker was iced-in in Franklin Bay until the ice break-up in June. The onboard multifrequency EK60 then recorded the most extraordinary aggregation of overwintering arctic cod, the key forage fish of the Arctic. The fish density in the lower half of the 225-m deep water column reached so high values that the top of the fish layer triggered the EK60 bottom detection algorithm. It appeared that the hydrodynamic circulation drove the fish towards the bay where they accumulate as result of their depth-keeping behaviour. Long-term passive recordings from AURAL autonomous hydrophones allowed tracking the habitat utilisation over the annual cycle at the mooring stations. Unexpected whale vocalisations in the middle of the winter revealed possible changes in the occupation of space in response to changing ice conditions. The occurrence of sounds from soniferous fish at some periods may indicate their breeding season. The Arctic ocean is one of the last frontiers to explore on earth. Its remoteness and harsh environment conditions ask for several other effective remote sensing and sampling gears to improve our limited knowledge on this rapidly changing large marine ecosystem of the planet.

6.16 Nils Olav Handegard[1] and David Demer[2]. Designing an Ocean Mid-trophic Automatic Acoustic Sampler

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There is an initiative to develop a novel tool for large-scale monitoring of mid-trophic level prey organisms, using autonomous buoys equipped with multi-frequency echosounders and satellite communication. The ambition is for a ubiquitous bio-sampling adjunct to hydrographic drifters, using the ARGOS satellite system. The initiative is encouraged by the Global Ocean Ecosystem Dynamics (GLOBEC) under the CLimate Impacts on Oceanic TOp Predators (CLIOTOP) initiative, and funding is presently being sought under the EU-FP7 program. We present the general framework as outlined by the CLIOTOP project, and the particular design as presented in the FP7 funding application.

In the first phase of the project, we will develop the prototype Mid-trophic Autonomous Acoustic Sampler drifter-buoy (MAAS-drifter), including: the drifter-buoy, the echo sounder

module, data processing techniques, and infrastructure to handle data and glean information for ecosystem-based investigations. The goal of the EU FP7 proposal is to set up a test network of approximately six buoys, demonstrating its potential as an addition to ocean observing systems. For example under EU FP7 or NSF, it could result in world-wide augmentation of the existing Argos-drifter program.

Our vision is that a version of the MAAS-drifter will become a standard tool for real-time global observations of marine ecosystems and a vial part of international programs like GLOBEC and Census of Marine life. The goal of this presentation is to inform the FAST community about the activity, and to link persons and institutions with similar ambitions.

6.17 Subgroup discussion session on Topic 2: "Survey techniques for epi-benthic and shallow water species"

The main group was split into 6 subgroups to discuss two key questions about the topic session being:

- What are the key issues in implementing the ecosystem approach for acoustic surveys/observations?
- Identify the key research needs to address the identified issues.

The groups reported back on these two questions with the main points recorded. On the first question it is clear that there is a need to focus our efforts over a range of scales and trophic levels. The focus should be on integration/ multidisciplinary approach to data collection with clearly defined objectives. A clear example of the trade offs with this need to focus was outline by John (6.3) who demonstrated the loss of precision in different survey designs that have competing objectives. To focus there needs to be an assessment of the monitoring objectives defining the key components of the ecosystem to be monitored how the monitoring will be used as an indicator or within a fisheries assessment/ecological model and the necessary precision required. This assessment of monitoring requirements also needs to factor the cost and benefit of the monitoring and the allocation of appropriate resources so that there is not just a call for doing more monitoring with less resources. Whilst there is a need for a bottom up design from researchers to advise what can be measured there needs to be a top down (managers and key stake holders) input to commit to the designs and monitoring framework to allocate and focus the resources. In summary the groups concluded that the key issues were:

- A common understanding between scientists and stakeholders of how to implement the ecosystem approach.
- Commitment to the ecosystem approach and the associated monitoring framework.
- Ability to reduce the data overload to producing information and then gaining knowledge.
- Continued hypothesis testing of ecological processes.
- Integration of the data and monitoring strategy into hindcast and forecast models.

The key research needs identified to address the issues raised above were automation of data collection and processing with quality assurance and verification of measurements. Linkage of the monitoring strategy with the model developments is necessary so that data collections can be readily integrated with a knowledge of precision and accuracy preserved.

It should be emphasised that acoustics is the only technology that can address ecological questions such as population dynamics, habitat mapping, substrate classification, and spatial-temporal interactions throughout the entire water column (pelagic zone) including key forage species. Therefore there is a need for the WGFAST to focus on the issues raised in this section

in coming years to assist ICES in the goal of applying an ecosystem approach to fisheries management.

7 Topic 3: Species identification techniques (e.g. Acoustic, optical and nets) for multispecies assessments, bycatch reduction and automated data processing

7.1 Caristona I.H. Anderson[1], John K. Horne[1], and John Boyle[2]. Challenges associated with applying probabilistic classification to multi-frequency acoustic data

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A robust probabilistic classification technique, using expectation maximization of finite mixture models, was developed to analyze multi-frequency fisheries acoustic data. The number of clusters is chosen using the Bayesian Information Criterion (BIC). Likelihood values are approximated using maximum probabilities of cluster membership from each sample (i.e. pixel). Posterior probabilities are also used to classify each sample.

This approach has been extended by fitting new data to existing clusters for automated processing, and is being refined to improve probability estimates by incorporating probability density functions (PDF). Other fundamental methodological issues being examined include: spatial coincidence of samples within and between pings, choice of metric used to quantify the match between models and data.

7.2 Toby Jarvis and Natalie Kelly. Towards an objective and automated system for the post-processing and analysis of echosounder data in studies of aquatic ecosystems

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Echosounder data are commonly used for single-species biomass estimates, and are being increasingly used within whole-ecosystem studies. In developing and implementing protocols for achieving one or both of these objectives in a timely way, we have endeavoured to create a flexible and holistic processing system that is objective and automated wherever possible. We wish to take this opportunity to present our system to WG-FAST for their expert opinion. In brief, our system encompasses the following steps: archiving of raw survey data; creation of survey metadata files; creation and pre-loading of Echoview files from a pre-defined template; scrutiny of Echoview files and documentation of key post-processing settings; export of user-defined variables from Echoview; creation and loading of Microsoft Access databases with post-processed echosounder and ancillary data; summarisation of data into distance-based bins (EDSUs); additional analyses as required. Many of these steps are script based, using either VBScript or R, enabling parameters to be changed and analyses to be easily re-run. The overall aim is to contribute to a toolbox of procedures that can be shared and developed within the scientific community.

7.3 Sophie Fielding[1], Martin Collins[1], Inigo Everson[2], Alex Reid[3]. "Improving target identification of mackerel icefish using commercial and scientific acoustic observations"

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A combination of commercial and scientific acoustic data, collected during both pelagic and benthic trawls, is used to devise key target description parameters for the commercially fished mackerel icefish *Champsocephalus gunnari*.

