WORKING GROUP OF FISHERIES ACOUSTICS, SCIENCE AND TECHNOLOGY (WGFAST)

VOLUME 4 | ISSUE 54

ICES SCIENTIFIC REPORTS

RAPPORTS SCIENTIFIQUES DU CIEM

ICES INTERNATIONAL COUNCIL FOR THE EXPLORATION OF THE SEA
CIEM CONSEIL INTERNATIONAL POUR L'EXPLORATION DE LA MER

International Council for the Exploration of the Sea
Conseil International pour l'Exploration de la Mer

H.C. Andersens Boulevard 44-46
DK-1553 Copenhagen V
Denmark
Telephone (+45) 33 38 67 00
Telefax (+45) 33 93 42 15
www.ices.dk
info@ices.dk

ISSN number: 2618-1371

ICES Scientific Reports

Volume 4 | Issue 54

WORKING GROUP OF FISHERIES ACOUSTICS, SCIENCE AND TECHNOLOGY (WGFAST)

Recommended format for purpose of citation:

ICES. 2022. Working Group of Fisheries Acoustics, Science and Technology (WGFAST).
ICES Scientific Reports. 4:54. 93 pp. https://doi.org/10.17895/ices.pub.20178464

Editor

Michael Jech

Author

Michael Jech

ICES
International Council for the Exploration of the Sea
CIEM
Conseil International pour l'Exploration de la Mer

Contents

i Executive summary

The Working Group of Fisheries Acoustics, Science and Technology (WGFAST) focuses on the development and application of science and technology to observe the marine environment. In this report, WGFAST summarizes 40 presentations addressing the three themes: "Acoustic methods to characterize populations, ecosystems, habitat, and behaviour", "Acoustic characterization of marine organisms", and "Emerging technologies, methodologies, and protocols", and discussions addressing these three themes. Common themes throughout these sessions were the increasing use of autonomous vehicles for collecting data and the increasing use of advanced statistical methodologies to process and quantitatively interpret acoustic data. Acoustical, environmental, and biological data collected by a variety of mobile and stationary platforms provide multiple data streams to characterize ecosystems, and many of the presentations highlighted statistical methodologies to utilize long term dataseries to improve our understanding of how ecosystems change in response to human and natural stressors.

This report also summarizes WGFAST survey, research, and publication output for 2020 through 2022, and connections to other ICES expert groups. WGFAST reviewed its response to the Working Group on International Pelagic Surveys (WGIPS) query about acoustic extinction and its effect on abundance estimates of schooling fish, and the ICES Cooperative Research Report Collecting Quality Echosounder Data in Inclement Weather. Additionally, WGFAST discussed future plans for the working group, including details for the 2023 WGFAST/ICES Symposium and publication of its proceedings.

WGFAST is a leader in transforming "Big Data" to information that is used to conserve and manage ecosystems and contributes to a number of activities in this area of development. WGFAST is co-hosting a theme session with the Working group on Machine Learning in Marine Science (WGMLEARN) at the 2022 ICES Annual Science Conference. WGFAST will assess how its use of acoustic symbols and definitions corresponds to internationally recognized definitions by the International Organization for Standardization (ISO). With a goal of advancing the use of fisheries acoustic data in fisheries and ecosystem science, WGFAST continues to promote development of open-source data formats (SONAR-netCDF4), metadata (AcMETA), and open-source software through active participation in subgroups and postings to the ICES and WGFAST GitHub sites.

This report pays tribute to Ron Mitson who was a pioneer in the field of fisheries acoustics and provides a policy to celebrate past members.

ii Expert group information

Expert group name	Working Group on Fisheries Acoustics, Science and Technology (WGFAST)
Expert group cycle	Multiannual fixed term
Year cycle started	2020
Reporting year in cycle	3/3
Chair	Michael Jech, USA
Meeting venue(s) and dates	22 April 2020, online meeting hosted by the Institute of Marine Research, Bergen, Norway (120 participants)
	19-20, 22-23 April 2021, online meeting hosted by the Institute of Marine Research, Bergen, Norway (156 participants)
	25-28 April 2022, hybrid format hosted by Institute for Research and Development, Somone, Senegal (16 in person, 114 online)

1 Report on Terms of Reference

1.1 ToR a)

WGFAST members provided information on their resource surveys, research activities, interactions with other ICES expert groups, and publications that derived from exchange and collaboration with other WGFAST members. The report on resource surveys is provided in Annex 5, the report on research activities is provided in Annex 6, the report on interactions with other expert groups is provided in Annex 7, and a list of publications is provided in Annex 8.

1.2 ToR b)

Although the meeting was hybrid format, 38 live and 2 recorded presentations addressed the three topics: "Acoustic methods to characterize populations, ecosystems, habitat, and behaviour"; "Acoustic characterization of marine organisms"; and "Emerging technologies, methodologies, and protocols" were held. Presentations (See Annex 3: for abstracts) and discussions comprised these sessions. Summaries of each session are given here.

Acoustic Methods to Characterize Populations, Ecosystems, Habitat, and Behaviour

Fifteen presentations addressed this theme. Shifts in spatial distributions of pelagic fish observed in time-series survey data. Lekanda et al. suggested that positional variables (e.g. three-dimensional location of a school) were important to the success of a machine learning method using acoustic school classifications and geographical variables. Sarre et al. showed spatial shifts in pelagic fish species off the coast of western Africa in response to climatic variables, e.g. water temperature. Domokos highlighted the variability in spatio-temporal distributions of micronekton that can complicate predictive models. Zytko et al. showed promising results from a method to estimate the orientation of Baltic herring by comparing Kirchhoff model predictions to data. Larson studied the effects of the target strength (TS) to length intercepts on abundance estimates of Baltic herring, and suggested an improvement in estimates when relationships from other species where integrated. Thorvaldsen et al. developed a three-dimensional self-overlap index to quantify the behaviour of *Maurolicus meulleri* during vertical migrations and suggested that self-overlap was useful for discriminating juveniles who migrate from adults who do not migrate. Horne et al. presented ongoing efforts to collect fisheries data using acoustics on an artisanal fishery in Cambodia and highlighted the hurdles involved in sampling a fleet with 1e5 to 1e6 small boats. Lee and Staneva presented a method to decompose time-series acoustic data into components that were useful for defining and eliminating outliers and noise. Rong et al. (presented by T. Forland) showed that TS of salmon in pens, when they were not allowed access to the surface, decreased by 10 dB over about 3.5 weeks. Mouget et al. presented comparisons of spatial location of pelagic species in the Canary Current Large Marine Ecosystem. Izard et al. characterized vertical distributions using functional analysis (e.g. PCA). Fonvieille et al. investigated and compared acoustic data collected by vessel-borne and animal-borne echosounders. Silva et al. investigated whether areas predicted to have higher productivity have increased volume backscatter using shipboard echosounders and a tethered broadband system. Lawrence and Fernandes investigated effects of North Sea oil and gas platforms on fish aggregating behaviour. Annasawmy et al. mapped animal tracks (e.g. dives) on stationary, upward looking echosounder data in the Antarctic.

Discussion centered around the utility of the traditional TS-to-length relationships when estimating abundance of pelagic fish. The consensus was that these relationships are still useful, and sometimes the only method to convert acoustic energy to biological metrics, but that they need to be updated when acoustic data include mixed species. There was also discussion about the shifts in temporal and spatial distributions of pelagic nekton and plankton in response to environmental changes, especially sea temperature. These shifts not only affect how surveys need to adapt, but can have serious consequences for local and regional communities and economies that depend on fish as a primary food source and income.

Acoustic Characterization of Marine Organisms

Five presentations highlighted the utility of theoretical and empirical models in characterizing and understanding how behaviour affects acoustic backscatter. Barbin et al. computed the predicted forward-scatter based on trawl hauls and showed that trawls seem to underestimate the magnitude of acoustic data by 3-20 dB. Gastauer and Chu investigated the Distorted Wave Born Approximation (DWBA) and effects of orientation of non-spherical targets on TS. Palermino et al. performed TS measurements on tethered chub (*Scomber colias*) and horse mackerel (*Trachurus mediterraneus*) and compared these to backscatter models. Khodabandeloo et al. estimated gas-filled swimbladder elongation of mesopelagic fish using empirical data and theoretical models. Diogoul et al. showed correspondence between net tows and the ability to discriminate copepods using 38 and 120 kHz data collected along the Senegalese coast.

Discussion centered around the utility of broadband data and acoustic backscattering models to improve classification of acoustic data. There are a number of acoustic models available and there was discussion about how to move these forward so that they are available to the broader community, i.e. beyond the theoriticians. There was no consensus on developing a training course, but WGFAST will continue to monitor the use of theoretical and empirical backscatter models for classification and abundance estimates.

Emerging Technologies, Methodologies, and Protocols

Fourteen presentations showcased emerging technologies, methodologies, and protocols. Due to technical difficulties, McGowan-Yallop was unable to provide a presentation. Lowe et al. (presented by L. McGarry) presented Echofilter, a software implementation of machine learning models designed to identify the ambit of air entrained into the water column and thereby specify the contaminated portion of the water column to be excluded from biological analyses. Andersen et al. presented that Simrad will soon be providing open-source Python code and documentation to read and process Simrad wideband acoustic data. Silverman et al. (presented by J. Horne) have developed "pseudograms" that summarize volume backscatter into EchoMetrics that allow efficient transfer of data from autonomous gliders. Lee et al. provided an update on Echopype, and open-source Python convention for processing acoustic data. Calise et al. are developing ways to quantify data collected during tuna fishing operations by fish attracting devices (FADs) outfitted with echosounders. Fernandes and Lawrence highlighted the benefits and limitations of using autonomous platfors for surveying in and around offshore windfarms and gas and oil platforms. McGarry et al. quantified the seasonal and current speed effects influencing the depth-of-penetration of entrained bubbles in data collected at ocean-energy installations. David et al. investigated the use of acoustic instruments in shallow-water (i.e. < 30 m water depth) ecosystems, such as lagoons. M. Peña showed how the colour representation of acoustic data can influence interpretation of these data. Le Bouffant et al. are developing methods to compare data collected with an autonomous platform with those collected by crewed vessels. Coley et al. presented evidence that areal backscatter can be affected by as much as 40% when an average sound speed is used instead of a sound-speed profile when processing echosounder data. Handegard et al. provided an update of CRIMAC's progress on developing and implementing machine learning methods on acoustic data. Berger and Le Bouffant highlighted multiple conditions and transducer issues that can contribute to excessive noise in acoustic data, and mitigation measures to deal with these issues. Urmy et al. are developing a probabilistic approach, e.g, Bayesian, to the inverse problem of estimating densities from multifrequency and wideband data.

Discussion centred on how to best utilize wideband data for classification of acoustic backscatter and how to begin incorporating autonomous vehicles into resource surveys. Both topics are in their beginning stages and while there are no definitive answers, there is increasing effort addressing these topics.

Poster Presentations

The hybrid format of the meeting did not allow for live viewing of posters by all participants, so authors of the posters were given about five minutes to present their posters to the in-person and online participants. Five presentations were given. N. Diogoul presented two posters that investigated large-scale acoustic/biological phenomena and their responses to environmental forcing. The first addressed the resiliency of an eastern-boundary upwelling ecosystem to multiple environmental stressors, and the second looked at sound-scattering layers on the Senegalese continental shelf as a characteristic of pelagic habitat. A. Mouget presented two posters that investigated different ends of the spatial spectrum. The first looked at the importance of small, shallow coastal areas on the biology of pelagic communities, and the second investigated acoustic scattering layers and their importance to the Atlantic African Large Marine Ecosystems on the continental shelf of West Africa. The final presentation was given by Y. Kande who applied spatial functional analysis to survey data and corresponding fine-scale environmental data.

Presentations by Commercial Entities

Historically, commercial entities, e.g. sonar manufacturers and software developers, participated in the WGFAST meeting as exhibitors, but were allowed to highlight their company and new innovations to those that chose to stay "after hours". The online format of the WGFAST meetings in 2020 and 2021 curtailed that exchange of information. During this meeting, WGFAST allowed ten-minute presentations at the end of each day by commercial entities so that members could catch up with the newest innovations. ASL Environmental, Simrad, Zunibal, and Echoview provided presentations showcasing their recent products and software.

Interesting Sidelights we did During COVID

The COVID pandemic drastically changed the way most of the WGFAST members conducted their science. In many cases, these impacts were temporarily detrimental to the overall goals and missions of each institution. However, the change in work environment also provided opportunities for collaborations that may not have occurred otherwise. Two WGFAST members presented efforts above and beyond the traditional products we normally produce. Claudine Arendt partnered with Sven Gastauer to create functional art based on acoustic backscatter by different types of zooplankton (https://claudinearendt.net). Gildas Roudaut, Anne Lebourges Dhaussy, and Jérémie Habasque collaborated with high school art students to produce a leaflet that describes the mesopelagic environment with emphasis on lanternfish (https://www-iuem.univ-brest.fr/lemar/wp-content/uploads/2019/11/La-lanterne-web.pdf).

1.3 ToR c)

Members of WGFAST submitted two theme sessions for the 2022 ICES Annual Science Conference (ASC) in partnership with other expert groups. "New insights from Combining observations in ecosystem understanding" was submitted by members of WGFAST (Verena Trenkel and Michael Jech) and the Working Group on Integrative, Physical-biological and Ecosystem Modelling (WGIPEM; Sonja van Leeuwen), but was not accepted by the ASC scientific steering committee (SCICOM). "Processing and interpreting big data using machine learning: Acoustic, optic, and other observations in marine research" was submitted by members of WGFAST (Wu-Jung Lee and Nils Olav Handegard) and WGMLEARN (Ketil Malde) and was accepted as Theme Session D.

1.4 ToR d)

The acoustic metadata and open data format conventions have been developed and published and are available for use. Erin LaBrecque, the new chair of TGMeta, provided an update of the acoustic metadata convetion, AcMeta, which resides on the ICES Publications GitHub site, https://github.com/ices-publications/AcMeta. Laurent Berger provided an upadate on the open data format, SONAR-netCDF4, which resides on the ICES Publications GitHub site, https://github.com/ices-publications/SONAR-netCDFf. These are living documents in that anyone interested can use the conventions, suggest revisions, or add new information. Erin LaBrecque is the contact for AcMeta, and Gavin Macaulay and Laurent Berger are the primary contacts for SONAR-netCDF4. Once the full functionality of the ICES Library is online later this year, both AcMeta and SONAR-netCDF4 will have a landing page in the ICES library that will be searchable with all other ICES material, and will link to the GitHub repositories.

1.5 ToR e)

An ICES Cooperative Research Report (CRR) was published in 2021 which addresses how to deal with inclement weather when collecting and processing acoustic data: Jech, J. M., Schaber, M., Cox, M., Escobar-Flores, P., Gastauer, S., Haris, K., Horne, J., et al. 2021. Collecting Quality Echosounder Data in Inclement Weather, ICES CRR 352, https://doi.org/10.17895/ices.pub.7539. The practical aims of the CRR were to (i) review current knowledge and experience on the impact of weather conditions on acoustic data collected with a variety of echosounders operating on research vessels at common acoustic frequencies used in fisheries acoustics; (ii) developstandard procedures and methods for identifying unsuitable survey conditions, i.e. situations that are considered too degraded to continue collecting acoustic data; and (iii) propose methods for dealing with degraded data.

2 Discussion Topics

2.1 Proposed Symposium in 2023

WGFAST has proposed to convene the 8th international symposium of fisheries acoustics in Portland, Maine, USA the 27-30 March 2023. Anne Lebourges-Dhaussy (IRD, France), Gayle Zydlewski (UMaine, USA), and Michael Jech (NOAA, USA) are co-conveners. The symposium was approved SCICOM, so it will take place during the 50th anniversary of the first symposium held in Bergen, Norway in 1973.