ES60 38 kHz echosounder data, collected from the fishing vessel New Polar, during January 2007 indicate that icefish on the South Georgia shelf were diffusely present in the bottom 100 m of the water column during night-time, whereas in the daytime they were either concentrated close to the sea bottom or schooling within the water column.

EK500 38 and 120 kHz data, collected during the 2006 South Georgian groundfish survey from the MV Dorada, show that the 120-38 dB difference for icefish targets is in the same range as that for Antarctic krill. Swarm/school characteristics, including threshholding and the shape of the dB difference frequency distributions were required to delineate between krill and icefish targets. Catch weights of icefish, when representing >80% of total catch weight, were compared with acoustic data within the trawl vicinity to create tentative TS to icefish size relationships for both 120 and 38 kHz frequencies. The different shapes of these relationships are discussed with reference to other non-swim-bladdered fish and the likely main acoustic scattering mechanisms of the icefish.

7.4 Rolf J. Korneliussen. Experiences using LSSS on abundance estimation surveys

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Institute of Marine Research (IMR) is responsible for research and monitoring of marine resources in Norwegian waters. To fulfil these tasks, IMR collects acoustic survey data from large ocean areas, and need to process these data to the best possible quality for abundance estimation. Due to the extensive field activities from 2000 ship days, most of the data is processed and scrutinized at sea. From January 2007, the Large Scale Survey System (LSSS) has replaced the Bergen Echo Integrator (BEI) as the primary system for processing acoustic data to be used in abundance estimation of fish stocks. LSSS is used to scrutinize raw echo sounder data at six frequencies. Experiences from the first production surveys are revealed and discussed, including which adjustments to LSSS these experiences have led to. LSSS has a dynamic and scalable design that is independent of computer platforms. The workflow of LSSS has evolved from BEI and previous systems to achieve optimal quality of the scrutinized data achievable within two hours of scrutinizing per day. Much of the data processing in LSSS are done in real-time prior to the scrutinizing session itself, so that school detection, noise removal, data convolution, data filtering, generation of synthetic multi-frequency echograms, species identification and inversion of multi-frequency data to estimate type and size of zooplankton are available to the interpretation team when the acoustic data are scrutinized.

7.5 Laurent Berger[1], Valerie Mazauric[1], and Verena Trenkel[2]. "Description of the new acoustic platform of FRV "*Thalassa*" to address the challenges of biomass estimate of the mixed pelagic community in the bay of Biscay"

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Multibeam echo-sounders and sonars are increasingly used in fisheries acoustics due to their ability to sample a much larger area than traditional vertical echo-sounders. However the quality of the data of existing multibeam echo-sounders is not comparable with classical single beam echo-sounders used for biomass estimation. In order to solve this problem, Ifremer and Simrad AS have started in 2003 the development of the multibeam echo-sounder ME70 which improves the quality of the data for biomass estimates.

The system was installed on board FRV "Thalassa" in September 2005 and this new equipment belongs to the same range of equipments than traditional single beam vertical echosounder currently used for biomass estimates. With a larger volume sampled at a higher resolution, it will be complementary of broadband multifrequency transducers currently used for species identification. It will also contribute to study school structure and school behaviour.

Experience gained in the past two years during the validation at sea of ME70 enables to define a strategy for coherent settings of these two sets of equipments for improved data collection to address different challenges.

This strategy will be presented and illustrated with first data. The HERMES software (Hydroacoustics Efficient Recording Module for Echo-Sounders) developed for the setting of the sounders, the performance prediction and qualified data acquisition will be presented.

7.6 Valerie Mazauric[1], Laurent Berger[1], and Verena Trenkel[2]. "Preliminary results with the acoustic platform of FRV "*Thalassa*" combining single vertical echo-sounders and the new scientific multibeam echo-sounder ME70"

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The challenge for improving biomass estimates of multi-species community composed of small schools in the bay of Biscay has led Ifremer to develop in cooperation with Simrad (Norway) a new calibrated multi-beam echo-sounder dedicated to fishery research (ME70). The system, complementary with single beam echo-sounders, is under validation at sea on board the FRV "Thalassa" since September 2005, and data collected during this time period demonstrate the potential of this new and innovative tool in biomass assessment.

Various types of data collected at the same time with single and multi-beam systems are presented: Herring aggregates in shallow water, tracks of multiple single targets distributed in the 3D explored volume, and schools of small pelagic species (horse-mackerel, sardine, mackerel…) along the continental slope of the Bay of Biscay.

The contribution of this multi-beam echo-sounder in the analysis of school structure and school behaviour is demonstrated with data collected in shallow water showing vessel avoidance. The refined angular resolution in a wider sampled volume combined with the beam

stabilisation (roll and pitch) clearly show the improvement gained with the ME70 in comparison with traditional single beam tools.

7.7 Verena M. Trenkel[1], Carla Scalabrin[2], Laurent Berger[2] and Valérie Mazauric[2]. Impact of beam angle on shoal structure and energy measurements: comparison of simulation results with data from new multibeam echosounder (ME70)

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Past attempts for species identification have generally been based on using geometric, energetic and geographic shoal descriptors. Two factors might impact the precision of the estimates of the first two categories of descriptors: shoal size relative to beam width and reaction behaviour. As a consequence species specific differences in shoal descriptors might be drowned in the estimation noise. Simulations indicate that estimates of acoustic energy (σ_{ag}) of small shoals might be expected to be underestimated if shoal size is small compared to the beam width. For example, the cumulated energy of a 5 m long shoal located at 200 m depth if detected by a 7° beam is expected to be underestimated by about 8 dB. Similarly, shoal size, but also the perimeter etc. will be overestimated for small shoals. Using data from a recent cruise in the Bay of Biscay that employed both traditional 7° single beam echo-sounders (ER60) and the new multibeam echo-sounder (ME70) with reduced beam angles, the impact of beam angle on shoal geometric and energetic shoal parameters for small shoals is studied and confronted to the theoretical expectations.

7.8 Kyoung-Hoon LEE[1], Heui-Chun AN[1], Tohru MUKAI[2], Kohji IIDA[2]. Classification of 2 species by a measurement of swimming speed

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There are such various techniques as a multi frequency method, in situ TS characteristics, and digital imaging processing methods for species identification techniques. Acoustic Doppler Current Profiler for determining simultaneous current fields has been used to observe the swimming speed and behaviour patterns of pelagic fish's shoal in natural conditions.

This study was aimed to examine the classification method by estimating the swimming velocity of 2 species fish shoal, Pacific saury (*Cololabis saira*) and lanternfishes (*Diaphus theta*) with ADCP (153.6kHz) and scientific echosounder (38, 200kHz). To calculate their actual swimming speed, each stratified bins must be considered between the mean surrounding current velocity 3-D vectors and their mean swimming velocity vectors.

Results showed that the averaged 3-D swimming velocity of Pacific saury' shoal was calculated to be 91.3cm/s, while that of lanternfishes' shoal was 28.1cm/s. In addition, they were estimated to be 4.19 times and 4.26 times relative to body length (BL/s), respectively. Based on these results, it was expected that this swimming velocity information would be one of useful species identification methods for various fishes distributed in the survey area

7.9 Yvan Simard[1,2], and Marc Sourisseau[3]. Modulation of krill target strength and net catches by diel vertical migration: comparisons of vertical echosounding with intensive net sampling

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Multiple gears were used to track the fine dynamics of krill diel vertical migration (DVM) in the persistent krill aggregation at the head of the Laurentian channel in the St. Lawrence Estuary. Multifrequency acoustics (38, 120 and 200 kHz) and high-resolution stratified Bioness samples (1 tow h^{-1}) with measurements of chlorophyll content of krill stomachs were used to follow the DVM mass transfers and individual interchanges over a 72-h time-series. In daytime, the krill scattering layer (SL) was located between 90 and 130 m in the lower part of the 150-m deep water column at the study site. The krill SL showed typical dusk and dawn vertical mass transfers, synchronised by light intensity, for feeding into the phytoplankton-rich surface layer during night. However, a large proportion of the krill did not stay in surface for the whole night, but rapidly migrated down to reformed a deep SL or digest at intermediate depths before returning to the surface layer a few h before dawn descent. This diel dynamics affected both the krill average TS and catches as indicated by the different day and night slopes of the Sv (backscattering volume strength) vs Bioness catch regressions. Results support that daytime krill tilt angle is near horizontal but nocturnal tilt angle distribution is much more variable, with possible narrow distributions around the heading directions at twilight. This diel pattern should be considered for krill biomass estimation in around-the-clock surveys as well as for acoustic classification from multifrequency TS models.

7.10 Hector Pena. Acoustic identification of Horse mackerel (*Trachurus trachurus*) using multi-frequency echo sounder

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In October 2006, acoustical data from schools of horse mackerel (*Trachurus trachurus*) was collected in the Norwegian Sea, using a Simrad EK60 echo sounder equipped with 5 frequencies (18, 38, 70, 120 and 200 kHz). The transducers are installed in a 2.5 m protruding keel onboard a Norwegian commercial vessel and their calibration were done by standard methods before the data collection. Frequency response was calculated as the ratio between the S_A of each frequency in relation of the sum of the S_A of all frequencies for each school (Ona, 1999). Together with the data used for acoustic identification of sandeel (*Ammodytes marinus*) (Mohammed, 2006), a discriminant analysis was done using the frequency response for 11 schools. Results showed that 100% of horse mackerel schools were classified correctly and only 1 herring school was classified as horse mackerel. Commercial purse seine catches for species identification verified that the schools selected in this study corresponds to horse mackerel.

7.11 Julian M. Burgos[1] and John K. Horne[1]. Characterizing and classifying spatial distributions of nekton

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Familiar distribution patterns are often found when viewing or scrutinizing echograms. Echo-trace classification (ETC), the detection of aggregations within echograms, attempts to describe and analyze spatial distributions of pelagic organisms. This approach is appropriate for aggregations with well-defined boundaries, but is limited when describing demersal or diffuse pelagic layers. As an alternative to ETC metrics, we used landscape indices to quantify and characterize spatial heterogeneity walleye pollock (*Theragra chalcogramma*) density distributions. Survey transects were divided into 1 nm segments and a series of 20 landscape metrics were calculated to measure occupancy, patchiness, size distribution of patches, distances among patches, acoustic density, and vertical location and dispersion. Factor analysis parsimoniously described the metric set using four factors: spatial occupancy,

aggregation level, pixel acoustic density, and vertical distribution. Correlations among all factors were significant with the exception of vertical distribution and spatial occupancy. All factors were spatially autocorrelated. An echogram classification typology was formed using 12 clusters identified in a model-based cluster analysis. Spatial patterns were consistent within echogram types, but overlapping patterns suggest that walleye pollock density distributions are continuous rather than categorical.

7.12 Discussion on Topic 3: "Species identification techniquest (e.g. acoustic, optical and nets) for multispecies assessments, bycatch reduction and automated data processing"

This session was motivated and directed by the ICES requirement to move to an ecosystem approach for marine management. The previous section (6.17) discussed the need to focus our observation efforts on the key species in the ecosystem. Acoustics methods are a unique tool to observe these key species simultaneously when there are robust species identification methods. The session highlighted the necessary moves we need to make in realising objective species classification using probabilistic and deterministic methods (7.1, 7.11). Of particular interest was the incorporation of spatial and temporal information in the classification method (7.11).

As outlined in Section 6.17 implementing the monitoring requirements for the ecosystem approach requires us to reduce the data overload to produce information that can be translated to knowledge. Steps in this direction were presented with new software using automated and expert based methods (7.2 and 7.4). Automation of acoustic data into dominant acoustic scattering groups will continue but it many situations it is expected that experts will still be required for final quality assurance. We were reminded that we still have a long way to go to understand the variability and uncertainty associated with species identification methods. It remains a challenge to incorporate behaviour and spatial and temporal variability into the automated classification systems.

To advance our ability to remotely classify species new technologies (ME70) have been manufactured which allow us to test established methods through hypothesis testing (7.5, 7.6). The data produced by the new multibeam (ME70) is just starting to be analysed and after more refinements will provide unique data sets to test various school classification hypotheses (7.7). We were also reminded of the need to explore existing technologies that still have great potential when deployed from moorings or operated from commercial vessels and integrated with other physical and biological data (7.3, 7.9, and 7.10). The ability to use ADCP information to collect both, water current, swimming speed and backscatter information gives new insights into ecosystem functioning and species behaviour. This information is critical to improve our knowledge of species identification, species biomass and providing the conceptual framework for development of ecosystem models (7.8 and 7.9).

Many of the species identification methods used thus far have worked well in specific environments with a limited number of species/species groups or acoustic scattering groups. A clear direction of WGFAST will be to improve our methodology on key trophically important species/species groups within the ecosystem that can be reliably measured with acoustics and provide quantitative metrics with measured uncertainty that can readily be incorporated into fisheries and ecosystem models.