2.2 Symposium Proceedings

WGFAST discussed publication of the symposium proceedings. Most of the historical proceedings have followed the format of a traditional proceedings in that the papers have a page limit (5-7 pages) with about 60-70 papers published in a single volume. These were all published by *ICES JMS* and volume of *Aquatic Living Resources*. *ICES JMS* no longer allows the "traditional" proceedings format and all papers follow the submission procedures for the *ICES JMS*. In 2016, this and other factors led to an all-time low publication of 16 papers. WGFAST considered alternative publishers for the symposium in 2023. *Frontiers in Marine Science*, *Progress in Oceanography*, and *American Society of Limnology and Oceanography* are a few alternatives. Each come with benefits and limitations. For example, *Frontiers in Marine Science*: will allow guest editors, will allow traditional format, $3000 per article. Whereas *ICES JMS*: will not allow guest editors, will not allow traditional format, but does not have page charges $0 per article.

Discussions at this meeting revealed that there were several factors that resulted in a low number of papers published. Submissions not being required prior to the meeting, and the heavy workload by ICES editorial staff were two primary factors that influenced the number of submissions.

The consensus of WGFAST was to i) retain the historical connection to *ICES JMS*, ii) require manuscript submissions prior to the meeting, iii) and for the scientific steering committee to bring the selected manuscripts up to publication quality before being submitted to the journal so that the burdon on editorial staff is alleviated. The symposium conveners discussed these requirements with *ICES JMS* editorial staff and the decision was made to publish the symposium proceedings in *ICES JMS* to produce a proceedings volume that is representative of the breadth of innovation within WGFAST and the broader fisheries acoustics community.

2.3 WGFAST Chair for 2023-2025

Anne Lebourges-Dhaussy was confirmed by WGFAST as the next chair. Anne and current-chair Michael Jech will work with SCICOM to confirm Anne as the next chair.

2.4 Tribute to Ron Mitson

Ron Mitson (1930 - 2021) was a pioneer in the field of fisheries acoustics. Ron was a kind man who always had time to talk to experts and students alike. He was an electrical engineer by training and worked at Cefas (the UK Centre for Environment, Fisheries and Aquaculture Science) and its predecessors from the early 1960s until his retirement.

He worked alongside such luminaries as David Cushing, Roy Harden Jones, and Geoff Arnold developing and adapting technologies for tracking fish and quantifying their abundance. His early work included acoustic target counting (Mitson and Wood, 1962) and development of acoustic transponding tags and application of World War 2 sonar technology for observing flatfish behavior relative to tidal currents (Mitson and Cook, 1971; Mitson and Storeton West, 1971)

His extensive list of publications in fisheries acoustics includes Ona and Mitson (1996), a classic contribution on the acoustic dead zone, at least two seminal publications, and many others that have influenced much of what we do.

- Fisheries Acoustics, A practical manual for aquatic biomass estimation, K. A. Johannesson and R. B. Mitson (1983) FAO Fisheries Technical Paper 240, https://www.fao.org/3/x5818e/x5818e00.htm. I highly recommend revisiting this publication. It reminds us of our analogue "roots", which is especially important in this age of digital data.
- ICES CRR #209 (1995) Underwater Noise of Research Vessels: Review and Recommendation. This publication is notable because of its influence beyond the fisheries acoustics community to that of vessel design and quality of life aboard research vessels. Most fisheries institutions have built "quiet" vessels based on requirements provided in this document. We have all been the beneficiaries of improved data quality through less ambient and radiated noise. Additionally, passive acoustic data collection and overall "quality of life" while sailing have benefited (I know I don't walk off one of our quiet vessels screaming at everyone I meet).

I (Dick Wood, FIOA, retired) met Ron in the early 1980's as he was then working at the Ministry of Agriculture, Fisheries, and Food in Lowestoft and they were putting out "feelers" for noise consultants to assist them in the development of a low noise research vessel. I was working as a noise consultant for Acoustic Technology Limited (which was later bought out by Bureau Veritas). We were fortunate enough to get the contract despite having little experience in underwater noise. Ron was very patient and understanding with my total lack of knowledge in the field of fisheries acoustics and helped me understand the importance of vessel radiated noise for the onboard scientists – even though my role was very much in the development of engineering orientated noise reduction measures. This first vessel we worked on was RV Corystes – the vessel which later became the template for the seminal publication ICES CRR #209 listed above and Kay et al. (1991). The importance of the ICES publication cannot be overstated as, in the mid-1990's, this was the only reference document which identified specific vessel source strength goals resulting in these criteria being used as a yardstick for numerous other types of vessel. I worked on several vessels with Ron right through from project inception through to the ranging trials when the underwater noise radiation from the vessel was finally fully understood. Ron also introduced me to many other projects where he was sometimes peripherally involved including Scotia, Cefas Endeavour, Oscar Dyson, Celtic Explorer etc. I have provided four photos of Ron taken at the Heggernes range in Norway during the underwater noise trials of Celtic Explorer in November and December 2002. Ron also introduced me to ICES and helped me get involved with study groups such as the Study Group on Fish Avoidance to research Vessels (SGFARV) etc. We always kept in touch until quite recently when he passed away and I will always appreciate his friendship.

Figure 2. **A picture of Ron Mitson**

2.5 Tributes to Past Members

WGFAST discussed how to pay tribute to those past members who have had significant influence on the field of fisheries acoustics. Historically, retired members have been recognized during the banquet at the annual meeting where an active member of WGFAST pays recognition to a retired member. In cases where the former member has had significant and profound influence on the field, a more substantial tribute should be provided. The consensus of WGFAST was to provide tributes in the annual report (see section 2.4 for a tribute to Ron Mitson). More substantial efforts (e.g. WGFAST nominated David MacLennon for the ICES Prix d'Excellence award) will be evaluated and pursued if an active member takes the lead.

2.6 Consistency of Terminology with International Standards

Toby Jarvis lead a discussion on the consistency of underwater-acoustics terminology used by the WGFAST community with international standards. The preliminary focus was on active sonar and the relatively new standard, ISO 18405:2017(E). WGFAST terminology has evolved somewhat separately to ISO 18405:2017(E), and a recent publication by some of the standard's authors (Ainslie et al. 2022, doi: 10.1109/JOE.2021.3085947) put forward the following case for the benefits of standardization: "By adopting a common language, we facilitate the effective communication of concepts and information in underwater acoustics, whether for research, technology, or regulation". An initial document has been drafted (See WGFAST_Supplementary-file-1.pdf) to facilitate discussion and assessment.

The consensus of WGFAST was to continue evaluation by making this a formal ToR, and forming a subgroup of volunteers, led by T. Jarvis, who will continue the effort over the next three years.

2.7 SPRFMO Symposium Announcement

Aquiles Sepulveda announced a symposium sponsored by the SPRFMO (South Pacific Regional Fisheries Management Organisation), "State of the Art of Habitat Monitoring". The symposium is to be held in Concepción, Chile, late January 2023. The WGFAST chair will disseminate more details as they become available.

2.8 WGFAST Response to WGIPS

WGFAST responded to a request for information by WGIPS as to whether acoustic extinction by dense schools should be considered as their surveys post-process acoustic survey data. Michael Jech presented the response and the response is provided in Annex 4. The two recommendations were

- Inspect historical data for the prevalence of aggregations that may be affected by acoustic shadowing (e.g. $\widehat{s_A}$ values greater than 100,000 $m^2\ nmi^{-2}$), and develop metrics to estimate the magnitude of the effects. Metrics include percentage of aggregations with acoustic shadowing, magnitude of acoustic shadowing, and effects on abundance estimates.
- If acoustic shadowing is determined to be significant, devote resources to develop survey protocols and collecting additional data.

2.9 New ToRs

WGFAST decided to continue its existence and discussed new ToRs. These ToRs have been developed as a new resolution and submitted to SCICOM for evaluation and approval.

3 References

Kay B.J., Jones D.K. & Mitson R. B. "FRV Corystes: A purpose-built fisheries research vessel". The Royal Institution of Naval Architects, London. Spring Meetings 1991 12p

Ona, E., and Mitson, R. B. 1996. Acoustic sampling and signal processing near the seabed: the deadzone revisited *ICES Journal of Marine Science*, Volume 53, Issue 4, August 1996, Pages 677–690, https://doi.org/10.1006/jmsc.1996.0087.

Mitson, R. B., and Wood, R. J. 1962. An automatic method of counting fish echoes. Journal du Conseil International pour l'Exploration de la Mer, 26: 281-291.

Mitson, R. B,, and Cook, J. C. 1971. Shipboard installation and trials of an electronic sector scanning sonar. Radio and Electronic Engineering, 41: 339-350.

Mitson, R. B., and Storeton West, T. J. 1971. A transponding acoustic fish tag. Radio Electron. Eng., 41: 483-489.

Annex 1: List of participants

Meeting 2022

Name	Institute	Country (of institute)	E-mail
Alegría, Nicolás	Instituto de Investigación Pesquera (INPESCA)	Chile	nicoalegria1@gmail.com
Algroy, Tonny	Kongsberg Maritime AS	Norway	tonny.algroy@km.kongsberg.com
Andersen, Lars Nonboe	Kongsberg Maritime	Norway	lars.nonboe.andersen@km.kongs-berg.com
Anderson, Chuck	CIRES CU-Boulder / NOAA NCEI	US	charles.anderson@noaa.gov
Annasawmy, Angelee Pavanee	Lynker Corporation	US	angelee-pavanee.annasawmy@ird.fr
Arendt, Claudine	Claudine Arendt	The Netherlands	claudine.a.c.arendt@gmail.com
Ariza, Alejandro	Institut de Recherche pour le Développement IRD	France	alejandro.ariza@ird.fr
Barbin, Laure	IRD	New Caledonia, France	laure.barbin@ird.fr
Berger, Laurent	Ifremer	France	Laurent.berger@ifremer.fr
Boyra, Guillermo	AZTI	Spain	gboyra@azti.es
Brehmer, Patrice	IRD – CSRP / SRFC	Senegal	Patrice.Brehmer@ird.fr
Bristow, Martina	University of East Anglia	UK	martina.bristow@uea.ac.uk
Calise, Lucio	Zunibal S.L	Spain	lucio.calise@zunibal.com
Carlsen, Astrid	SLU	Sweden	astrid.carlsen@slu.se
Cermak, Joseph	Coop. Instit. Clim. Ocean, & Ecosys. Studies (CICOES)	US	jcerma@uw.edu
Chawarski, Julek	Memorial University of Newfoundland / ASL Environmental Science	Canada	julek.chawarski@mi.mun.ca
Chu, Dezhang	NOAA Fisheries, NWFSC	US	Dezhang.chu@noaa.gov
Coly, Youssouph	UASZ	Senegal	youssouphcoly98@gmail.com
Condiotty, Jeff	Kongsberg Underwater Technology LLC	US	Jeff.Condiotty@km.kongsberg.com
Cornejo Urbina, Rodolfo Martín	IMARPE (Peruvian Marine Institute)	Peru	rcornejo@imarpe.gob.pe
Cox, Martin	Australian Antarctic Division	Australia	martin.cox@aad.gov.au
De Robertis, Alex	NOAA Fisheries	US	Alex.DeRobertis@noaa.gov

Demer, David	NOAA Fisheries, Southwest Fisheries Science Center	US	david.demer@noaa.gov
Diogoul, Ndague	IRD – ISRA/CRODT	Senegal	Ndague.Diogoul@ird.fr
Domokos, Réka	NOAA/NMFS/PIFSC	US	reka.domokos@noaa.gov
Dornan, Tracey	British Antarctic Survey	UK	tarrna70@bas.ac.uk
Dunn, Muriel	Memorial University of Newfoundland/ Akvaplan-niva	Norway	mbd@akvaplan.niva.no
Fernandes, Paul	University of Aberdeen	UK	fernandespg@abdn.ac.uk
Fonvieille, Nadège	Mediterranean In	France	nadege.fonvieille@univ-amu.fr
Forland, Tonje Nesse	Institute of Marine Research	Norway	tonje.nesse.forland@hi.no
Gastauer, Sven	Thünen Institute for Sea Fisheries/Scripps Inst. Ocean.	Germany	sven.gastauer@thuenen.de
Gauthier, Stéphane	DFO	Canada	stephane.gauthier@dfo-mpo.gc.ca
Geoffroy, Maxime	Marine Institute of Memorial University	Canada	maxime.geoffroy@mi.mun.ca
Gjeitsund Thorvaldsen, Kjetil	DTU Aqua	Denmark	kjgth@aqua.dtu.dk
Gonzalez, Silvana	NOAA	US	Silvana.gonzalez@noaa.gov
Gorska, Natalia	Institute of Oceanology Polish Academy of Sciences	Poland	gorska@iopan.pl
Grados, Daniel	IMARPE	Peru	danny.grados@gmail.com
Gutierrez, Mariano	IHMA	Peru	mgutierrez@ihma.org.pe
Habasque, Jérémie	IRD	France	jeremie.habasque@ird.fr
Handegard, Nils Olav	IMR	Norway	nils.olav.handegard@hi.no
Hassan, Moustahfid	NOAA	US	Hassan.Moustahfid@noaa.gov
Higashiyama, Hiroyuki	FURUNO Electric Co. Ltd.	Japan	hiroyuki.higashiyama@furuno.co.jp
Honkalehto, Taina	NOAA, National Marine Fisheries Service	US	taina.honkalehto@noaa.gov
Horne, John	CICOES, University of Washington	US	jhorne@uw.edu
Hutton, Briony	Echoview Software	Australia	briony.hutton@echoview.com
Iglesias, Ilysa	UCSC	US	iiglesia@ucsc.edu
Iriarte, Federico	Albor Tecnologico	Peru	Federico.iriarte@albortecnologico.com

Izard, Lloyd	Sorbonne University; LOCEAN	France	lloyd.izard@locean.ipsl.fr
Jacobsen, Jan Arge	Faroe Marine Research Institute	Faroe Islands	janarge@hav.fo
Jarvis, Toby	Echoview Software	Australia	toby.jarvis@echoview.com
Jónsson, Sigurður Þór	Marine and Freshwater Research Institute	Iceland	sigurdur@hafro.is
Kaljuste, Olavi	Department of Aquatic Resources, Swedish University of Agricultural Sciences	Sweden	olavi.kaljuste@slu.se
Kamal, Mamza	INRH	Morocco	kamalmamza@gmail.com
Khodabandeloo, Babak	Institute of Marine Research (IMR)	Norway	babak.khodabandeloo@hi.no
Klevjer, Thor	IMR	Norway	thor.klevjer@hi.no
Kubilius, Rokas	Institute of Marine Research	Norway	rokas@hi.no
LaBrecque, Erin	Marine Mammal Commission	US	erinlab@gmail.com
Larson, Niklas	SLU	Sweden	Niklas.larson@slu.se
Lavery, Andone	Woods Hole Oceanographic Institution	US	alavery@whoi.edu
Lawrence, Joshua	University of Aberdeen	Scotland	joshua.lawrence1@abdn.ac.uk
Le Bouffant, Naig	Ifremer	France	naig.le.bouffant@ifremer.fr
Lee, Wu-Jung	Applied Physics Laboratory, University of Washington	US	leewj@uw.edu
Levine Robert	University of Washington	US	Leviner@uw.edu
Macaulay, Gavin	Institute of Marine Research (IMR)	Norway	gavin.macaulay@hi.no
Martin, Antonio	Furuno Spain	Spain	Antonio.martin@furuno.es
Matsuura, Tomohiko	Japan Fisheries Research and Education Agency	Japan	imat@affrc.go.jp
Maurice, Alicia	NIWA	New Zealand	alicia.maurice@niwa.co.nz
Mayorga, Emilio	Applied Physics Laboratory, University of Washington	US	emiliom@uw.edu
McGarry, Louise	Fundy Ocean Research Centre for Energy (FORCE)	Canada	louise.p.mcgarry@gmail.com
McGowan-Yallop, Chelsey	Scottish Association for Marine Science	Scotland	chelsey.mcgowan-yallop@sams.ac.uk
McQuinn, Ian H.	DFO	Canada	ian.mcquinn@dfo-mpo.gc.ca
Michael, Jech	NOAA/Northeast Fisheries Science Center	US	michael.jech@noaa.gov
Misonoo, Satoshi	Furuno electric co., ltd.	Japan	Satoshi.misonoo@furuno.co.jp