8 Topic 4: Target strength modelling and measurement

8.1 David A. Demer and Josiah Renfree. Variations in echosounder transducer performance versus water temperature

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Electro-acoustic transducers are central components of multi-frequency echosounders used in remote target identification and acoustical surveys for fish and zooplankton. While these transducers, constructed from multiple materials such as piezoelectric ceramics, polyurethanes, and metals are designed to be insensitive to performance changes versus time, pressure, and temperature, it has been shown that appreciable changes in echosounder system gains result from shifts in transducer resonant frequency, quality factor, electrical impedance, and efficiency versus water temperature. Because it is standard practice to calibrate echosounder systems in one environment and apply the resulting gains to interpret data collected over a range of sea temperatures, the survey results may be biased. The bias may be different for estimates derived from each echosounder frequency. The magnitudes of these frequency-dependent biases depend upon the temperature-dependent performances of the survey transducers, and the range of temperatures encountered during the survey. Here, the performance has been measured for ten commonly used survey transducers versus water temperature ranging from approximately 1 to 18 ºC, using four different techniques. Temperature-dependent system gain corrections are proposed which can be used to minimize bias in multi-frequency target identifications and biomass estimations

8.2 Sascha M.M. Fässler[1,2] and Paul G. Fernandes[1]. Using a simple scattering model to investigate target strength variability in physostomous fish

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A simple backscattering model, representing the swimbladder and fish body as geometric shapes, was used to investigate the effects of tilt, frequency, shape, and water depth on target strength in Atlantic herring, a physostomous fish. Special emphasis is given to the differences in backscatter when using either a prolate spheroid or ellipsoid to represent the fluid-filled fish body component. Additionally, a range of surface swimbladder volumes were used to examine depth dependent changes in backscatter caused by the bladder contraction according to Boyle's law. Differences between dorsal aspect and tilt-angle averaged backscatter were investigated for both the body and the swimbladder component. Changes in depth dependent relative contributions of swimbladder and body components to total backscatter are presented. Generally, the ellipsoid gave higher backscattering values when compared to a spheroid of the same volume. Averaging over tilt-angle resulted in reduced amplitudes of fish body backscatter as a function of frequency and a decrease in backscatter with increasing frequency was observed for the swimbladder. Following the results of the sensitivity analysis, an alternative length and depth based target strength relationship is proposed. This target strength relationship is compared to previous versions available for Atlantic herring. Finally, ideas to obtain corroborative empirical data from in situ measurements during routine surveys are outlined.

8.3 Gavin Macaulay[1], Rudy Kloser[2]. Acoustic models of orange roughy at 38 and 120 kHz. Is what we see real?

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An acoustic scattering model has been applied to two Australian orange roughy at 38 and 120 kHz and a range of tilt angles from –40 to +40°. Estimates of the target strength at these angles have been calculated and are broadly in line with in-situ estimates. The models indicate that the target strength at 120 kHz is considerably higher than at 38 kHz, which is consistent with the in-situ estimates. Images of the scattered wave field at various stages in the scattering event are presented, and aspects of the field discussed in relation to the scattering processes.

8.4 Geir Pedersen, Olav Rune Godø, and Egil Ona. Uncertainty in *in situ* target strength measurement of blue whiting (*Micromesistius poutassou*)

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In situ target strength measurements of blue whiting were performed during the annual survey of the main spawning areas of blue whiting west of the British Isles from 2003–2007. Additional data has also been collected on a separate methods cruise along the Norwegian coast. The measurements were performed using Simrad EK60 echosounders with pressure stable transducers (38 and 120 kHz). In order to obtain high quality target strength data several different submersible measurement platforms were used in these experiments, ranging from simply a stationary submersed transducer to a large moving towed body. Potential platform effects on the results from these experiments are considered in terms of the platform influence on the fish, in addition to depth effects on fish and measurement system. The effect on the results caused by different platform stability as well as day/night difference in the observed target strength of blue whiting is also considered. The goal is to quantify the uncertainty related to the target strength of blue whiting and to obtain a new target strength relationship for this species for use in stock assessment.

8.5 Roar Joergensen and Kjell Olsen. Effects of different tilt-angle distribution and ambient pressure on the acoustic target strength of capelin (*Mallotus villosus*)

Norwegian College of Fishery Science, University of Tromsoe, N-9037 Tromsø, Norway

Acoustic backscattering characteristics of capelin when swimming at different depth have been investigated by use of a submersible experimental rig with a 38-kHz split-beam echo sounder system. The experimental system made it possible to separate the effects of swimbladder compression at various depths (5. 20 and 40m) from the effect of changes in swimming behaviour (tilt angle). The experiments demonstrate that the acoustic target strength of capelin depends both of the ambient pressure and the actual tilt angle distribution. The findings indicate that differences in vertical distribution of capelin in different areas and seasons may significantly influence absolute acoustic estimates of stock abundance of capelin. It is recommended that a depth dependent function should be included in the TS – fish length equation used for capelin.

8.6 Panel discussion on Topic 4: "Target strength modelling and measurement" led by Gavin Macaulay and John Horne

There were four presentations. Three were concerned with target strength and one with potential variations in echo sounder calibration accuracy.

David Demer (8.1) reported on an experiment to investigate the effect of water temperature on echosounder transducer characteristics, and hence the effect on echosounder calibration. Significant changes were observed, with no consistent trend across transducer type or frequency. This effect can be important if, for example, an echosounder was calibrated in temperate waters but then used in polar regions (this is of particular relevance, with several nations planning to do acoustic work in polar regions as part of the International Polar Year). The importance of quantifying all possible sources of calibration variability was discussed.

Sascha Fassler (8.2) reported on an investigation into how various acoustic scattering models (of gas-filled swimbladders) resulted in different target strength estimates, and also the effect of varying fish depth and tilt angle on the target strength. Considerable variation was observed.

Gavin Macaulay (8.3) reported on a comparison between observed differences in S_v at 38 and 120 kHz from suspected orange roughy aggregations, and a scattering model of orange roughy at those frequencies. The model results were consistent with the in-situ data and give more confidence for using the differential scattering as a means to identify orange roughy aggregations.

Geir Pedersen (8.4) provided an overview of recent efforts to collect in-situ target strength data from blue whiting from Norwegian vessels was presented. Increasingly sophisticated deployments of echosounders have been used, leading to improved in-situ target strength data quality. No analysis of the target strength data were presented at this time, but the work should lead to an updated length to TS relationship for blue whiting.

The key issues arising from these presentations and the following panel discussion including a contribution by Kjell Olsen (8.5) were target identification, the need to understand how fish behaviour contributes to target strength variability, and the need to be aware of all sources of variability in acoustic system calibrations. These issues are not new, and are the subject of many ongoing research programmes. The challenges to the fisheries acoustics community is to continue to increase our understanding of how fish scatter sound and to use this to reduce issues with target identification, and to also more fully understand target strength variability for species of interest. Continued development of more sophisticated observing equipment (such as autonomous echosounders and optical instruments) is required to address the key issues.

Synthesis of key issues by John Horne:

- We are at the point where we need imaging at depth
- We need truly controlled ex-situ measures at depth
- Assumed neutral buoyancy for all fish needs to be investigated
- Amazed at the complexity of scattering when the physics meets the biology
- Require a physiologist to look at what is happening to complete the picture

In summary acoustic target strength of fish is complicated and that even after many years of research: we are yet to fully understand the variability inherent in acoustic scattering from biological objects. Incorporating target strength uncertainty into acoustic biomass estimates was seen as an important part of accommodating and recognising the natural variability in fish target strength.