Mouget, Anne	MNHN	France	Anne.Mouget@mnhn.fr
Mouget, Anne	MNHN C/o IRD	France	anne.mouget@mnhn.fr
Mowbray, Fran	Department of Fisheries and Oceana	Canada	Fran.mowbray@dfo-mpo.gc.ca
Nogueira, Miguel	Furuno España	Spain	Miguel.nogueira@furuno.es
O'Connell, Steven	Marine Scotland	Scotland	steven.oconnell@gov.scot
O'Donnell, Ciaran	Marine Institute	Ireland	Ciaran.odonnell@marine.ie
O'Driscoll, Richard	National Institute of Water & Atmospheric Research Ltd	New Zealand	richard.odriscoll@niwa.co.nz
O'Malley, Michael	Marine Institute	Ireland	michael.omalley@marine.ie
Okunishi, Akira	FURUNO electric Co., Ltd.	Japan	akira.okunishi@furuno.co.jp
Ona, Egil	IMR	Norway	egil.ona@hi.no
Ordóñez Cebrián, Patricia	Zunibal S.L	Spain	patricia.ordonez@zunibal.com
Palermino, Antonio	Organisation CNR-Irbim; UNIBO	Italy	antonio.palermino@irbim.cnr.it
Parker-Stetter, Sandra	NOAA-NMFS-AFSC	US	sandy.parker-stetter@noaa.gov
Parner, Hjalte	ICES	Denmark	hjalte@ices.dk
Pearce, Steve	ASL Environmental Sciences	Canada	spearce@aslenv.com
Pedersen, Audun Oppedal	University of Bergen	Norway	audun.pedersen@uib.no
Peltonen, Heikki	Finnish Environment Institute	Finland	Heikki.peltonen@syke.fi
Pena, Hector	Institute of Marine Research	Norway	hector.pena@hi.no
Peña, Marián	Spanish Insitute of Oceanography (IEO)	Spain	marian.pena@ieo.es
Petrusevich, Vladislav	Northwest Atlantic Fisheries Centre, Fish. & Oceans	Canada	vladislav.petrusevich@dfo-mpo.gc.ca
Phillips, Elizabeth	NOAA Fisheries	US	Elizabeth.phillips@noaa.gov
Proud, Roland	University of St Andrews	UK	rp43@st-andrews.ac.uk
Renfree, Josiah	NOAA / Southwest Fisheries Science Center	US	Josiah.renfree@noaa.gov
Ressler, Patrick	NOAA Alaska Fisheries Science Center	US	patrick.ressler@noaa.gov
Roa, Camilo	Florida International University	US	croa@fiu.edu
Rodrigues, Elizandro	Instituto do Mar – Imar	Cabo Verde	elizandro.rodrigues@oscm.cv

Roudaut, Gildas	IRD	France	gildas.roudaut@ird.fr
Rousseau, Shani	Fisheries and Oceans Canada	Canada	shani.rousseau@dfo-mpo.gc.ca
Ryan, Tim	CSIRO	Australia	tim.ryan@csiro.au
Sakinan, Serdar	Wageningen Marine Research	Netherlands	serdar.sakinan@wur.nl
Salvetat, Julie	University of Montpellier	France	ju.salvetat@gmail.com
Sarré, Abdoulaye	ISRA, CRODT	Senegal	ablaysarrey@yahoo.fr
Sawada, Kouichi	Fish. Tech. Institute, Japan Fish. Res. & Educ. Agency	Japan	ksawada@fra.affrc.go.jp
Schaber, Matthias	Thünen Institute of Sea Fisheries	Germany	matthias.schaber@thuenen.de
Schmidt, Beata	National Marine Fisheries Research Institute	Poland	bschmidt@mir.gdynia.pl
Sepp, Elor	Estonian Marine Institute	Estonia	elor.sepp@ut.ee
Sepúlveda, Aquiles	Instituto de Investigación Pesquera	Chile	asepulveda@inpesca.cl
Sidibeh, Momodou	FD	The Gambia	mbailo85@hotmail.com
Silva, Teresa	Marine and Freshwater Research Institute	Iceland	teresa.silva@hafogvat.is
Slonimer, Alex	ASL Environmental Sciences	Canada	aslonimer@aslenv.com
Smith, Abigail	Australian Antarctic Program Partnership	Australia	Abigail.smith@utas.edu.au
Sørhagen, Robert	Kongsberg Maritime AS	Norway	robert.sorhagen@km.kongsberg.com
Staneva, Valentina	University of Washington	US	vms16@uw.edu
Strods, Guntars	BIOR	Latvia	guntars.strods@bior.lv
Swan, Jackson	University of Washington	US	jswan13@uw.edu
Taleb, Mohamed Ahmed Jeyid	IMROP	Mauritanie	moahtaje@yahoo.fr
Taylor, Chris	NOAA Ocean Service	US	Chris.Taylor@noaa.gov
Thomas, Rebecca	NOAA/Northwest Fisheries Science Center	US	Rebecca.Thomas@noaa.gov
Urmy, Sam	NOAA Alaska Fisheries Science Center	US	sam.urmy@noaa.gov
Wall, Carrie	University of Colorado / NOAA National Centers for Environmental Information	US	carrie.wall@noaa.gov
Wangen, Ivar	Simrad/Kongsberg Maritime	Norway	ivar.wangen@simrad.com
Warren, Joseph	Stony Brook University	US	joe.warren@stonybrook.edu
Weber, Tom	ONR	US	Thomas.c.weber16.civ@us.navy.mil

Whitton, Tim	Bangor University	UK	t.whitton@bangor.ac.uk
Xu, Jinshan	Bedford Institute of Oceanography	Canada	Jinshan.xu@dfo-mpo.gc.ca
Zhuang, Zhaozhong	MIT-WHOI	US	zzhuang@whoi.edu
Żytko, Aleksander	Institute od Oceanology Polish Academy of Sciences	Poland	azytko@iopan.pl

Meeting 2021

Name	Institute	Country (of institute)	E-mail
Koki Abe	Japan Fisheries Research and Education Agency	Japan	abec@fra.affrc.go.jp
Mette Agersted	Institute of Marine Research, Norway	Norway	metteagersted@gmail.com
Nicolás Alegría Landeros	INPESCA	Chile	nalegria@inpesca.cl
Tonny Algroey	Kongsberg Maritime AS	Norway	tonny.algroy@simrad.com
Anibal Aliaga	TASA	Peru	anibaljar@gmail.com
Lars Nonboe Andersen	Kongsberg Maritime	Norway	lars.nonboe.andersen@kongsberg.com
Charles Anderson	NCEI/CIRES	US	charles.anderson@noaa.gov
Angelee Pavanee Annasawmy	University of Washington	France	pannasawmy@yahoo.com
Alejandro Ariza	IRD	Spain	alejandro.ariza@ird.fr
Sigvaldi Árnason	Marine and Freshwater Research Institute	Iceland	sigvaldi.arnason@hafogvatn.is
Fiona Bairstow	St Andrews	UK	fjb5@st-andrews.ac.uk
Laure Barbin	IRD	France	laure.barbin@ird.fr
Birkir Bardarson	MFRI	Iceland	birkir.bardarson@hafogvatn.is
Laurent Berger	Ifremer	France	laurent.berger@ifremer.fr
Arnaud Bertrand	IRD	France	Arnaud.Bertrand@ird.fr
Arthur Blanluet	Queensland University	France/ Australia	arthur.blanluet@noos.fr
Kevin Boswell	Florida international university	US	kevin.boswell@fiu.edu
Guillermo Boyra	AZTI	Spain	gboyra@azti.es
Patrice Brehmer	IRD	Senegal	Patrice.brehmer@ird.fr
Andrew Brierley	University of St Andrews	UK	asb4@st-andrews.ac.uk
Martina Bristow	University of East Anglia	UK	martina.bristow@uea.ac.uk

Steven Brodet	Kongsberg Underwater Technology	Sweden	steve.brodet@km.kongsberg.com
Jan Buermans	ASL Environmental Sciences Inc.	Canada	jbuermans@aslenv.com
Lucio Calise	Zunibal SL	Spain	lucio.calise@zunibal.com
Fabio Campanella	Cefas	UK	fabio.campanella@cefas.co.uk
Julek Chawarski	Centre for Fisheries Ecosystem Research	Canada	julek.chawarski@mi.mun.ca
Dezhang Chu	NOAA Fisheries, NWFSC	US	dezhang.chu@noaa.gov
Jeff Condiotty	Kongsberg Underwater Technology	US	jeff.condiotty@km.kongsberg.com
Rodolfo Cornejo Urbina	IMARPE	Peru	rcornejo@imarpe.gob.pe
Martin Cox	Australian Antarctic Division	Australia	martin.cox@aad.gov.au
Alex De Robertis	NOAA Fisheries	US	Alex.DeRobertis@noaa.gov
David Demer	NOAA / NMFS /SWFSC	US	david.demer@noaa.gov
Réka Domokos	Pacific Islands Fisheries Science Center, NMFS, NOAA	US	reka.domokos@noaa.gov
Mathieu Doray	Ifremer	France	mdoray@ifremer.fr
Tracey Dornan	British Antarctic Survey	UK	tarna70@bas.ac.uk
Ryan Downie	CSIRO	Australia	ryan.downie@csiro.au
Muriel Dunn	Memorial University of Newfoundland / Akvaplan-niva	Norway	muriel.dunn@mi.mun.ca
James Dunning	University of Aberdeen	UK	j.dunning.18@abdn.ac.uk
Pablo Escobar-Flo-res	NIWA	New Zealand	pablo.escobar@niwa.co.nz
Paul Fernandes	University of Aberdeen	UK	fernandespg@abdn.ac.uk
Sophie Fielding	British Antarctic Survey	UK	sof@bas.ac.uk
Peer Fietzek	Kongsberg Maritime	Germany	peer.fietzek@km.kongsberg.com
Tonje Forland	Institute of Marine Research	Norway	tonje.nesse.forland@hi.no
Sven Gastauer	Thünen Institute for Sea Fisheries	Germany	sven.gastauer@thuenen.de
Stephane Gauthier	Fisheries and Oceans Canada	Canada	stephane.gauthier@dfo-mpo.gc.ca
Maxime Geoffroy	Fisheries and Marine Institute of Memo-rial University of Newfoundland	Canada	maxime.geoffroy@mi.mun.ca
Teresa Sofia Gie-sta da Silva	Marine and Freshwater Research Institute	Iceland	teresa.silva@hafogvatn.is
Silvana Gonzalez	University of Washington	US	silgonz@uw.edu
Natalia Gorska	Institute of Oceanology Polish Academy of Science	Poland	gorska@iopan.pl

Daniel Grados	IMARPE	Peru	danny.grados@gmail.com
Jerome Guiet	UCLA	US	Jerome.c.guiet@gmail.com
Mariano Gutierrez	Humboldt Institute	Peru	msgutierrezt@gmail.com
Jeremie Habasque	IRD	France	jeremie.habasque@ird.fr
Nils Olav Handegard	IMR	Norway	nilsolav@hi.no
Daniel Hasselman	Fundy Ocean Research Center for Energy	Canada	dan.hasselman@fundyforce.ca
Hiroyuki Higashiyama	FURUNO ELECTRIC CO., LTD.	Japan	hiroyuki.higashiyama@furuno.co.jp
Taina Honkalehto	NOAA Fisheries	US	Taina.Honkalehto@noaa.gov
John Horne	University of Washington	US	jhorne@uw.edu
Lawrence Hufnagle	NOAA Fisheries	US	lawrence.c.hufnagle@noaa.gov
Briony Hutton	Echoview Software	Australia	briony.hutton@echoview.com
Ilysa Iglesias	University of California, Santa Cruz and NOAA Southwest Fisheries Science Center	US	iiglesia@ucsc.edu
Tomohito Imaizumi	National Research Institute of Fisheries Engineering, Japan Fisheries Research and Education Agency	Japan	imat@affrc.go.jp
Jan Arge Jacobsen	Faroe Marine Research Institute	Faroe Islands	janarge@hav.fo
Michael Jech	NOAA/NEFSC	US	michael.jech@noaa.gov
Teunis Jensen	DTU Aqua	Denmark	tej@aqua.dtu.dk
Espen Johnsen	Institute of Marine Research	Norway	espen.johnsen@hi.no
Jennifer Johnson	WHOI	US	jjjohnson@whoi.edu
Sigurður Jónsson	Marine and Freshwater Research Institute, Reykjavík, Iceland	Iceland	sigurdur@hafro.is
Rachel Kahn	MIT-WHOI Joint Program	US	rkahn@whoi.edu
Olavi Kaljuste	Swedish University of Agricultural Sciences	Sweden	olavi.kaljuste@slu.se
Zacharias Kapelonis	Hellenic Centre for Marine research	Greece	zkapelonis@hcmr.gr
Ailbhe Kavanagh	Marine Institute	Ireland	ailbhe.kavanagh@marine.ie
Babak Khodabandeloo	Norwegian Institute of Marine Research	Norway	babak.khodabandeloo@hi.no
Thor Klevjer	IMR	Norway	thor.klevjer@hi.no
Rolf Korneliussen	Institute of Marine Research	Norway	rolf.korneliussen@hi.no

Rokas Kubilius	Institute of Marine Research	Norway	rokas@hi.no
Erin LaBrecque	US Marine Mammal Commission	US	erinlab@gmail.com
Niklas Larson	IMR, Aqua, SLU	Sweden	niklas.larson@slu.se
Andone Lavery	Woods Hole Oceanographic Institution	US	alavery@whoi.edu
Naig Le Bouffant	Ifremer	France	naig.le.bouffant@ifremer.fr
Anne Lebourges-Dhaussy	IRD	France	anne.lebourges.dhaussy@ird.fr
Wu-Jung Lee	University of Washington Applied Physics Laboratory	US	wjlee@apl.washington.edu
Robert Levine	University of Washington	US	leviner@uw.edu
Lilian Leiber	University Belfast Marine Laboratory	UK	L.Lieber@qub.ac.uk
Scott Loranger	Woods Hole Oceanographic Institution	US	sloranger@whoi.edu
Zhen Lu	postdoctoral researcher	Japan	roshin@affrc.go.jp
Susan Lusseau	DTU Aqua	Denmark	smalu@aqua.dtu.dk
Gavin Macaulay	Institute of Marine Research	Norway	gavin.macaulay@hi.no
Nicholas Makris	MIT	US	makris@mit.edu
Alicia Maurice	Ifremer	France	alicia.maurice@ifremer.fr
Emilio Mayorga	University of Washington	US	mayorga@apl.washington.edu
Louise McGarry	FORCE: Fundy Ocean Research Center for Energy	Canada	louise.mcgarry@fundyforce.ca
David McGowan	NOAA AFSC	US	david.mcgowan@noaa.gov
Chelsey McGowan-Yallop	Scottish Association for Marine Science	UK	sa06cm@sams.ac.uk
Denise McKelvey	Alaska Fisheries Science Center, NOAA Fisheries	US	denise.mckelvey@noaa.gov
Satoshi Misonoo	FURUNO ELECTRIC CO., LTD.	Japan	satoshi.misonoo@furuno.co.jp
Hassan Moustah-fid	NOAA	US	hassan.moustahfid@noaa.gov
Fran Mowbray	Fisheries and Oceans Canada	Canada	Fran.Mowbray@dfo-mpo.gc.ca
Miad Al Mursaline	MIT/WHOI	US	mmursaline@whoi.edu
Lauren Nelson	IOTC	Seychelles	lauren.nelson@fao.org
Miguel Nogueira	FURUNO	Spain	miguel.nogueira@furuno.es
Michael O’Malley	Marine Institute	Ireland	Michael.O'Malley@Marine.ie
Steven O'Connell	Marine Scotland Science	UK	Steven.O'connell@gov.scot

Ciaran O'Donnell	Marine Institute	Ireland	Ciaran.odonnell@marine.ie
Akira Okunishi	FURUNO ELECTRIC CO., LTD.	Japan	akira.okunishi@furuno.co.jp
Egil Ona	Institute of Marine Research	Norway	egil.ona@imr.no
Patricia Ordonez	ZUNIBAL SL	Spain	patricia.ordonez@zunibal.com
Egoitz Ormaechea	Zunibal	Spain	egoitz.ormaetxea@zunibal.com
Antonio Palermino	CNR-National Research Council, IRBIM-Institute for Marine Biological Resources and Biotechnologies	Italia	antonio.palermino@irbim.cnr.it
Sandra Parker-Stetter	NOAA-AFSC-MACE	US	sandy.parker-stetter@noaa.gov
Hjalte Parner	ICES	Denmark	hjalte.parner@gmail.com
Audun Oppedal Pedersen	University of Bergen	Norway	audun.pedersen@outlook.com
Geir Pedersen	Institute of Marine Research	Norway	geir.pedersen@hi.no
Heikki Peltonen	Finnish Environment Institute	Finland	heikki.peltonen@syke.fi
Hector Pena	Institute of Marine Research	Norway	hector.pena@hi.no
Marian Peña	IEO	Spain	marian.pena@ieo.es
Salvador Peraltilla	Peruvian National Fisheries Society	Peru	speraltilla@snp.org.pe
Vladislav Petrusevich	DFO, NAFC	Canada	vladislav.petrusevich@dfo-mpo.gc.ca
Elizabeth Phillips	NOAA	US	elizabeth.phillips@noaa.gov
Marissela Pozada	IMARPE	Peru	marissela.pozada.herrera@gmail.com
Roland Proud	University of St Andrews	UK	rp43@st-andrews.ac.uk
Madhu Ramakrishnan	ICAR-Central Institute of Fisheries Technology	India	madhucift@gmail.com
Aurore Receveur	Thuenen Institute	Germany	aurore.receveur@9online.fr
Frank Reier Knudsen	Kongsberg Maritime	Norway	frank.reier.knudsen@km.kongsberg.com
Josiah Renfree	NOAA	US	josiah.renfree@noaa.gov
Patrick Ressler	NOAA Alaska Fisheries Science Center	US	patrick.ressler@noaa.gov
Shani Rousseau	Fisheries and Oceans Canada	Canada	shani.rousseau@dfo-mpo.gc.ca
Tim Ryan	CSIRO	Australia	Tim.ryan@csiro.au
Serdar Sakinan	Wageningen Marine Research	Netherlands	serdar.sakinan@wur.nl
Julie Salvetat	UFRPE, IRD	France	ju.salvetat@gmail.com

Kouichi Sawada	Japan Fisheries Research and Education Agency, Fisheries Technology Institute	Japan	ksawada@fra.affrc.go.jp
Matthias Schaber	Thünen Institute of Sea Fisheries	Germany	matthias.schaber@thuenen.de
Ben Scoulding	CSIRO	Australia	ben.scoulding@csiro.au
Elor Sepp	Estonian Marine Institute	Estonia	elor.sepp@ut.ee
Jacob Sobin	Kongsberg Maritime	US	jacob.sobin@km.kongsberg.com
Valentina Staneva	University of Washington	US	vms16@uw.edu
Chelsea Stanley	Institute of Ocean Sciences	Canada	chelsea.stanley@dfo-mpo.gc.ca
Jonas Sundberg	Swedish University of Agricultural Sci-ences	Sweden	jonas.sundberg@slu.se
Chris Taylor	NOAA Ocean Service	US	Chris.Taylor@noaa.gov
Michala Techau	Strategic Innovation Ltd	UK	m.techau@strategic-innovation.co.uk
Rebecca Thomas	NOAA/NWFSC	US	rebecca.thomas@noaa.gov
Verena Trenkel	Ifremer	France	verena.trenkel@ifremer.fr
Sam Urmy	NOAA Alaska Fisheries Science Center	US	sam.urmy@noaa.gov
Jeroen Van Der Kooij	Cefas	UK	jeroen.vanderkooij@cefas.co.uk
Gary Vargas	Universidade Federal Rural de Per-manbuco	Peru	garyrvc@gmail.com
Carrie Wall	University of Colorado Boulder / NOAA NCEI	US	carrie.wall@noaa.gov
Ivar Wangen	Kongsberg Maritime	Norway	ivar.wangen@simrad.com
Joseph Warren	Stony Brook University	US	joe.warren@stonybrook.edu
David Warwick	Seafish	UK	david.warwick@seafish.co.uk
Tim Whitton	Bangor University	UK	t.whitton@bangor.ac.uk
Alina Wieczorek	Marine Institute Ireland	Ireland	Alina.Wieczorek@marine.ie
Jinshan Xu	Fisheries and Oceans of Canada	Canada	jinshan.xu@dfo-mpo.gc.ca
Yawen Zhang	University of Colorado Boulder	China	yawen.zhang@colorado.edu
Zhaozhong Zhuang	MIT-WHOI	US	zzhuang@whoi.edu
Aleksander Żytko	Institute of Oceanology, Polish Academy of Science	Poland	azytko@iopan.pl

Meeting 2020

Name	Institute	Country (of institute)	E-mail
Alejandro Ariza	British Antarctic Survey	UK	aletea@bas.ac.uk
Alex de Robertis	Alaska Fisheries Science Center	US	Alex.DeRobertis@noaa.gov
Alireza Rezvanifar	University of Victoria	Canada	arezvani@uvic.ca
Andone C. Lavery	Woods Hole Oceanographic Institution	US	alavery@whoi.edu
Anne Lebourges-Dhaussy	L'IRD en Bretagne	France	Anne.Lebourges.Dhaussy@ird.fr
Aquiles Sepulveda	Instituto de Investigación Pesquera	Chile	asepulveda@inpesca.cl
Arnaud Bertrand	Centre de Recherche Halieutique Méditerranéenne et Tropicale	France	arnaud.bertrand@ird.fr
Arthur Blanluet	Ifremer Nantes Centre	France	arthur.blanluet@ifremer.fr
Ben Scoulding	CSIRO Marine and Atmospheric Research	Australia	ben.scoulding@csiro.au
Benoit Berges	Wageningen University & Research	Netherlands	benoit.berges@wur.nl
Birkir Bardarson	Marine and Freshwater Research Institute	Iceland	birkir.bardarson@hafogvatn.is
Carlos Robinson	Instituto de Ciencias del Mar y Limnologia UNAM	Mexico	robmen@servidor.unam.mx
Carrie Wall	Cooperative Institute for Research in Environmental Sciences	US	carrie.wall@noaa.gov
Charles Anderson	National Oceanic and Atmospheric Administration (NOAA)	US	charles.anderson@noaa.gov
Christopher Taylor	Southeast Fisheries Science Center	US	Chris.Taylor@noaa.gov
Ciaran O'Donnell	Marine Institute	Ireland	Ciaran.ODonnell@Marine.ie
Daniel Grados	Instituto del Mar del Peru	Peru	dgrados@imarpe.gob.pe
Danny Copland	Marine Science Scotland	UK	danny.copland@gov.scot
David Demer	Southwest Fisheries Science Center	US	david.demer@noaa.gov
David McGowan	University of Washington	US	mcgowand@uw.edu
Denise McKelvey	Alaska Fisheries Science Center	US	Denise.mckelvey@noaa.gov
Dezhang Chu	Northwest Fisheries Science Center	US	dezhang.chu@noaa.gov
Egoitz Burggraaf	Zunibal, S.L.	Spain	egoitz.ormaetxea@zunibal.com
Elizabeth Phillips	University of Washington	US	emp11@uw.edu
Erin LaBrecque	Independent Consultant	US	erinlab@gmail.com

Fabio Campanella	Centre for Environment, Fisheries and Aquaculture Science	US	fabio.campanella@cefas.co.uk
Fletcher Thompson	DTU Aqua, National Institute of Aquatic Resources	Denmark	fletho@aqua.dtu.dk
Geir Pedersen	Institute of Marine Research	Norway	geir.pedersen@hi.no
Guillermo Boyra	AZTI-Tecnalia	Spain	gboyra@azti.es
Haris Kunnath	CSIRO Marine and Atmospheric Research	Australia	haris.kunnath@csiro.au
Hassan Moustahfid	NOAA Integrated Ocean Observing System (IOOS)	US	Hassan.Moustahfid@noaa.gov
Hector Peña	Institute of Marine Research	Norway	hector.pena@hi.no
Hjalte Parner	ICES Secretariat	Denmark	hjalte@ices.dk
Ilysa Iglesias	University of California Santa Cruz	US	ilysa.iglesias@noaa.gov
Ivar Wangen	Simrad	Norway	ivar.wangen@simrad.com
J. Michael Jech	NOAA Fisheries	US	michael.jech@noaa.gov
Jan Buermans	ASL Environmental Sciences Inc.	Canada	jbuermans@aslenv.com
Jeff Condiotty	Simrad Fisheries	US	jeff.condiotty@simrad.com
Jennifer Johnson	University of New Hampshire	US	jenniferj@ccom.unh.edu
Jenni McDermid	Fisheries and Oceans Canada Charlottetown	Canada	Jenni.McDermid@dfo-mpo.gc.ca
Jeremie Habasque	French National Research Institute for Sustainable Development	France	jeremie.habasque@ird.fr
John Horne	University of Washington	US	jhorne@u.washington.edu
Jose Rojas	Austral Group S.A.A. Peru	Peru	jrojas@austral.com.pe
Joseph Warren	Stony Brook University	US	joe.warren@stonybrook.edu
Julek Chawarski	Memorial University of Newfoundland	US	Julek.Chawarski@mi.mun.ca
Kathryn Gavira O'Neill	Satlink	Spain	kgo@satlink.es
Kevin M. Boswell	Florida International University	US	kevin.boswell@fiu.edu
Kjetil Gjeitsund Thorvaldsen	DTU Aqua, National Institute of Aquatic Resources	Denmark	kjgth@aqua.dtu.dk
Lars Nonboe Andersen	Simrad	Norway	lars.nonboe.andersen@simrad.com
Laurent Berger	Ifremer Centre de Brest	France	Laurent.Berger@ifremer.fr
Lawrence Hufnagle	Northwest Fisheries Science Center	US	Lawrence.C.Hufnagle@noaa.gov
Lilian Lieber	Queen's University Belfast	UK	l.lieber@qub.ac.uk

Lucio Calise	Zunibal, S.L.	Spain	lucio.calise@zunibal.com
Lu Guan	University of Victoria	Canada	lguan@uvic.ca
Marian Peña	Centro Oceanografico de Baleares	Spain	marian.pena@ieo.es
Mariano Gutierrez Torero	Humboldt Institute of Marine and Aquacul-ture Research	Peru	msgutierrezt@gmail.com
Marissela Pozada	Instituto del Mar del Peru	Peru	mpozada@imarpe.gob.pe
Mathieu Doray	Ifremer Nantes Centre	France	Mathieu.Doray@ifremer.fr
Matthias Schaber	Institute of Sea Fisheries	Germany	matthias.schaber@thuenen.de
Maxime Geoffroy	Memorial University of Newfoundland	Canada	Maxime.Geoffroy@mi.mun.ca
Mei Sato	College of Earth, Ocean and Atmospheric Sciences	US	msato@coas.oregonstate.edu
Miles Parsons	Center for Marine Science and Technology	Australia	miles.parsons@student.curtin.edu.au
Muriel Barbara Dunn	Akvaplan-niva AS/ Polar Environmental Center	Norway	mbd@akvaplan.niva.no
Naig Le Bouffant	Ifremer Centre de Brest	France	Naig.Le.Bouffant@ifremer.fr
Natalia Gorska	University of Gdańsk	Poland	natalia.gorska@univ.gda.pl
Nicolás Algeria Landeros	Institutio de Investigacion Pesquera	Chile	nicoalegria1@gmail.com
Nils Olav Handegard	Institute of Marine Research	Norway	nils.olav.handegard@hi.no
Olavi Kaljuste	Institute of Coastal Research	Sweden	olavi.kaljuste@slu.se
Pablo Carrera	Centro Oceanografico de Vigo	Spain	pablo.carrera@ieo.es
Pablo Escobar-Flo-res	NIWA Wellington	New Zea-land	pablo.escobar-flores@niwa.co.nz
Patrice Brehmer	L'IRD en Bretagne	France	patrice.brehmer@ird.fr
Patricia Ordoñez	Polytechnic University of Valencia	Spain	patricia.ordonez@zunibal.com
Patrick Schneider	AQUASON	Spain	patrick@aquason.com
Paul Fernandes	University of Aberdeen	UK	fernandespg@abdn.ac.uk
Pilar Cordoba	Instituto Espanol de Oceanografia	Spain	pilar.cordoba@ieo.es
Rebecca Thomas	Northwest Fisheries Science Center	US	rebecca.thomas@noaa.gov
Richard O'Driscoll	NIWA Wellington	New Zea-land	richard.odriscoll@niwa.co.nz
Rika Shiraki	Furuno Espana	Japan	rika.shiraki.hc@furuno.co.jp
Rokas Kubilius	Institute of Marine Research	Norway	rokas.kubilius@hi.no

Rolf Korneliussen	Institute of Marine Research	Norway	rolf.korneliussen@hi.no
Rudy Kloser	CSIRO Marine and Atmospheric Research	Australia	rudy.kloser@csiro.au
Ryan Downie	CSIRO Marine and Atmospheric Research	Australia	ryan.downie@csiro.au
Salvador Peraltilla Neyra	Instituto del Mar del Peru	Peru	speraltilla@snp.org.pe
Sandra Parker-Stet-ter	Northwest Fisheries Science Center	US	sandy.parker-stetter@noaa.gov
Sebastien de Hal-leux	Saildrone Inc.	US	sebastien@saildrone.com
Sigurdur Thor Jónsson	Marine and Freshwater Research Institute	Iceland	sigurdur.thor.jonsson@hafogvatn.is
Stephane Gauthier	Institute of Ocean Sciences	Canada	stephane.gauthier@dfo-mpo.gc.ca
Stephen Brandt	Department of Fisheries and Wildlife	US	Stephen.brandt@oregonstate.edu
Steve Pearce	ASL Environmental Sciences Inc.	Canada	spearce@aslenv.com
Sophie Fielding	British Antarctic Survey	UK	s.fielding@bas.ac.uk
Susan Mærsk Lus-seau	Marine Laboratory	UK	s.lusseau@marlab.ac.uk
Sven Gastauer	Center for Marine Science and Technology	Australia	sven.gastauer@postgrad.curtin.edu.au
Tim Acker	BioSonics Inc.	US	tacker@biosonicsinc.com
Tim Ryan	CSIRO Marine and Atmospheric Research	Australia	Tim.Ryan@csiro.au
Timothy Whitton	School of Ocean Sciences	UK	t.whitton@bangor.ac.uk
Toby Jarvis	Southern Ocean Ecosystems Program	Australia	toby.jarvis@echoview.com
Tonny Algroy	Simrad	Norway	tonny.algroy@simrad.com
Tunia Porto Marques	University of Victoria	Canada	tunaip@uvic.ca
Wu-Jung Lee	University of Washington	US	wjlee@apl.washington.edu
Zacharias Kapelo-nis	Institute of Marine Biological Resources and Inland Waters	Greece	zkapelonis@hcmr.gr

Because of the remote meeting, we only have the participants Webex login name and their e-mail address for some participants.

List of participants: guests to the 2020 WGFAST meeting

Name	Institute	Country	E-mail
Adrian Ibieta	Fisheries Development Institute (IFOP)	Chile	adrian.ibieta@ifop.cl
Aron Paz			Aron.pazv@gmail.com
Camilo			croa@fiu.edu

Carlos Valdez Mego			car- losvaldezmego@gmail.com
Collins Onyongo On- gore	Kenya Marine Fisheries Institute	Kenya	collongore@gmail.com
Cyrille Poncelet	Ifremer	France	cyrille.poncelet@ifremer.fr
Isobel Cave	Saildrone Inc.	US	isobel.cave@saildrone.com
Jennifer Herbig	Marine Institute of Memorial University of Newfoundland	Canada	jennifer.herbig@mi.mun.ca
Jinshan Xu	Fisheries and Oceans Canada	Canada	jinshan.xu@dfo-mpo.gc.ca
Jsalveta			Ju.salvetat@gmail.com
Kimberly Sparling	Saildrone Inc	US	kim@saildrone.com
Luis			Lacruz.luis2886@gmail.com
Marta D'Elia	Florida International University	US	madelia@fiu.edu
Pierre Priou	Marine Institute of Memorial University of Newfoundland	Canada	pierre.priou@mi.mun.ca
Ramilla Assuncao			ramillavieira@hotmail.com
Richard Mangeni Sand			Rms28@st-andrews.ac.uk
Savannah LaBua	Florida International University	US	slabua92@gmail.com
SG Conti			Stephane.conti@espci.org
Youssouph Coly	University of Ziguinchor (UASZ)	Senegal	Youssou- phcoly98@gmail.com
Yang	University of St. Andrews	UK	yyy1@st-andrews.ac.uk

Annex 2: Resolutions

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

2019/FT/EOSG09 **A Working Group on Fisheries Acoustics, Science and Technology (WGFAST)**, chaired by J. Michael Jech, USA, will work on ToRs and generate deliverables as listed in the Table below.