9 Review of the reports of the Study and Planning Groups

9.1 Report of the Study Group on Fisheries Optical Technologies (SGFOT)

The Study Group on Fisheries Optical Technologies (SGFOT) held its first meeting at the Crowne Plaza Dublin Airport in Dublin, Ireland from 21–22 April 2007. Eirik Tenningen (Norway) was Chair and Terje Torkelsen (Norway) was Rapporteur. There were 19 participants from Australia, Canada, Denmark, New Zealand, Norway, Portugal, Sweden, UK and USA.

Based on the Terms of Reference, the outline for an *ICES Cooperative Research Report* was agreed and authors for the different sections suggested. The chapter headings are:

- Introduction
- Optical Technologies
- Integration
- Data Processing
- Application
- Recommendations
- Glossary
- Suppliers
- References

There is a need for expertise from outside the group and possible linkages were discussed, WGFTFB in particular. To get a better overview of the optical technologies currently used by the involved institutions, their respective members will submit a national technology review to the group before 20 May 2007. Terms of Reference for 2008 and recommendations are given below.

SGFOT will report by 14 May 2007 for the attention of the Fisheries Technology Committee.

9.2 Report of the Planning Group on the HAC common data exchange format (PGHAC)

Laurent Berger (France) Chair of PGHAC presented an update of activities of the PGHAC and future work for 2007. PGHAC has worked by correspondence to achieve the following terms of reference:

a) co-ordinate the further development of the HAC standard data exchange format;
b) provide information on the changes in the format and its evolution;
c) share information between manufacturers and users on the way acoustic data are processed and stored;
d) review the final version of tuples for multi-beam echosounders and support first data exchanges;
e) review the final version of a tuple for acoustic trawl geometry instruments and support its first uses.

Progress on these terms of reference for 2006 was presented with the following key points:

- No new development of tuples in 2006.
- The final versions of MBES tuples (220, 2200, 2210) and trawl geometry tuple (50) were adopted.
- The current version of HAC format is described in ICES CRR 278 and available at: http://www.ices.dk/pubs/crr/crr278/crr278.pdf.

- The final version of multibeam tuples and geometry tuples will be made available in PHAC report, the HAC format document will be updated to keep a unique document for the description of the format.
- a new version of ER60 will be made available in the second quarter of 2007, small adjustments are requested to Simrad for current HAC output
- DFO can make its tool HacView available to the community members who want to deal with HAC format. This tool enables the user to load a HAC file check its validity in terms of structure and check numerically its content tuple by tuple.

Next year (2007) it is not envisaged that the format of HAC will be changed and PGHAC will focus on term of reference c), share information between manufacturers and users on the way acoustic data are processed and stored. It should be emphasized that the HAC format is a good solution for merging EK60 and ME70 data in a unique file for later easier post processing as these two equipments appear to be complementary.

9.3 Report of the Study group on Fish Avoidance of Research Vessels (SGFARV)

The Study Group on Fish Avoidance of Research Vessels (SGFARV) held its first meeting at the Crowne Plaza Dublin Airport in Dublin, Ireland from 28–29 April 2007. Francois Gerlotto (France) was Chair and Emma Jones (UK) was Rapporteur. There were 14 participants from six countries.

A proposal for defining the scope of the SG to be used as a first draft of the CRR plan was discussed. The revised proposal is given below. The SG agreed on changing the title of the future CRR as “Vessel induced fish behaviour”. Indeed there are several effects to fish, from attraction to repulsion at various levels (from "precautionary avoidance" to fleeing), the avoidance being the sum of these different components.

The draft chapter headings are:

- State of the art (vessel and fish) on the effect of noise reduced vessels and on fish hearing
- The platform
- The environment (surrounding)
- The fish behaviour
- The fish physiology
- Experiments:
- Results / Recommendations

As not all the participants of SGFARV could be present at the meeting (including the Co-Chair Dr Julia Parrish), it was agreed that the report would be disseminated to all the members for revision and input. A draft agenda was defined for the activities of SGFARV in 2007-2008.

- 30 May report delivered to everybody
- 1 July input and revision of report by SG members;
- Mid July: presentation of draft of CRR structure by Co-Chairs and list of non-CRR activities
- Mid-July to mid September: discussion by correspondence on CRR structure
- End September: approval of CRR structure and agreement for involvement of authors (or participants) and distribution of contributing author names
- 15 May: delivery of contribution from authors to SG members
- 21–22 June: second meeting FARV

The next meeting will take place at Bergen, Norway, before or after the symposium on fisheries acoustics (SEAFACTs). Two options are submitted to the WGFAST Chair with the best option (for SGFARV members) being after the symposium: Saturday 21s^{t} and Sunday 22nd June, 2008.

9.4 A tribute to Ole Mathisen by John Horne and Vidar Wespestad

Ole Alfred Mathisen died 12 March 2007 at the age of 88. He was born in Oslo, Norway on 9 February 1919 and studied Zoology at the University of Oslo. During World War II he served in the Norwegian Underground Service. He came to the US after the war to continue his studies at the University of Washington and earned his Ph.D. in Fisheries Biology in 1955. He was a Professor at the College of Fisheries, University of Washington, teaching and conducting research, from 1955 to 1982. During this time he spent summers in Bristol Bay, Alaska studying the population dynamics of sockeye salmon. In 1983, he became the Dean of the College of Fisheries and Ocean Science, University of Alaska in Juneau. He served as a visiting scholar at the University of Moscow in 1960–1961 and also was a Fulbright Scholar in Norway in 1965–1966 and in Malaysia in 1988–1989.

9.5 A tribute to William C. Acker by John Horne

William C. Acker, age 75, of Index, and Seattle, died peacefully at home on 8 February 2007, after a short battle with cancer. Bill was born on 23 June 1931 and grew up in Index, Washington, fishing and exploring along the North Fork of the Skykomish River. He graduated from Sultan High School. After serving in the Army during the Korean War, Bill attended the University of Washington, where he received his Bachelor's and Master's Degrees in Electrical Engineering. He worked as a research scientist at the Applied Physics Lab at the University of Washington for many years. In 1978, Bill founded BioSonics, Inc., a Seattle consulting, engineering and manufacturing firm that specializes in applying SONAR technology to monitor and assess aquatic biological resources. Later in life, Bill became a professor of Electrical Engineering at the University of Washington, where he was twice voted as "professor of the year". Bill also served for many years as the Mayor of Index, Washington, reviving the town's historic Fourth of July celebration.

9.6 Consideration of a literature database

Siebren Venema, a retired fisheries biologist has compiled a database of acoustic literature with over 9300 citations, including grey literature publications. He has requested that the WGFAST consider if the database should be posted on an ICES web site. The database was presented to the group by John Horne and David MacLennan. The database is stored in Procite but can be readily imported to other citation database software (Endnote for example). John Horne noted that the ability to search via keywords would be limited as they have not been separated into separate terms; some tidy up work would be required to fix this. The consensus of the group was that the database was useful and that it was desirable to make it accessible however it was noted that Siebren Venema did not want the program copied at this point. Siebren Venema's email was ambiguous on this point and it was recommended that the Chair contacts Siebren to clarify how he would like the database distributed.

9.7 Topic group for calibration of Simrad EK60 echosounder

At its 2007 meeting, the ICES Planning Group for Herring Surveys (PGHERS) made the following recommendation that was brought to the attention of WGFAST:

PGHERS has recognised differences in the calibration results between Simrad EK500 and EK60 echosounders. PGHERS recommends ICES WGFAST to advise PGHERS and other acoustic survey planning groups (e.g. PGNAPES) on the implications of following the procedure in the EK60 manual for calibrations of this new echosounder.

Several members of WGFAST met to discuss how to answer this request. It soon became clear that the procedure for calibration of the Simrad EK60, as described in this equipment's manual, was questionable to the point that very few members of WGFAST follow this for on-axis calibration. In the course of the discussion, several other points were raised with regard to calibration, including: calibration of multibeam sonars; standard target options; receiver delays; logistics; and environmental effects. The issue generated significant interest, which resulted in the formation of a Calibration Topic Group. Geir Pederson and Toby Jarvis were nominated as Co-Chairs of this Topic Group. The group will work by correspondence, meeting inter-sessionally at the ICES annual science conference, with the following terms of reference:

1) To review the current calibration procedure of the Simrad EK60 echosounder as described in the equipment's manual, and make recommendations for improvements to the derivation of on-axis sensitivity (s_A correction). This review will be submitted as a working document to WGFAST 2008.

2) To identify other issues associated with the calibration of active sonar equipment. These will be presented to WGFAST in 2008.

3) To draft terms of reference for a Calibration Study Group, starting in 2008, with the ultimate objective of updating the last cooperative research report on this issue (Foote *et al*., 1984). The study group would conduct a literature review of issues that need to be addressed when calibrating acoustic equipment for water column and seabed research and address some of the wider issues, such as the calibration of multi-beam sonars. The topic group will also consider how long the Study Group should meet for and identify an appropriate Chair.

The topic group consists of the following people:

Table.1. List of participants for the EK60 calibration topic group.

Name	***Email***
Paul Fernandes	*fernandespg@marlab.ac.uk*
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10 Recommendations

10.1 Terms of Reference for the 2008 WGFAST meeting

The discussion on the terms of reference for the next WGFAST meeting resulted in the following recommendations:

The **Working Group on Fisheries Acoustics, Science and Technology** [WGFAST] (Chair: Rudy Kloser, Australia) will meet in Bergen, Norway on Monday 23 June 2008 following the ICES Fisheries Acoustic Symposium 16–20 June:

a) review the major outcomes of the ICES Fisheries Acoustic Symposium by the theme sessions of:
   i) Ecosystem and Fisheries monitoring;
   ii) Remote classification and identification;
   iii) Target strength modelling and measurement;
   iv) Behaviour and assessments;
   v) Data quality and integration into ecosystem models.

To review any new and innovative methods and technologies for consideration by the FAST Working Group in 2009.

b) review the reports of the:
   i) Planning Group on the HAC (PGHAC) common data exchange format;
   ii) Study Group on Fisheries Optical Technologies (SGFOT); and
   iii) Study Group on Avoidance Reactions to Vessels (SGARV);
   iv) Topic group on EK60 calibration.

WGFAST will report by 31 July 2008 for the attention of the Fisheries Technology Committee.

10.2 Study, Planning and Topic Groups

Recommendation: WGFAST recommends that SGFOT, Eirik Tenningen (Norway), Chair, continue to work towards an ICES Cooperative Research Report and meet in Bergen Norway from 14 to 15 June. The results of their meeting are to be reported to the WGFAST on 23 June 2008.

Recommendation: WGFAST recommends that SGARV, Francois Gerlotto (France), Chair, continue to work towards an ICES Cooperative Research Report and meet in Bergen Norway from 21–22 June. The results of their meeting are to be reported to the WGFAST on 23 June 2008.

Recommendation: WGFAST recommends that the PGHAC, Laurent Berger (France), Chair, should continue its work via correspondence and report to the WGFAST on the 23 June 2008.

Recommendation: WGFAST recommends that a Calibration Topic Group be formed with Geir Pederson (Norway) and Toby Jarvis (Australia) nominated as Co-Chairs. The results of their out of session correspondence are to be reported to the WGFAST on the 23 June 2008.

10.3 Terms of Reference for the 2009 WGFAST-WGFTFB Joint Session

Recommendation: WGFAST recommends that WGFAST and WGFTFB meet jointly in Italy, in April 2009. The Terms of Reference are to be mutually decided by the Working Group Chairs and a designated joint session Chair.

10.4 Theme Sessions for the ICES 2008–2009 Annual Science Conference

Recommendation: In its continuing effort to contribute to the ICES Annual Science Conferences, WGFAST proposes the following three Theme Sessions for the 2009-2010 Annual Science Conferences:

SGFOT and WGFAST recommend a theme session on "Optical and image based technologies for ecosystem approach to fisheries management" be proposed for the 2009 ASC. Co-Chairs: Eirik Tenningen (Norway) and Bill Michaels (USA).

WGFAST recommends a theme session of monitoring requirements and methods for pelagic organisms at local and basin scales for input into ecosystem based fisheries management and climate impact models; be proposed for the 2009 ASC. With a particular focus on the acoustic indicators required for trophic groups such as zooplankton and micronekton. Co-Chairs Olav Rune Godoe (Norway) and cross linked with Chairs from CLIOTOP, LR, FTC.

WGFAST recommends a theme session of "Observation of animals in water column with multi-beam sonars" be proposed for 2009 or 2010. Multi-beam instruments provide unique opportunities to describe the abundance and spatial patterns of marine organisms through quantitative measurements within the water column. These tools not only provide a greater sampling volume than traditional echo sounders as well as the ability to estimate potential bias in traditional surveys, but may also allow greater capability to provide information needed to describe ecological processes that structure marine pelagic communities. The increased use of these systems will facilitate efforts to move more towards an ecosystem-based approach to fisheries research and management. Co-Chairs: Verena Trenkel (France), Rolf Korneliussen (Norway) and Stratis Georgakarakos (Greece).

10.5 ICES Acoustics Symposium 2008

The 2008 Symposium of Fisheries Acoustics Science and Technology will be held form 16–20 June, 2008 in Bergen Norway. The Conveners for the meeting are Egil Ona (Norway), Rudy Kloser (Australia), and David Demer (USA).

10.6 Other recommendations

That the Chair of WGFAST contact Siebren Venema to clarify how best to distribute the bibliography so that it can be used by WGFAST members.