	Meeting dates	Venue	Reporting details	Comments (change in Chair, etc.)
Year 2020	22 April	Online meeting	Interim report by 22 May 2020 to ACOM-SCICOM	Michael Jech takes over as chair
Year 2021	19-23 April	Online meeting	Interim report by 30 June 2021 to ACOM-SCICOM	
Year 2022	25-28 April	Dakar, Senegal	Final report by 30 June 2022 to ACOM-SCICOM	

ToR descriptors

ToR	Description	Background	Science Plan codes	Duration	Expected Deliverables
a	Collate information on acoustic related research and surveys, and interactions with ecosystem and assessment expert groups.	a) Science Requirements b) Advisory Requirements A summary of the information will be presented in the final report	3.1, 3.2, 3.4	3	
b	Review presented recent work within the topics: “Acoustic methods to characterize populations, ecosystems, habitat, and behaviour”; “Acoustic characterization of marine organisms“; and “Emerging technologies, methodologies, and protocols“. Provide guidance by identifying: (1) where training opportunities could be developed; and (2) gaps in knowledge and challenges that should be prioritized by the community.	Create a venue for informing the group members on recent activities and seeking input to further development. An overview of the different contributions and guidance will be presented in the annual report	3.3, 4.1, 4.4	1, 2, 3	
c	Organize a conference session on integrating fisheries acoustics with ecosystem assessment and monitoring at an international scientific meeting such as ASC.		3.1, 3.2, 4.1	2 or 3	

d	Develop, and maintain acoustic metadata and data format conventions and coordinate with acoustic survey groups.	Data format conventions for acoustic metadata and data are required for efficient data interchange and processing of acoustic data, but are lacking in the fisheries acoustics field. CRR 341 (2018) and SISP 4 (2016) have partially addressed this need, but further types of data and acoustic equipment need to be supported.	3.2, 3.5, 4.2	1, 2, 3	Updated metadata convention publication (new guide/handbook series) Revised sonar-netcdf4 convention publication that includes echosounder data (new guide/handbook series
e	Develop and recommend procedures for collecting and processing quality acoustic data in inclement weather.	Acoustic data are collected from a variety of vessels that respond to inclement weather in diverse ways. Procedures are needed to provide quality control for data collected in inclement weather to stock assessment.	3.3, 3.6	1	CRR; recommendations on methodology improvements to acoustic survey coordination groups to implement on surveys and update SISPs

Summary of the Work Plan

Year 1	Produce the annual overview of recent developments within the field. Produce an ICES CRR recommending procedures for collecting and processing quality acoustic data in inclement weather. Develop and maintain metadata and acoustic data formats.
Year 2	Produce the annual overview of recent developments within the field. Propose a conference session at an international scientific meeting. Develop and maintain metadata and acoustic data formats.
Year 3	Produce the annual overview of recent developments within the field. Collate information on acoustic related research and surveys. Develop and maintain metadata and acoustic data formats. Publish new guides with updated metadata convention and revised sonar-netcdf4 convention publication that includes echosounder data.

Supporting information

Priority	Fisheries acoustics and complementary technologies provide the necessary tools and methods to implement the ecosystem approach to fisheries management within ICES and research into their application and further development is vital.
Justification for venue 2022 (in non-ICES member country)	WGFAST has a long and rich history of collaborating with our West African partners, and hosting a meeting in Senegal will facilitate the participation of scientists from Africa (particularly West Africa and the south Mediterranean area), improve the exchange of science and communication on Fisheries Acoustics, Science and Technology between European and African colleagues, and promote the UN Ocean decade initiative. We expect to recruit several new members to WGFAST and even at higher levels, gain new "observatory" countries for ICES in Africa.
Resource requirements	No new resources will be required. Having overlaps with the other meetings of the Working, Planning, Study and Topic Groups increases efficiency and reduces travel costs.
Participants	The Group is normally attended by some 60-100 members and guests.
Secretariat facilities	None.
Financial	No financial implications.

Linkages to ACOM and groups under ACOM	Stock assessment groups using acoustic abundance indices.
Linkages to other committees or groups	The work in this group is closely aligned with complementary work in the FTFB Working Group. The work is of direct relevance to a number of data collection and coordination groups within EOSG (e.g. WGIPS, WGBITS, WGISUR)
Linkages to other organizations	The work of this group is closely aligned with similar work in FAO, the Acoustical Society of America, the South Pacific Regional Fisheries Management Organization, the Commission for the Conservation of Antarctic Marine Living Resources, and the American Fisheries Society.

Annex 3: Presentation Abstracts

Acoustic Methods to Characterize Populations, Ecosystems, Habitat, and Behaviour

Probabilistic school classification of multiple species in acoustic echograms based on machine learning

A. Lekanda[1], G. Boyra[1] and M. Louzao[1]

[1] AZTI, *Txatxarramendi Ugartea z/g, 48395 Sukarrieta (Bizkaia, Spain), e-mail: alekanda@azti.es*

Multifrequency trawl-acoustic surveys are used worldwide for continuous monitoring of pelagic ecosystems. Acoustic backscattering energy partitioning in different species is typically done by visual scrutiny of the echograms with the aid of trawl species composition, which may be subjective and time-consuming. Alternatively, machine learning techniques may provide well-stablished, objective, and reproducible methods for automatic school classification in acoustic echograms. The pelagic ecosystem is a diverse one, where many species co-occur in space and time, being mixed catches very common during scientific surveys. However, most of the school classification models are built using single species composition trawls due to difficulties to assign a class to each school in multispecific trawls. The present study has the aim of developing and comparing different probabilistic multivariate models to identify pelagic species in mixed scenarios based on trawl catch proportions. In addition to the standard predictors, a novel variable, collective mean TS per nautical mile measured on the periphery of the schools, has shown to play an important role in species discrimination. The methods were applied on data from 7 consecutive years of an acoustic survey in the Bay of Biscay. Preliminary results yielded classification performances near 95 % in classifying 10 different pelagic species.

Acoustics surveys in North-West Africa reveal a spatial shift of small pelagic fish related to intense warming

Abdoulaye SARRE[1], Hervé DEMARCQ[2], Noel KEENLYSIDE[3], Jens-Otto KRAKSTAD[4], Salaheddine EL AYOUBI[5], Ahmed Mohamed JEYID[6], Saliou FAYE[1], Adama MBAYE[1], Momodou SIDIBEH[7], Patrice BREHMER[8,1]

[1]*ISRA, Centre de Recherches Océanographiques de Dakar-Thiaroye, CRODT, BP 2241, Dakar, Sénégal*

[2]*IRD, Institut de Recherche pour le Développement, UMR Marbec, Centre de Sète, Avenue Jean Monnet, CS 30171, 34203 Sète cedex, France;*

[3]*Geophysical Institute, Univ of Bergen and Bjerknes Centre for Climate Research, Norway;*

[4]*Institute of Marine Research, P.O. Box 1870 Nordnes, N-5817 Bergen, Norway;*

[5]*INRH, Institut National de Recherche Halieutique, Casablanca, Maroc ;*

[6]*Institut Mauritanien de Recherche Océanographique et des Pêches (IMROP), BP 22, Nouadhibou, Mauritanie,*

[7]*Fisheries Department (FD), Banjul, The Gambia ;*

[8]*IRD, Univ Brest, CNRS, Ifremer, LEMAR, Dakar, Sénégal*

In the southern part of the CCLME, northward shifts in the distribution of sardinella and other species have been attributed to an intense warming trend in sea surface temperature. Such

warming is higher than 0.5 °C per decade in the southern part of the CCLME, the greatest increase in SST observed in the tropical Atlantic. The acoustics abundance of *Sardinella aurita*, the most abundant species along the coast, has increased in the subtropics and fallen in the intertropical region. Small pelagic acoustics assessment surveys confirm a robust northward shift of around 180 km per decade in *S. aurita* habitat, while *S. maderensis* did not move significantly. Spatial shifts in biomass from 70 to 230 kilometres were observed for six others exploited small pelagic species during the last 20 years, at similar ranges to those recorded for surface isotherms in their habitat. The change occurs more quickly in the central part of the CCLME. This shift widely overlaps national boundaries and combined to overexploitation adds a new threat on the pelagic fish resources. Such results are an advocacy to continue to lead acoustics survey on small pelagic in the West Africa.

Spatiotemporal variability of micronekton at two fronts in the central North Pacific

R. Domokos

Pacific Islands Fisheries Science Center, NMFS, NOAA, 1845 Wasp Blvd, Bldg. 176, Honolulu, Hawaii, 96819, USA.

The North Pacific Subtropical Frontal Zone (STFZ) seasonally aggregates economically important fish and protected species, hypothesized in results of enhanced prey biomass due to convergence at the Subtropical Front (STF) and a sharp northwards increase in primary productivity, the Transition Zone Chlorophyll Front (TZCF), both prominent in the STFZ. Given existing data gaps, characteristics of micronekton, forage for top predators, were investigated using multi-frequency active acoustics and the effects of STF and TZCF accessed from a combination of *in situ* and satellite environmental data. Results of this study show a significant increase in micronekton biomass across the STF with differing taxonomic composition from south to its north. The Pacific Decadal Oscillation as well as mesoscale events and subsurface processes were indicated to play important roles in affecting micronekton distribution and/or biomass. The largescale 2014-2017 extreme warming event positively corresponded with micronekton biomass and changes in its composition in the region, findings that are in agreement with expectations. Results of this work highlight the importance of our need to further our understanding of the role of largescale variability, extreme events, and subsurface processes on micronekton in the region's ecosystem to improve management of our living marine resources.

Development of a hydroacoustic technique for determination of the orientation of aggregated Baltic herring

A. Żytko[1], N. Gorska[2], D. Chu[3], and B. Schmidt[4]

[1]*Institute of Oceanology PAS, Powstańców Warszawy 55, 81-712 Sopot, Poland, azytko@iopan.pl;*

[2]*Institute of Oceanology PAS, Powstańców Warszawy 55, 81-712 Sopot, Poland, gorska@iopan.pl;*

[3]*NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112, USA;*

[4]*National Marine Fisheries Research Institute, ul. Kołłątaja 1, 81-332 Gdynia, Poland, bschmidt@mir.gdynia.pl;*

The spatial distribution of fish orientation is a very important factor influencing their target strength (TS), and thus the hydroacoustic assessment of fish biomass. A method is being developed to estimate the orientation distribution of the Baltic herring in schools by comparing the measured herring TS histograms with the TS histograms obtained from the theoretical backscattering model. The target strength data were collected by the National Marine Fisheries Research

Institute in Gdynia (R/V *Baltica*) in the Polish component of the Baltic International Acoustic Survey (*BIAS*) surveys under the EU Data Collection Framework (CDF). We employed a modified resonance scattering model to describe backscattering by herring swimbladders, using available morphometry data of Baltic Herring. Target strength histograms are generated based on the scattering models for different probability density functions of fish orientation, and are then compared with the measured TS histograms. Based on the similarity of the histograms, the most likely distribution of herring orientation can inferred.

Can target strength research improve acoustic survey indices in the Baltic?

N. Larson

SLU, Sweden

This study analyses the effects of target strength on the acoustic indices of abundance produced for stock assessment. The BIAS and BASS surveys produce indices of abundance for herring and sprat in the Baltic Sea, based on a b_{20} value of -71,2 for both these two species and stickleback. The three species together constitute more than 99% of the abundance. Using published b_{20} values from the Baltic Sea, different indices of abundance were calculated. Then, systematic changes were made to these b_{20} values and new indices were created, which were compared with the original indices, in order to analyse the tolerance of a wrong target strength. Results show that changing one or two b_{20} to a more accurate value can produce a bigger error than keeping the b_{20} values used in BIAS. Furthermore, the difference in b_{20} between the species in the community has greater influence on index error than the difference between the TS found in the literature and the TS used in BIAS. We propose a more ecological approach to the study of target strength, with a focus on investigating the difference in TS between the species, instead of solely studying TS for individual species. We discuss as well how to best introduce a new TS value in a running time series when recalculation of the whole time series is impossible.

Hiding in plain sight: Predator avoidance behaviour of mesopelagic fish during foraging

K.G Thorvaldsen[1], S. Neuenfeldt[1], P. Mariani[1], and J. R. Nielsen[1]

[1]*Kemitorvet 201, 2800 Kgs Lyngby, kjgth@aqua.dtu.dk, stn@aqua.dtu.dk;*

[2]*Kemitorvet 201, 2800 Kgs lyngby, pat@aqua.dtu.dk:Kemitorvet 201, 2800 Kgs lyngby,*

[2]*Kemitorvet 201, 2800 Kgs lyngby, rn@aqua.dtu.dk*

Mesopelagic fishes are ubiquitous, ecologically important as well as a potential protein resource. However, how mesopelagic fish maneuver in their 3D environment, facilitating encounters with prey and avoiding predators is relatively unknown. Individual behavioral studies have been historically challenging due to previous limitations to technology. During a short period, we observed high-resolution 3d-trajectories of mesopelagic fishes within a Norwegian fjord. We acoustically tracked the swimming trajectories of juvenile and adult *M.muelleri* and *B. glaciale* separated within two distinct vertical layers, measured swimming speed, and used a self-overlap model (ψ) to analyse the geometry of the trajectories. Our aim was to investigate, if and how the fishes were optimizing their swimming behaviour. We found that mesopelagic were moving actively within a large range between ballistic to convoluted movements. Some of the fishes were moving in a manner that minimized self-overlap in relation to prey search (ψ<0.1), while increasing self-overlap with regards to a piscivorous predator (ψ>0.6) with a hypothetical visual range of 1 m, while the large variation can possibly be explained by several factors driving the different behaviors.

Monitoring Seasonal Fish Migration and Fishing Mortality in the Tonle Sap River, Cambodia

J. K. Horne[1], J.A. Swan[1], G.W. Holtgrieve[1]

[1]*School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195, USA, jhorne@uw.edu, jswan13@uw.edu, gholt@uw.edu*

Over 60 million Cambodians rely on fisheries and aquaculture to supply 80% of their animal protein and micronutrients, with the majority sourced from the Tonle Sap River. From November through February, commercial and artisanal fisheries catch over 130 species that migrate from the Tonle Sap Lake to the ocean after the rainy season. Two monitoring stations (solar powered, WBTminis, 200 kHz) were installed on upstream and downstream commercial fishing platforms and programmed to sample at 1 Hz for 15 minutes every hour of the day. Data are sent through a wireless network to an AWS server in Singapore and then downloaded to a local server. Scripts are used to automate data file creation, most processing, exports, and standard graphic production for each week. Fish densities peaked at night and in association with a four-day window around the full moon. River depth decreased 2.5 – 3 m through the two-month fishing season. Differences in fish flux at the two stations is being developed into a fishing mortality index. This system can be used as a near-real-time monitoring system for inseason fisheries management.

Summarizing low-dimensional patterns in long-term echosounder time series from the U.S. Ocean Observatories Initiative network

W.-J. Lee[1] and V. Staneva[2]

[1]*Applied Physics Laboratory, University of Washington, 1013 NE 106th St, Seattle, WA 98105, USA, leewj@uw.edu;*

[2]*eScience Institute, University of Washington, 3910 15th Ave NE, Seattle, WA 98195, USA, vms16@uw.edu.*

As a remote sensing tool, moored echosounders have played an important role in observing temporal changes of animal distributions in the water column over large temporal scales, ranging from days, months to seasons and even years. In this work we take advantage of the power of matrix decomposition techniques in exploiting regularity in the data to automatically discover low-dimensional structures in large data sets, and develop a methodology that can effectively remove noise and extract dominant daily echogram patterns from long-term echosounder series collected by moored echosounders deployed by the U.S. Ocean Observatories Initiative (OOI). These echosounders are located on the continental shelf and the shelf break in the rich Northern California Current System that is strongly influenced by seasonal upwelling. The echosounders are collocated with a suite of oceanographic sensors, allowing systematic analysis of multi-modal data streams. Our analysis results in an array of daily echogram patterns (components) whose time-varying linear combination (activations) captures major structures in these time series. Together, these components and variations provide a compact representation that allows intuitive interpretation of such a long-term observational dataset.

Monitoring salmon with broad band echo sounders – investigate acoustic parameters as indicators for welfare

M. F. Rong[1], F. Oppedal[2], G. Pedersen[2], N. O. Handegard[2] and T. N. Forland[2]

[1]*University of Bergen, 5007 Bergen, Maren.Rong@student.uib.no;*

[2]*Institute of Marine Research, 5004 Bergen, Tonje.Nesse.Forland@hi.no*

Salmon lice is challenging for salmon aquaculture. A new innovative preventative solution is to submerge the salmon net-pen to avoid the surface-dwelling infestative lice larvae. However, the physostomous salmon require daily air surface access or the swim bladder will deflate. The negative buoyancy lead to increased swimming and positive tilt angles. Over extended time (2-3 weeks), the appetite, growth rate is reduced, spine compressed and more injuries appear resulting in poor welfare. To study the swim bladder inflation level as an indicator for fish well-being, we deployed three split beam 70, 120 and 200 kHz broad-band transducers under a net-pen for 30 days. Using an underwater net roof, salmon was denied air access for 23 days and the change in swim bladder inflation and fish behavior was observed. A method for early detection of swim bladder deflation from acoustic FM pulses and CW pulses are being developed, and we already see clear patterns in the TS attenuating by 10 dB. Results can be used to develop automatic alarms on lack of swim bladder inflation/poor welfare and have already given us new key knowledge of backscattering from the salmon swim bladder with degree of fulness.

Comparative analysis of pelagic compartment organization by bathymetric strata in the Canary Current Large Marine Ecosystem

Anne Mouget[1,2], Patrice Brehmer[2,3], Mohamed Ahmed Jeyid[4] Abdoulaye Sarré[5], Salahedine El-Ayoubi[6], Ndague Diogoul[7,5,2], Momodou Sidibeh[8], Yannick Perrot[2]

[1]*Muséum National d'Histoire Naturelle (MNHN), Station de biologie marine, CRESCO, Dinard, France*

[2]*Institut de Recherche pour le Développement (IRD), UMR Lemar, Campus Ifremer, Délégation régionale IRD ouest France, 29280, Plouzané, France*

[3]*Commission Sous Régional des Pêches, CSRP, SRFC, Dakar, Sénégal*

[4]*Institut Mauritanien de Recherche Océanographique et des Pêches (IMROP), BP 22, Nouadhibou, Mauritania*

[5]*Institut Sénégalais de Recherche Agricole (ISRA), Centre de Recherche Océanographique de Dakar Thiaroye (CRODT), Pôle de recherche de Hann, Dakar, Sénégal*

[6]*Institut National de Recherche Halieutique (INRH), Casablanca, Maroc*

[7]*Centre de Recherches Océanologiques (CRO), BP V 18 Abidjan, Côte d'Ivoire*

[8]*The Fisheries Department (FD), 6 marina parade, Banjul, The Gambia*

The Canary Current Large Marine Ecosystem (CCLME) is located along the North West African coast from Morocco to Guinea Bissau. In this work, 14 Nansen fisheries acoustics surveys have been led from the southern border of Senegal (12.15°N) to the Cape Blanc (20.77°N) during the hot wet season, *i.e.*, outside the seasonal upwelling period, from 1995 to 2015. The aim of this study was to scrutinize the water column organization in a bathymetric gradient starting from the coast to the offshore area, discretised in three areas: inshore (< 150m), transition (150-500m) and off shore (> 500m). Here, we worked on acoustic sound scattering layers (SSL) and on the whole water column through echointegrated data (EI). SSL and EI descriptors highlighted significant difference between the three depth strata. Study of the Diel Vertical Migration (DVM) highlighted that volume backscattering coefficient (proxy of pelagic abundance) vertical profile

from transition area has a pattern globally similar to offshore one while inshore presented an inversed pattern. Analyse of annual change using EI descriptors reveal one common trait: the number of SSLs significantly increase whatever the depth strata considered. This study highlights differences and similarity in water column organization between depth strata.

Switching off the Sun to observe the twilight zone spatial dynamics across Saint-Paul and New-Amsterdam Islands, Southern Indian Ocean

L. Izard1, N. Fonvieille2, D. Nerini2, A. Lebourges-dhaussy3, G. Roudaut3, J. Habasque3, C. Cotté1

[1]*Sorbonne University, CNRS, IRD, MNHN, Oceanography and Climate Laboratory: Experiments and Numerical Approaches (LOCEAN-IPSL), Paris, France*

[2]*Aix-Marseille University, Toulon University, CNRS, IRD, Mediterranean Institute of Oceanography (MIO), Marseille, France*

[3]*Marine Environmental Sciences Laboratory (LEMAR), UBO-CNRS-IRD-Ifremer IUEM, Plouzané, France*

Information on micronekton (> 1 cm organisms) is globally scarce in the open ocean, and its vertical and horizontal distribution in relation to oceanographic structures is poorly known. The complex biodiversity composing micronektonic functional groups lead to even more challenging interpretations of their spatial dynamics. Advanced generations of echosounders emit simultaneously several acoustic signals (multi-frequency device), allowing a finer view of the micronektonic community. While data becomes more abundant and complex, it is crucial to develop statistical tools aiming to objectively extract key components of its variability. In this study, we analyse data recorded onboard the R/V Marion Dufresne from an EK80 echosounder emitting at 18, 38, 70, 120 and 200 kHz. We developed a Multivariate Functional Data Analysis method to identify patterns in micronekton structures across Saint-Paul and New Amsterdam economic exclusive zone, at the boundary between vast oceanic domains. This approach proposes an objective method to analyse the vertical backscatter distribution and quantify temporal and spatial modes of variability in multivariate acoustic data. By filtering the temporal mode, we uncovered a latitudinal acoustic pattern in concordance with hydrological features and biological samples distribution. Such methods could be implemented at a global or local scale and allow 3-D modelling of micronekton structuring.

A finer look into the twilight zone: comparing acoustic records from an animal-borne miniature sonar and a multifrequency echosounder

N. Fonvieille1*, L. Izard3, P. Goulet2, C. Guinet2, D. Nerini1, A. Lebourges, G. Roudaut, J. Habasque, J. Chevassu, C. Castrec, M. Tournier2, B. Picard2, M. Johnson and C. Cotté3

1 Mediterranean Institute of Oceanography (MIO), Marseille, France,

2 Centre of Biological Studies Chizé, Villiers-en-Bois, France

3 Laboratory of Oceanography and Climate, Experiments and numerical Approaches (LOCEAN), Paris, France

An animal-borne miniature active echo-sounder has been recently deployed on southern elephant seals (*Mirounga leonina*) from the Kerguelen and Argentinian colonies. This high frequency sonar (1.5 MHz) has shown a strong potential in detecting small mid-trophic level targets (zooplankton and micronekton). Relative abundance and distribution can be assessed, allowing to observe temporal (diel migration) and spatial patterns of plankton. However, the interpretation

of the collected data remains uncertain. To address this lack of information, we conducted *in situ* experiments onboard the Marion Dufresne vessel in the Southern Ocean (10th February to 6th March 2022). The microsonar was fixed on the rosette sampler at 13 locations and attached 16 times to a trawling net (4 mm mesh). Records will be analyzed applying a recent method developed on elephant seals data to detect targets in the beam and estimate organisms abundance. The result will be compared with biological samples and backscattering layers detected by a multifrequency EK80 echosounder (18, 38, 70, 120 and 200 kHz), offering an acoustic landscape of the seals foraging area. This study will benefit to ongoing research regarding biological fields visited by the elephant seals, bringing precision on microsonar target detection capacities.

Fish aggregation around North Sea oil and gas platforms

J. M. Lawrence[1] and P.G. Fernandes[1]

[1]*School of Biological Sciences, Tillydrone Avenue, University of Aberdeen, Scotland. AB24 2TZ*

Many offshore oil and gas rigs will soon require decommissioning. In northern Europe, current legislation requires their complete removal, but it is unclear what the environmental impacts of this will be. Fish aggregate at offshore structures, but the horizontal extent and strength of this aggregation remains unknown. Here, we use fisheries acoustic data collected during a bottom-trawl survey of the North Sea to investigate the relationship between fish distributions and rig densities. Acoustic backscatter from schooling fish was isolated and quantified, and echoes from individual, non-schooling, fish were processed to give relative areal fish densities. The distribution of offshore oil and gas rigs was estimated using a surface of rig kernel density. Parametric (generalised linear modelling) and non-parametric (random forests) modelling revealed relationships between rig density and the fish density of both schooling and individual fish, with higher densities of fish found in areas of higher rig density. However, very few data were collected within 500m of rigs due to the exclusion zones in force. Future work will address this by negotiating access to the exclusion zones with operators and using a novel platform (an uncrewed surface vehicle) which can safely survey much closer to rigs (within 10s of metres).

Characterizing predator dive patterns on a common prey base from stationary echosounders in Antarctica

A. P. Annasawmy[1], J. K. Horne[1], Christian S Reiss[2], and Gavin J Macaulay[3]

[1]*School of Aquatic and Fisheries Sciences (SAFS) and Cooperative Institute for Climate, Ocean and Ecosystem Studies (CICOES), University of Washington, Seattle, USA*

[2]*Antarctic Ecosystem Research Division, NOAA Southwest Fisheries Science Center, La Jolla, California, USA*

[3]*Institute of Marine Research, Norway*

The Antarctic Peninsula, which stretches from Antarctica towards South America, is a critical habitat to penguins and other seabirds, seals, and whales, with Antarctic krill (*Euphausia superba*) serving as a significant diet component. Kongsberg WBAT echosounders fixed on moorings were deployed close to Deception and Nelson Islands in Bransfield Strait. Aggregations of krill were detected using Echoview's school detection module and classified in three categories using hierarchical clustering on a metric suite including NASC, mean depth, center of mass, inertia, equivalent area, aggregation index, and proportion occupied. 'V', 'U' and 'W'- shaped predator dive profiles were visible in the echograms from the moorings at both sites. A dive consisted of a descent from the surface, time at depth and an ascent. Additional dive metrics related to the descent, bottom, and ascent durations, maximum dive depth and wiggle counts, were measured using Echoview. Dive angles were measured and used to calculate descent and ascent velocities using ImageJ software. Potential predators were determined by hierarchical clustering of dive metrics and classified in four groups. This study advances knowledge on detection and classification of predator dive profiles for predator-prey interaction studies using stationary platforms with echosounders.

Acoustic Characterization of Marine Organisms

Abundance estimates of micronekton organisms in tropical Pacific Ocean from trawl sampling, acoustic survey & backscatter models

L. Barbin[1], A. Lebourges-Dhaussy[2], V. Allain[3], G. Roudaut[4], J. Habasque[5], A. Receveur[6], P. Lehodey[7] and C. Menkes[8]

[1]*IRD Noumea, New-Caledonia, laure.barbin@ird.fr;*

[2]*anne.lebourges.dhaussy@ird.fr, IRD Brest, France;*

[3]*ValerieA@spc.int, SPC (Pacific Community), Noumea, New-Caledonia;*

[4]*gildas.roudaut@ird.fr, IRD Brest, France;*

[5]*jeremie.habasque@ird.fr, IRD Brest, France;* [7]*aurore.receveur@fondationbiodiversite.fr, CESAB – FRB, Montpellier, France;*

[8]*patrickl@spc.int, (Pacific Community), Noumea, New-Caledonia & CLS, Toulouse, France;*

[8]*IRD Noumea, New-Caledonia, christophe.menkes@ird.fr;*

Micronekton, ubiquitous to all oceans plays a pivotal role in the trophic organisation and constitutes the food of most top predators. Due to the paucity of sampling, estimates of these organisms abundance and specie distribution is largely unknown. Such sampling comes either from trawls or active acoustic. One key question remains on how these two means of observations compare and complement each other. Our study focuses on the analysis of active acoustic data from 8 oceanographic surveys in South Pacific. Two active acoustic methods were used simultaneously: hull-mounted echo sounders and a wideband profiler. These data are examined together with biological samples obtained by trawling which brings a ground truth to the acoustic measurements. By comparing the *in situ* acoustic response, the modelled response from biological sampling and the density of organisms calculated from wideband profiles, we obtain an order of abundance estimates of micronekton in depth layers. This comparison enables us to estimate the observed differences of organisms abundance between the three methods and helps understanding. Over the entire cruises, the average ratio between abundances derived from acoustic sounders and those obtained from trawled samples is on the order of 10 but varies strongly with depth.

A DWBA based fluid shell model towards improved modelling of weakly scattering organisms

S. Gastauer[1,2], D. Chu[3]

[1]*Thünen-Institute of Sea Fisheries, 27572 Bremerhaven, Germany sven.gastauer@thuenen.de;*

[2]*Scripps Institution of Oceanography, University of California, San Diego, La Jolla CA 92037, United States;*

[3]*NOAA Fisheries, NWFSC, 2725 Montlake Blvd. E., Seattle, WA 98112*

Acoustic scattering is largely dependent on the acoustic impedance, shape and orientation of marine organisms. Including information on the internal structure, such as lipid sacks or other body parts with a density or sound speed different from the surrounding body can improve the accuracy of scattering models. Acoustic scattering models are especially useful to help us better understand the complex signals we receive from broadband frequency spectra and can help us to better interpret collected acoustic data. Here we present an analytical 3D Distorted Wave Born Approximation (DWBA) model with a fluid shell. We compare the results of our model outputs to those from a computationally more intense Boundary Element Mode model outputs, provide examples on how to size weakly scattering targets theoretically based on the broadband spectrum, and discuss limitations of the presented models.

Study of the acoustic reflectivity of pelagic fishes in the Mediterranean Sea: from ex-situ experiments to backscattering model.

A. Palermino1[1,2], A. De Felice2[1], G. Pedersen3[3], G. Canduci4[1], I. Biagiotti5[1], I. Costantini6[1], M. Centurelli7[1], R. Korneliussen8[3], and I. Leonori9[1]

[1]*CNR-National Research Council, IRBIM-Institute of Marine Biological Resources and Biotechnologies, Largo Fiera della Pesca, 1 - 60125 Ancona, Italy; antonio.palermino@irbim.cnr.it 1; andrea.defelice@cnr.it 2; giovanni.canduci@cnr.it 4; ilaria.biagiotti@cnr.it 5; ilaria.costantini@cnr.it 6; michele.centurelli@irbim.cnr.it 7; iole.leonori@cnr.it 9*

[2]*ALMA MATER STUDIORUM, Università di Bologna, Via Zamboni, 33 - 40126 Bologna, Italy, antonio.palermino2@unibo.it 1*

[3]*Institute of Marine Research, Nykirkekaien 1, 5004, Bergen, geir.pedersen@hi.no, 3; rolf.korneliussen@hi.no 8*

Accuracy of the target strength is one of the most important sources of uncertainty in fish biomass estimates by acoustic methods. In order to convert the volume backscattering strength to an absolute number-density of species, the knowledge of species-specific acoustic reflectivity is essential. Likewise, observation of broadband backscatter proprieties might be powerful in distinguishing between species, especially for regions characterized by mixed-species fisheries such as the Mediterranean Sea. However, at date, there are no works on the use of broadband in this basin and only sardine and anchovy are well studied using discrete frequencies. We performed four ex-situ experiments in the Adriatic Sea using a novel approach on tethered specimens of *Scomber colias* and *Trachurus mediterraneus*. Successively, 45 individuals of the two species were collected during the MEDiterranean International Acoustic Survey (MEDIAS) 2020 and 2021 for the application of backscattering models. Here the results on new conversion parameter values (b20) obtained through these two methods are compared. Moreover, the first insights on the broadband backscatter of fishes in the Mediterranean Sea are given. Our results on backscattering models show the potential of broadband and multi-frequencies approaches to distinguish between species and sizes for *S. colias* and *T. mediterraneus*.