11 Closure of meeting

Rudy Kloser closed the meeting by thanking Dominic Rihan for his fantastic efforts in hosting the meeting, noting that to host a joint session is a very big task. Rudy Kloser thanked Tim Ryan for his work as Rapporteur, panel and subgroup leaders and all presenters and participants for their contributions to the working group. Rudy Kloser finished by saying that he was looking forward to seeing everyone at the 2008 ICES FACTS symposium.

Annex 1: List of participants

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Annex 2: Agenda

ICES Working Group on Fisheries Acoustics Science and Technology 2007 Meeting Agenda
Meeting place: Crowne Plaza, Dublin Airport, Dublin, Ireland.

Sunday 22 April
1700 – 19:00 Registration Crowne Plaza Hotel.

Monday 23 April
0900 **FTFB/FAST Opening**
Host at Crowne Plaza, Dublin Airport, Ireland
0915 **FAST Opening**
Welcome – acknowledgements
0930 **Science presentation of final report for the Study Group of Acoustic Fishing Vessels (SGAFV)**
Speaker – Rudy Kloser for Bill Karp
0950 **Science presentation of final report for the Study Group of Acoustic Seabed Classification (SGASC)**
Speaker – John Anderson
1020 Morning Tea Break
Topic 1: Fish behaviour in response to vessel and other platform related stimuli
1050 Dick Wood, Bureau Veritas. "Underwater Noise Issues associated with the latest NERC Research Vessel, RRS "James Cook".
1110 Bjarne Stage, Karl Johan Stæhr, and Bo Lundgren. "Planned experiments on vessel noise measurements and fish reactions to noise".
1130 Yvan Simard, and Richard Lepage. "Small- and meso-scale noise conditions experienced by demersal fish in Gulf of St. Lawrence"
1150 Alex De Robertis, Vidar Hjellvik, Neal Williamson, Christopher D. Wilson. "Inter-vessel comparison of acoustic backscatter recorded by a noise-reduced and a conventional research vessel".
1210 Vasilis Trygonis and Stratis Georgakarakos, "Investigation of school speed measurement errors by simulation".
1230 Lunch
1400 Marc Soria, Gaël Potin, Pascal Cotel, Emmanuel Tessier, Laurent Dagorn. Is there a relationship between FAD-associated and free shoals? "Lessons from acoustic surveys on small pelagic fish in a network of shallow FADs in Reunion Island".
1420 Egil Ona, Ingvald Svellingen and Ronald Pedersen.
"Vessel avoidance by herring during rough weather conditions".
1440 Panel session summing up
Topic 6: FAST Business
1500 David Demer, Egil Ona, Rudy Kloser 2008 ICES Acoustic Symposium update
1520 Afternoon Tea Break
1550 Sub Group Discussions
1610 Sub Group Reporting
Topic 2: Survey techniques for epi-benthic, epi-pelagic, and shallow water species
1630 Joseph D. Warren and David A. Demer. "Small vessel surveys of krill populations near Livingston Island".
1650 Ronan Fablet, Carla Scalabrin, Jacques Massé, Pierre Cauchy. Can we learn acoustics-based school classification models from multi-specific trawl catches?
1710 Close
1900 Buffet and wine reception Crowne Plaza Hotel

Tuesday 24 April
0850 Housekeeping
Topic 2: Survey techniques for epi-benthic, epi-pelagic, and shallow water species cont.
0900 John Simmonds, Mariano Gutierrez, Andres Chipolini, Francois Gerlotto and Arnaud Bertrand. "Progress in evaluation of acoustic surveys for Peruvian anchovetta is presented".
0920 Taina Honkalehto, Patrick Ressler, Rick Towler, Christopher Wilson. "Using acoustic data collected by commercial fishing vessels to develop an annual index of abundance for walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea".
0940 Richard L. O'Driscoll. "Mesopelagic backscatter in the Ross Sea, Antarctica".
1000 Tim. E. Ryan, Rudy. J. Kloser. "Advances and challenges with deep-towed bodies. A review of recent experiences".
1020 Morning Tea Break
1050 John T. Anderson, Candace Rose-Taylor, Christopher Lang, and Matthew Wilson. "Acoustic seabed classification and mapping of capelin spawning beds and migration corridors using single and multibeam acoustic systems".
1110 Ruben Patel, "Compression of single pings from the EK60 Scientific echo sounder".
1130 Kohji Iida, Yong Tang, Tohru Mukai, and Yasushi Nishimori. "Measurement of fish school volume by multi-beam sonar".
1150 Hector Pena, Atle Totland and Lene Vestrheim. Real time scientific acoustic data collection from the office.
1210 Andrew S. Brierley, Michael N. Dawson, and William G. Sanderson. An acoustic survey of near-surface jellyfish in a tropical marine lake.
1230 Lunch Break
1400 Martin J. Cox, David L. Borchers and Andrew S. Brierley "A statistical framework for biomass estimation using a multi-beam echosounder".

1420 J. Michael Jech. "Addressing differences in abundance estimates from acoustic and bottom-trawl surveys: Atlantic herring in the Gulf of Maine".
1440 Marshall Hall, Rudy Kloser. Estimating low frequency sonar detection range of fish near Forestier Peninsula, Tasmania.
1500 Yvan Simard, Delphine Benoit, Louis Fortier, Catherine Bédard, and Xavier Mouy. "Acoustics, an effective suite of tools to explore the warming Arctic ocean".
1520 Afternoon Tea Break
1550 Nils Olav Handegard and David Demer. "Designing an Ocean Mid-trophic Automatic Acoustic Sampler".
1610 Sub Group Discussion
1630 Sub Group Reporting

Topic 6: FAST Business

1650 Draft resolutions FAST
1710 Close

Thursday 26 April

0850 Housekeeping

Topic 4: Target strength modelling and measurement

0900 David A. Demer and Josiah Renfree. "Variations in echosounder transducer performance versus water temperature".
0920 Sascha M.M. Fässler and Paul G. Fernandes. "Using a simple scattering model to investigate target strength variability in physostomous fish".
0940 Gavin Macaulay, Rudy Kloser. "Acoustic models of orange roughy at 38 and 120 kHz. Is what we see real" ?
1000 Geir Pedersen, Olav Rune Godø, and Egil Ona. "Uncertainty in *in situ* target strength measurement of blue whiting (*Micromesistius poutassou*)".
1020 Morning Tea Break
1050 Kjell Olsen. "Perspective on Target strength measurements"
1110 Panel Discussion

Topic 6: FAST Business

1140 HAC/Optical/Behaviour group update
1210 Resolutions final
1230 Lunch Break

Topic 3: Species identification techniques (eg. acoustic, optical and nets) for multispecies assessments, bycatch reduction, and automated data processing.