Gas-baldder elongation estimation of mesopelagic organisms from wideband target strength frequency response

B. Khodabandeloo[1], E. Ona[2], G. Pedersen[3], R. Korneliussen[4], W. Melle[5] and T. Klevjer[6]

[1,2,3,4]*Ecosystem Acoustics Research Group, Institute of Marine Research, P.O. Box 1870 Nordnes, 5817 Bergen, Norway, [1]babak.khodabandeloo@hi.no; [2]egil.ona@hi.no; [3]geir.pedersen@hi.no, [4]rolf.korneliussen@hi.no*

[5,6] *Plankton Research Group, Institute of Marine Research, P.O. Box 1870 Nordnes, 5817 Bergen, Norway,* [5]*webjoern.melle@hi.no,* [6]*thor.klevjer@hi.no*

Backscattered acoustic energy from a target contains information about its shape, size, orientation, and material properties. The high uncertainties in the worldwide biomass estimates of mesopelagic fish limits our understanding of their actual importance and role in the ocean ecosystems. The major proportion (~99%) of the volume backscattering of deep scattering layers measured by a 38 kHz vessel-mounted echosounder can be due to the gas-bearing organisms, even if these organisms might make up a small fraction of the total biomass. Morphological features of the gas-filled organs have noticeable effects on the backscattering. Improved knowledge about the volume and actual shape (elongation) of swimbladders of mesopelagic fishes has been identified as important factors to reduce the overall uncertainties in acoustic survey estimates of mesopelagic biomass. Here, using the first and second resonance frequencies of a gas bubble's TS frequency response, a method is suggested to estimate its elongation. The method was applied to the *in situ* measured wideband (33-380 kHz) TS of single mesopelagic gas-bearing organisms from two stations in the North Atlantic (NA) and Norwegian Sea (NS). For the selected targets, the elongation of gas-bladder from the NS and NA stations were 2.86±0.50 and 1.49±0.52, respectively.

A bi-frequency discrimination method of copepods in the Senegalese coast

Ndague DIOGOUL[1,6*], Patrice BREHMER[1,2,6], Yannick PERROT[2], Elizandro Rodrigues RODRIGUES[3], Abou THIAM[4], Salaheddine EL AYOUBI[5], Anne MOUGET[2], Abdoulaye SARRÉ[6], and Anne Lebourges-Dhaussy[2]

[1] *IRD, Univ Brest, CNRS, Ifremer, LEMAR, Campus UCAD-IRD de Hann, Dakar, Senegal*

[2] *IRD, Univ Brest, CNRS, Ifremer, LEMAR, DR Ouest, Plouzané, France*

[3]*Instituto Nacional de Desenvlvimento das pescas, Cabo Verde*

[4]*University Cheikh Anta Diop UCAD, Institute of Environmental Science (ISE), BP 5005, Senegal*

[5]*Institut National de Recherche Halieutique INRH, Agadir, Morocco*

[6]*Institut Sénégalais de Recherches agricoles ISRA, Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), BP 2221 Dakar, Senegal*

The Canary Current Large Marine Ecosystem (CCLME) is one of the most productive marine ecosystem worldwide and is key for food security for numerous African countries. Nevertheless, its function remains poorly described and ecosystemic data collection are rare. Copepods are the key macrozooplankton group in the CCLME but their dynamic, their distribution and even their abundance remain poorly documented. Multinet net data allowed identifying large Copepod in CCLME. As small pelagic fish assessment acoustics survey were routinely done using 38 and 120 kHz frequencies, we used the same frequencies to propose a bi-frequencies inversion method to discriminate Copepod. We identified copepod backscatter using differences in volume backscattering strength (S_v). A close significant relationship were found between the size values of Copepod from multinet samples with those calculated by the acoustic highpass model. The correlation between copepod abundance and corresponding S_v were positive. This work showed that 38-120 kHz frequency can be used on Copepod and thus open the way to retrospective analysis in the CCLME. These results were important to better understand marine ecosystem, and constitute a first step for Copepod biomass estimation in the context of ecosystemic approach of small pelagic fish management and climate change.

Emerging Technologies, Methodologies, and Protocols

Echofilter: A Machine Learning Model Improves the Automated Placement and Standardization of the Line Defining the Ambit of Entrained Air

Scott C. Lowe[2,3], Louise P. McGarry[1], Jessica Douglas[1], Jason Newport[4], Sageev Oore[2,3], Christopher Whidden[2,4], and Daniel J. Hasselman[1]

[1]Fundy Ocean Research Centre for Energy (FORCE), 75 Alderney Drive, Dartmouth, Nova Scotia B2Y 2N7 Canada, louise.mcgarry@fundyforce.ca, jessica.douglas@fundyforce.ca, dan.hasselman@fundyforce.ca

[2]Faculty of Computer Science, 6050 University Avenue, Halifax, Nova Scotia B3H 4R2 Canada, scott.lowe@dal.ca, sageev@gmail.com, cwhidden@dal.ca

[3]Vector Institute, MaRS Centre, West Tower, 661 University Avenue, Toronto, Ontario M5G 1M1 Canada

[4]DeepSense, Dalhousie University, 6050 University Avenue, Halifax, Nova Scotia B3H 4R2 Canada

Understanding fish abundance and distribution in tidal energy streams is important for assessing risk presented by the introduction of tidal energy devices. Tidal currents favourable for development are characterized by complex hydrodynamics entraining air into the water. Algorithms available in Echoview are sufficient for automated detection of distinct and strongly reflective boundaries at the sea floor and sea surface. However, applying a single algorithm to identify the depth-of-penetration of entrained air is insufficient for a boundary that is discontinuous, depth-dynamic, porous, and widely variable across current flow speeds from slack tide to full flow at 5 m/s. We describe the development of a deep machine learning model that produces a pronounced and consistent improvement for the automated detection of the ambit of entrained air. Our model, Echofilter, is highly responsive to the dynamic range of turbulence conditions and sensitive to the fine-scale nuances in the boundary position, yielding a 95% agreement with human annotations. The time required to manually edit the line placement was reduced by half - doubling user productivity. The machine learning contribution to assessing the ecological impacts of tidal-stream energy devices is the improved analytical consistency and substantial improvement in the timeliness of analyses and subsequent reporting.

Quantitative processing of broadband data as implemented in a scientific split-beam echosounder

L. N. Andersen[1], D. Chu[2], N. O. Handegard[3], H. Heimvoll[1], R. Korneliussen[3], G. J. Macaulay[3], E. Ona[3], R. Patel[4] and G. Pedersen[3]

[1] Kongsberg Maritime AS, Strandpromenaden 50, 3191, Horten, Norway, lars.nonboe.andersen@km.kongsberg.com, harald.heimvoll@km.kongsberg.com;

[2] Fishery Resource Analysis and Monitoring Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Blvd. E. Seattle, WA, 98112, USA, dezhang.chu@noaa.gov;

[3] Marine Ecosystem Acoustics, Institute of Marine Research, Nykirkekaien 1, 5004 Bergen, nils.olav.handegard@hi.no, rolf.korneliussen@hi.no, gavin.macaulay@hi.no, egil.ona@hi.no, geir.pedersen@hi.no;

[4] Codelab Bergen AS, Thormøhlensgate 51, 5006 Bergen, Norway, ruben.patel@codelab.no

The use of quantitative broadband echosounders for biological studies and surveys offers considerable advantages over narrowband echosounders. These include improved spectral-based target identification and significantly increased ability to resolve individual targets. An understanding of current processing steps is required to fully utilize and further develop broadband acoustic methods in fisheries acoustics. We describe the steps involved in processing broadband acoustic data from raw data to frequency dependent target strength (TS(f)) and volume backscattering strength (Sv(f)) using data from the EK80 broadband scientific echosounder as examples. Although the overall processing steps are described and build on established methods from literature, multiple choices need to be made during implementation. To highlight and discuss some of these choices and facilitating a common understanding within the community, we have also developed a code which will be made publicly available and open source. The code follows the steps using raw data from two single pings, showing the step-by-step processing from raw data to TS(f) and Sv(f). This code can serve as a reference for developing own code or implementation in existing processing pipelines, as an educational tool and as a starting point for further development of broadband acoustic methods in fisheries acoustics.

Pseudograms: adding spatial context to EchoMetrics by embedding Sv values in output from underwater gliders

A. Silverman[1], J. R. Cermak[2], S.L. Danielson[2], and J. K. Horne[3]

[1]*University of South Florida, asilverman@usf.edu;* [2]*University of Alaska Fairbanks, jrcermakiii@alaska.edu, sldanielson@alaska.edu;* [3]*University of Washington, jhorne@uw.edu*

The EchoMetrics suite was developed to parsimoniously characterize acoustically detected, water column biomass. Data acquisition from alternate platforms, including underwater gliders, enables near-real-time metric value transmission through bandwidth limited satellites. While representing overall biomass distribution in the water column, metric only information limits locating depth specific biological features such as layers. To provide a parallel visual representation, Sv values from the WBT mini VBS 20-layer output are encoded within the seven Echometric output variable data stream without increasing data volume. Metric and Sv values are then sent through the glider science computer to an Iridium satellite connection and received by a shoreside server. Deconvolution of Echometric and Sv values provides separate data streams for plotting, interpretation, and can be used to target direct sampling. Data streams are formatted to update displays in platform or project web pages. Recent deployments have collected data in the Gulf of Mexico and in the Gulf of Alaska. Coincident graphic and statistical characterization increases our understanding of water column biomass distribution during autonomous platform deployment.

Updates from Echopype developers: changes and roadmap

W.-J. Lee[1], E. Mayorga[1], B.C. Reyes[1], L. Setiawan[2], I. Majeed[3], V. Staneva[4], and K. Nguyen[3]

[1]*Applied Physics Laboratory, University of Washington, 1013 NE 106th St, Seattle, WA 98105, USA, leewj@uw.edu, emiliom@uw.edu, bcreyes@uw.edu;*

[2]*School of Oceanography, University of Washington, 1501 NE Boat St, Seattle, WA 98195, USA, landungs@uw.edu;*

[3]*Department of Electrical and Computer Engineering, Paul Allen Center, 185 E Stevens Way NE AE100R, Seattle, WA 98195, USA, imranmaj@uw.edu, ngkavin@uw.edu,*

[4]*eScience Institute, University of Washington, 3910 15th Ave NE, Seattle, WA 98195, USA, vms16@uw.edu.*

Echopype is an open-source Python software package built to enhance the interoperability and scalability of fisheries acoustics data. By standardizing data from diverse instrument sources following a community convention and utilizing the widely embraced netCDF data model to encode data as labeled, multi-dimensional arrays, Echopype facilitates intuitive, user-friendly exploration and use of echosounder data in an instrument-agnostic manner. In addition, it directly enables computational interoperability and scalability in both local and cloud computing environments by leveraging existing open-source Python libraries optimized for distributed computing. Echopype is currently used by the US Ocean Observatories Initiative (OOI) Data Center to parse and serve echosounder data, and by the NOAA National Centers for Environmental Information as the data ingestion backend for interactive visualization on the cloud. In this presentation, we will summarize content of recent Echopype releases, including support for additional echosounder models, direct reading and writing interface with cloud object storage, enhanced data access and integration functionalities, documentation upgrades, and improved data structure adherence to the SONAR-netCDF4 convention. We will conclude by discussing our development roadmap and hope that you will join us to make this a community-driven effort.

The Zunibal Precatch System: a new tool to minimize bycatch in Tropical Tuna Fisheries

Lucio Calise, Patricia Ordoñez and Egoitz Ormaechea

Zunibal S.L., Idorsolo 1, 48160 Derio, Spain, lucio.calise@zunibal.com

The most common fishing method in tropical tuna fisheries is the deployment of seine nets around drifting Fish Aggregating Devices (dFADs). Although efficient, this method has significant bycatch, especially the "size-bycatch", i.e. individuals of target species of unmarketable size. Since there are no suitable tools capable of discriminating schools underneath the dFADs, fishing is always carried out if a sufficient amount of biomass is predicted. Therefore, the catch is composed by individuals of different species and sizes, and those belonging to non-target species and unmarketable size of target specie are discarded into the sea lifeless. Here, a new tool to minimize bycatch is presented: the Zunibal Precatch System, which is being used during the precatch phase of checking the satisfactory fishable quantity of biomass underneath the dFAD. The purpose is to acoustically detect, identify and estimate the fish schools underneath a dFAD in near real-time to help the fishing decision. Three elements compose the system: 1) a multi-frequency data acquisition buoy; 2) a buoy-vessel communication system and 3) an onboard processing unit. This presentation will illustrate the practical and marketing requests and consequently how the elements were designed and realized, with particular focus on the acoustic performances evaluation and data processing strategy.

Acoustic surveys at your desk: deploying a USV into an offshore windfarm and up to oil and gas platforms.

P.G.Fernandes[1], J.M.Lawrence[1]

[1]*School of Biological Sciences, Zoology Building, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ. Corresponding author: Fernandespg@abdn.ac.uk*

Acoustic surveys can provide precise estimates of the abundance and distribution of a variety of marine organisms at high spatial resolution. Uptake of broadband sonar has increased this capability, but circumstances may limit the technology, notably the platform that acoustic devices are typically deployed on and/or the type of habitat being surveyed. Traditional platforms (ships) suffer from high costs, a large carbon footprint, and, in the case of the coronavirus pandemic, limits on personnel; furthermore, they struggle to get close to certain habitats, particularly man-made marine structures such as oil and gas platforms and offshore windfarms. Here we present experience of an uncrewed surface vehicle (USV) survey of these habitats. We focus on some of the challenges and benefits of the USV and describe how it was operated remotely from the desk of navigators and sensor operators. Notable benefits include, in-situ calibration, getting very close to certain platforms, surveying straight through an offshore windfarm, and obtaining ancillary data such as regular 360° imagery for seabird detection. Challenges include the lack of alternative evidence for the acoustic data, acoustic noise at longer ranges and somewhat limited survey range. However, these challenges are not unsurmountable, so prospects for USV applications look good.

Recognizing the Influence of Turbulence-Induced Entrained Air When Monitoring for Risk to Fish at Ocean Energy Installations

Louise P. McGarry[1], Haley A. Viehman[2], Jessica Douglas[1], and Daniel J. Hasselman[1]

[1]*Fundy Ocean Research Centre for Energy (FORCE), 75 Alderney Drive, Dartmouth, Nova Scotia B2Y 2N7 Canada, louise.mcgarry@fundyforce.ca, jessica.douglas@fundyforce.ca, dan.hasselman@fundyforce.ca*

[2]*Echoview Software Pty Ltd., GPO Box 1387, Hobart, Tasmania 7001, Australia, haley.viehman@echoview.com*

For those tidal energy installations where it is required to quantify the potential risk to fish posed by the introduction of energy conversion devices into the habitat, scientific hydroacoustic echosounders provide quantifiable, stratified sampling of the whole water column with sufficiently high resolution in time and space. However, the impressive currents that are favourable to energy development are often turbulent and result in air entrainment into the water column. Entrained air limits the use of acoustic-based sampling systems to only those portions of the water column not contaminated with entrained air. To help regulators and developers recognize the potential implications to the understanding of fish presence, distribution, and abundance in ocean energy sites, we undertook a study of the proportion of water column obfuscated by entrained air as a function of tide direction, current speed, and season. Our findings demonstrate that site-specific localized hydrodynamics and seasonal winds can have a major impact on the observable portion of the water column. This information is critical for determining an optimal data collection site, establishing reasonable monitoring goals in dialogue with regulators, developers, and stakeholders, and for identifying periods of time when active acoustic technologies may not be an effective tool for monitoring.