1400 Caristona I.H. Anderson, John K. Horne, and John Boyle. "Challenges associated with applying probabilistic classification to multi-frequency acoustic data".
1420 Toby Jarvis and Natalie Kelly. "Towards an objective and automated system for the post-processing and analysis of echosounder data in studies of aquatic ecosystems".
1440 Sophie Fielding, Martin Collins, Inigo Everson, Alex Reid. "Improving target identification of mackerel icefish using commercial and scientific acoustic observations".
1500 Rolf J. Korneliussen. "Experiences using LSSS on abundance estimation surveys".
1520 Afternoon Tea Break
1550 Laurent Berger, Valerie Mazauric, and Verena Trenkel. "Description of the new acoustic platform of FRV "*Thalassa"* to address the challenges of biomass estimate of the mixed pelagic community in the Bay of Biscay".
1610 Valerie Mazauric, Laurent Berger, and Verena Trenkel. Preliminary results with the acoustic platform of FRV "*Thalassa"* combining single vertical echo-sounders and the new scientific multibeam echo-sounder ME70.
1630 Close
1700 Guinness Storehouse Diner

Friday 27 April

0850 Housekeeping

Topic 3: Species identification techniques (eg. acoustic, optical and nets) for multispecies assessments, bycatch reduction, and automated data processing.

0900 Verena M. Trenkel, Carla Scalabrin, Laurent Berger and Valérie Mazauric. "Impact of beam angle on shoal structure and energy measurements: comparison of simulation results with data from new multibeam echosounder (ME70)".
0920 Kyoung-Hoon LEE, Heui-Chun AN, Tohru MUKAI, Kohji IIDA. "Classification of 2 species by a measurement of swimming speed".
0940 Yvan Simard, and Marc Sourisseau. "Modulation of krill target strength and net catches by diel vertical migration: comparisons of vertical echosounding with intensive net sampling".
1000 Hector Pena. "Acoustic identification of Horse mackerel (*Trachurus trachurus*) using multi-frequency echo sounder".
1020 Morning Tea Break
1050 Julian M. Burgos and John K. Horne. "Characterizing and classifying spatial distributions of nekton".
1110 Session Discussion
1130 Session Discussion

Topic 6: FAST Business

1150 FAST Business
1230 Meeting Closed

Annex 3: Terms of Reference for WGFAST

The **Working Group on Fisheries Acoustic Science and Technology [WGFAST]** (Chair: R. Kloser, Australia) will meet in Bergen, Norway on Monday 23 June 2008 following the ICES Fisheries Acoustic Symposium 16 to 20 June to:

a) review the major outcomes of the ICES Fisheries Acoustic Symposium by the theme sessions of:
   i) Ecosystem and Fisheries monitoring;
   ii) Remote classification and identification;
   iii) Target strength modelling and measurement;
   iv) Behaviour and assessments
   v) Data quality and integration into ecosystem models.

To review any new and innovative methods and technologies for consideration by the FAST working group in 2009.

b) review the reports of the:
   i) Planning Group on the HAC (PGHAC) common data exchange format;
   ii) Study Group on Fisheries Optical Technologies (SGFOT); and
   iii) Study Group on Avoidance Reactions to Vessels (SGARV).
   iv) Topic group on EK60 calibration.

WGFAST will report by 31 July 2008 for the attention of the Fisheries Technology Committee.

Supporting Information

PRIORITY:	Fisheries acoustics and complimentary 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.
SCIENTIFIC JUSTIFICATION AND RELATION TO ACTION PLAN:	**Term of Reference a)** In 2008 the international ICES Symposium on the Ecosystem Approach with Fisheries Acoustic and Complementary Technologies (SEAFACTS) will be held in Bergen Norway under the auspices of the ICES WGFAST working group. The symposium themes and topics have been designed by WGFAST members to update the state of the science when applying acoustic and complimentary technologies to the ecosystem approach to fisheries management. The recent change to incorporate the ecosystem approach in fisheries management requires collecting data on several components of the ecosystem, multiple species and trophic levels. Acoustics and complimentary technologies (e.g. optics) are unique tools (usually being non-selective and non-intrusive) that can provide multi-species assessments. Following the symposium WGFAST members will meet to evaluate the science needs to be addressed at the 2009 meeting with particular attention to new emerging methods. A.N. #s 1.10, 1.12.5, 1.13.3, 1.13.4, 1.13.5, 1.14, 3.2, 3.13 **Term of Reference b)** PGHAC, SGFOT, SGARV and TGC meet before WGFAST in the same location and make their reports available to the WGFAST at its annual meeting according to their terms of reference. A.N. #s: 1.12.5
RESOURCE REQUIREMENTS:	No new resources will be required for consideration of this topic at WGFAST annual meeting. Having overlaps with the other meetings of the Working, Planning, Study and Topic Groups of the Fisheries Technology Committee increases efficiency and reduces travel costs; undertake additional activities in the framework of this group is negligible.
PARTICIPANTS:	The Group is normally attended by some 70-75 members and guests.
SECRETARIAT FACILITIES:	None.

FINANCIAL:	No financial implications.
LINKAGES TO ADVISORY COMMITTEES:	There are no direct linkages to the advisory committees but the work is of relevance to ACFM.
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 PGHAC, SGTSEB, SGASC, and SGAFV, PGSPUN, PGRS, PGHERS, WGBIFS and PGAAM.
LINKAGES TO OTHER ORGANIZATIONS:	

Annex 4: Recommendations

RECOMMENDATION	ACTION
1. The **Working Group on Fisheries Acoustics, Science and Technology** [WGFAST] (Chair: Rudy Kloser, Australia) will meet in Bergen, Norway on Monday 23 June 2008 following the ICES Fisheries Acoustic Symposium 16 to 20 June:	
2. WGFAST recommends that SGFOT, Eirik Tenningen (Norway), Chair, continue to work towards an ICES Cooperative Research Report and meet in Bergen Norway from 14 to 15 June. The result of their meeting to be reported to the WGFAST on the 23rd June 2008.	
3. WGFAST recommends that SGARV, Francois Gerlotto (France), Chair, continue to work towards an ICES Cooperative Research Report and meet in Bergen Norway from xx to xx. The result of their meeting to be reported to the WGFAST on the 23 June 2008.	
4. WGFAST recommends that the PGHAC, Laurent Berger (France), Chair, should continue its work via correspondence and report to the WGFAST on the 23 June 2008.	
5. WGFAST recommends that WGFAST and WGFTFB meet jointly in Italy, in April 2009. The Terms of Reference are to be mutually decided by the Working Group Chairs and a designated joint session Chair.	FTC, WGFTFB
6. The WGFAST proposes the following three Theme Sessions for the 2009 and 2010 Annual Science Conference: a. Theme session on "Optical and image based technologies for use in the ecosystem approach to fisheries management". b. Theme session on "Monitoring requirements and methods for pelagic organisms at local and basin scales for input into ecosystem based fisheries management and climate impact models. With a particular focus on the acoustic indicators required for species such as zooplankton and micronekton". c. Theme session on "Surveying the water column with multi-beam sonars".	SGFOT, LRC