Species identification of fish shoals combining multibeam and split-beam echosounders with visual observations from diving

Viviane David[1,2*], Corentin Minart[1,2], Anne Mouget[3,4], Yannick Perrot[2], Pierre Thiriet[1], Eric Feunteun[3,4], Adrien Cheminée[5], Loïc Le Goff[1], Anthony Acou[1], Patrice Brehmer[2]

[1] *PatriNat (OFB, CNRS, MNHN) – Centre de d'expertise et de données sur la nature – Station Marine de Dinard, CRESCO, 38 rue de Port Blanc, Dinard, France*

[2] *IRD, Univ Brest, CNRS, Ifremer, UMR Lemar, Plouzané, France*

[3] *Laboratoire BOREA (Museum National d'Histoire Naturelle, CNRS, Sorbonne Université, IRD, UniCaen, Univ Antilles Guadeloupe), 57 rue de cuvier, 75005 Paris, France*

[4] *Station Marine de Dinard, CRESCO, 38, rue du port Blanc, 35800 Dinard, France*

[5] *Septentrion Environnement, Campus Nature Provence, 89 Tra. Parangon, 13008, Marseille, France*

One challenge of acoustic observations of marine organisms is the identification of species, particularly in shallow waters where high diversity occurs. We deployed combining split-beam EK80 (70, 120 and 200 kHz) and M3 multibeam (500 kHz) echosounders to detect monospecific fish shoals in coastal shallow waters (5-60 m). Innovative protocols for the specific allocation were tested, using (i) scuba divers census on fish shoals and (ii) towed scuba diver. Stereoscopic video system was also used to assess fish length and abundance and compare with the visual estimations of divers. Several independent replicates of monospecific shoals from 5 fish species were obtained. The combined used of the echosounders allows to have complementary morphologic, acoustic and spatial descriptors to correctly discriminate the shoals. In addition, as the stereoscopic system has shown to provide precise measurements of individuals and could overcome the visual diver observations, our results suggest that a system equipped with cameras like a remotely controlled towed instrumentation platform could be used in a near future for ground trust in shallow and clear waters.

Using histogram equalization to visualize acoustic and ancillary data

M. Peña[1]

[1]*Instituto Español de Oceanografía, Muelle de Poiente s/n Palma, Spain, marian.pena@ieo.es*

Echogram visualization and processing is one of the most time-consuming tasks for fisheries acousticians. Analyzing target species or features is often based on experience while visualization settings are inherited from colleagues or established for standardization purposes within international efforts. Acoustic data is often visualized with a standard minimum threshold for Sv that varies with target species. For instance, small pelagic fishes are often visualized in European waters from − 60 dB re 1 m2 m− 3 while echograms of the mesopelagic zone (200–1000 m depth) usually employ a − 90 or − 80 dB re 1 m2 m− 3 minimum threshold. However, numerical volume density changes greatly with depth (particularly beyond the shelf), time of the day and season, and thus setting an incorrect threshold may mask part of the population at some times or areas. Following on Blackwell et al. (2019) that showed the best colormaps to be employed in fisheries acoustics, this presentation focus on further parameters (general thresholds and location of the color limits) of the colorbar. Most colormaps employ linear relationship between data and color, where every color represents a similar range of values. This can hide interesting features in only one or two colors. Histogram equalization is a non-linear interpolation technique that locates thresholds and color limits at the quantiles of the image data. Examples using acoustic and ancillary data will be shown to highlight the benefits of this technique. While no definite conclusion is provided, some food for thought on the influence of the number of colors employed will also be provided.

Target classification of individual zooplankton in *ex-situ* broadband acoustic data using supervised machine learning

C. McGowan-Yallop[1], K. Last[2], F. Cottier[3], S. Fielding[4] and A.S. Brierley[5]

[1]*Scottish Association for Marine Science, Oban, Argyll, PA37 1QA, UK, chelsey.mcgowan-yallop@sams.ac.uk,*

[2]*Scottish Association for Marine Science, Oban, Argyll, PA37 1QA, UK, kim.last@sams.ac.uk,*

[3]*Scottish Association for Marine Science, Oban, Argyll, PA37 1QA, UK, finlo.cottier@sams.ac.uk,*

[4]*British Antarctic Survey, High Cross, Madingley Road, Cambridge, CB3 0ET, UK, sof@bas.ac.uk,*

[5]*Scottish Oceans Institute, Gatty Marine Laboratory, University of St Andrews, St Andrews, KY16 8LB, UK, asb4@st-andrews.ac.uk*

Broadband echosounders offer the potential for improved target classification of zooplankton using measurements of backscattering strength across a wide frequency range (frequency response). Previous work has shown that supervised machine learning is a powerful tool for classifying unknown, single-species aggregations in acoustic data using frequency response. However, this volume backscatter-based approach is less effective for mixed-species aggregations. Here, a method for classification of individual zooplankton using target strength frequency response, TS(f), is proposed. Supervised classification algorithms were trained using *ex-situ* TS(f) measurements for future application to *in-situ* survey data. TS(f) measurements (283-383 kHz) were made of the copepods *Paraeuchaeta norvegica* and krill (a mixture of Northern krill, *Meganyctiphanes norvegica*, and *Thysanoessa* spp.) in a tank. Using these data, 12 supervised classification algorithms were compared. This method was then applied to a more realistic scenario using tank TS(f) measurements of *P. norvegica* and a community sample with *P. norvegica* removed ('non-target zooplankton'). The best-performing classification algorithm, XGBoost, classified *P. norvegica* or krill with 95.95% (± 0.47) accuracy, and *P. norvegica* or non-target zooplankton with 97.30% (± 0.41) accuracy. Results suggest that, where single target detection is possible, this is a highly accurate and robust method for target classification of zooplankton.

Comparing acoustic data acquired with research vessel l'Europe and USV DriX:

Naig Le Bouffant, Emeline Veit, Laurent Berger

Unité Navires et Systèmes Embarqués, Ifremer Brest, CS 10070 - 29280 Plouzané, France.

Developments of Unmanned Surface Vehicules substantially progressed over the past few years, enabling to provide extensive monitoring capacities for physical and biological processes and achieve sustainable management of the maritime domain. In order to investigate their performance and the way they could be used to complete traditional vessel survey acquisitions, a five-days technical survey with a 7 meters-long DriX USV has been carried out along Mediterranean coast. USV was equiped with ES70 and ES200 EK80, along with IcListen hydrophone and EM2040 multibeam. Simultaneous acquisitions were performed with l'Europe reasearch vessel fitted with similar echosounders. First analysis of comparative data will be presented, in terms of data quality (detection range and surface bubbling) as well as biomass observation and single target detection.

Estimation and correction of depth range and echo level errors due to water-column temperature and salinity on sound scattering layer.

Y. Coly[1,*], Y. Perrot[2], P. Brehmer[2,3], E. Machu[4] and B. A. Sow[1]

[1]*LOSEC, Université Assane Seck de Ziguinchor, Ziguinchor, Sénégal; youssouphcoly98@gmail.com*

[2]*IRD, CNRS, Univ Brest, Ifremer, DR Ouest, Lemar, Plouzané, France*

[3]*IRD, CNRS, Univ Brest, Ifremer, Lemar, CSRP, SRFC, Dakar, Sénégal*

[4]*Univ. Brest, CNRS, IRD, Ifremer, Laboratoire d'Océanographie Physique et Spatiale (LOPS), IUEM, Plouzané, France*

Water temperature and salinity are the key environmental parameters involved in the acoustic signal processing. In absence of clear procedure, temperature and salinity value are usually used at a fixed point in the water column to estimate the sound celerity in the studied area. Considering temperature and salinity as having negligible effects in estimates of acoustic variables may

lead to errors in dependent acoustic variables as the volume backscattering coefficient Sv, the nautical area backscattering coefficient sA and the target distance, i.e., depth for vertical echo-sounder. We examine the impact of environmental errors and their effects on the level of Sv, sA and range r. The results shown that the effect may not be negligible. The nautical area backscattering coefficient sA was the most affected by environmental errors. The deep ocean areas were the most concerned by these errors vs. surface and shallow coastal areas. Failure to correct for environmental errors in acoustic studies can lead to inaccurate results on the positions of the targets studied and biomass assessment. Abacuses were built to identify areas of interest where environmental corrections should be implemented and we share corrective code integrating temperature and salinity water profile for fisheries acoustics data correction.

Developing and deploying machine learning methods for acoustic data

N.O. Handegard[1], O. Brautaset[2], C. Choi[3], T. Furmanek[1], A.J. Hestnes, E. Johnsen[1], A. Ordonez[2], I. Utseth[2], S. Vatnehol[1], G. Huse[1]

[1]*Institute of Marine Research, Bergen, Norway, nilsolav@hi.no*

[2]*Norwegian Computing Center, P.O.Box 114, Blindern, 0314 Oslo, Norway*

[3]*Arctic University of Tromsø, Norway* [4]*Kongsberg Maritime, Horten, Norway.*

Machine learning methods are well suited for classification tasks and has been extensively used for acoustic data in the recent years. This presentation gives an overview of the effort on acoustic target classification using machine learning methods in Norway. The work includes new machine learning methods adapted to acoustic data, both fully supervised methods as well as semi supervised methods. We also investigate how to combine auxiliary information with classical convolutional methods. To efficiently use these new methods on acoustic data, the data needs to be prepared for efficient access and we have developed a cloud solution for efficient data access. Automated deployment of the methods on platforms like unmanned surface vehicles, research vessels and ships of opportunity is made possible through a combination of docker containers and Kongsberg Maritime's Blue Insight platform. This allows adaptive survey strategies, which is a step towards fully autonomous acoustic surveys. Finally, we present both the short term and the long term plan for how this will be used on IMRs surveys.

Investigating EK80 data quality on different platforms

Laurent Berger and Naig Le Bouffant

Unité Navires et Systèmes Embarqués, Ifremer Brest, CS 10070 - 29280 Plouzané, France.

Each time a new acoustic equipment is integrated on a new or existing platform, much care is taken to optimize its location and electronic integration. The performance of a system and the data quality remains however platform dependent and reduced performances sometimes require posterior investigation. Case of degradation of surface data of ES18 transducers on research vessels and example of broadband electric noise investigation on different platforms will be presented in order to exchange about possible issues and best practices.

Automated probabilistic echo solving: A scalable Bayesian inverse approach applied to echo integration

Samuel S. Urmy, Alex De Robertis, and Christopher Bassett

Identifying scatterers is a perennial challenge in fisheries acoustics. Most practitioners classify backscatter based on direct sampling and frequency-difference thresholds, then integrate at a single frequency. However, this approach struggles with species mixtures, and discards multi-frequency information when integrating. Inverse methods do not have these limitations, but are not widely used because their species identifications are often ambiguous and the algorithms are complicated to implement. We address these shortcomings using a probabilistic, Bayesian inversion method. Like other inversion methods, it handles species mixtures, uses all available frequencies, and extends naturally to broadband signals. Unlike prior approaches, it leverages Bayesian priors to rigorously incorporate information from direct sampling and biological knowledge, constraining the inversion and reducing ambiguity in species identification. Because it is probabilistic, it can be trusted to run automatically: it should not produce solutions that are both wrong and confident. Unlike some machine learning methods, it is based on physical scattering processes, so its output is fully interpretable. Finally, the approach is straightforward to implement using existing Bayesian libraries, and is easily parallelized for large datasets. We present narrowband and broadband examples using simulations and field data from the Gulf of Alaska, and discuss possible extensions and applications of the method.

Poster Presentations

On the resiliency of an eastern boundary upwelling ecosystem exposed to multiple stressors: an acoustic approach

Ndague DIOGOUL[1,5], Patrice BREHMER[1,5], Hervé DEMARCQ[2], Salaheddine El Ayoubi[3], Abou THIAM[4], Anne Mouget[6], Abdoulaye Sarré[5] and Yannick PERROT[6]

[1]*IRD, Univ Brest, CNRS, Ifremer, Lemar, CSRP, Dakar, Sénégal;*

[2]*IRD, IFREMER, CNRS, Univ Montpellier, MARBEC, Sète, France;*

[3]*Institut National de Recherche Halieutique INRH, Agadir, Morocco;*

[4]*University Cheikh Anta Diop UCAD, Institute of Environmental Science (ISE), BP 5005, Dakar, Senegal;*

[5]*Institut Sénégalais de Recherches agricoles (ISRA), Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), BP 2221 Dakar; Senegal;*

[6]*LEMAR, IRD, Univ Brest, CNRS, Ifremer, DR Ouest, Plouzané, France*

The resistance of an east border upwelling system was investigated using relative index of marine pelagic biomass estimates under a changing environment spanning 20-years in the strongly exploited southern Canary Current Large marine Ecosystem (sCCLME). We divided the sCCLME in two parts (north and south of Cap Blanc), based on oceanographic regimes. We delineated two size-based groups ("plankton" and "pelagic fish") corresponding to lower and higher trophic levels, respectively. Over the 20-year period, all spatial remote sensing environmental variables increased significantly, except in the area south of Cap Blanc where sea surface Chlorophyll-a concentrations declined and the upwelling favorable wind was stable. Relative index of marine pelagic abundance was higher in the south area compared to the north area of Cap Blanc. No significant latitudinal shift to the mass center was detected, regardless of trophic level. Relative pelagic abundance did not change, suggesting sCCLME pelagic organisms were

able to adapt to changing environmental conditions. Despite strong annual variability and the presence of major stressors (overfishing, climate change), the marine pelagic ressources, mainly fish and plankton remained relatively stable over the two decades, advancing our understanding on the resistance of this east border upwelling system.

Ichthyological importance of shallow coastal areas for pelagic communities: contributions of echosounding

Anne Mouget[1,2], Viviane David[3,4], Anthony Acou[3], Eric Feunteun[1,2], Pierre Thiriet[3], Yannick Perrot[4], Loïc Le Goff[2], Patrice Brehmer[4,5]

[1]*Laboratoire BOREA (Museum National d'Histoire Naturelle, CNRS, Sorbonne Université, IRD, UniCaen, Univ Antilles Guadeloupe), 57 rue de cuvier, 75005 Paris, France*
[2]*Station Marine de Dinard, CRESCO, 38, rue du port Blanc, 35800 Dinard, France*
[3]*PatriNat (OFB, CNRS, MNHN), Centre d'expertise et de données sur la nature – Station Marine de Dinard, CRESCO, 38 rue de Port Blanc, Dinard, FRANCE*
[4]*IRD, Univ Brest, CNRS, Ifremer, Lemar, Délégation régionale IRD ouest France, 29280, Plouzané, France*
[5]*Commission sous régionale des pêches, CSRP, SRFC, Dakar, Sénégal*

Marine communities are strongly structured by bathymetry and distance from the coast. Shallow coastal areas host diverse and abundant fish communities and are subjected to strong anthropogenic pressures. However, assessments of good ecological status of pelagic fish populations do not generally take into account the ultra-coastal fringe of the coastline (<20m depth and <5km from coast). Data presented in this study were acquired in Brittany (France) during eleven acoustic surveys conducted in 2020 and 2021 using a splitbeam EK80 echosounder (70, 120 and 200 kHz). Pelagic fish shoals were extracted from the echogram and characterized by spatial (location in the water column), morphological (size and shape of the shoal) and acoustic descriptors. Shoal descriptors were compared between coastal and ultra-coastal areas, taking into account variability between sites, seasons and years. Results showed different shoal structures with notably smaller shoals of pelagic fish in the ultracoastal zone but with a stronger acoustic response, suggesting a higher density per school than offshore and/or different species. This study highlights the uniqueness of ultra-coastal areas for marine pelagic fish communities and underlines the need to integrate their monitoring into marine management and action strategies to improve management and protection systems for these biocenoses.

Sound-scattering layers related to pelagic habitat characteristics: the case

Ndague Diogoul[1,2,6], Patrice Brehmer[2,3,6], Yannick Perrot[3], Maik Tiedeman[4], Abou Thiam[1], Salaheddine El Ayoubi[5], Anne Mouget[3], Abdoulaye Sarré[6]

[1]*University Cheikh Anta Diop UCAD, Institute of Environmental Science (ISE), BP 5005, Dakar, Senegal*

[2]*IRD, Univ. Brest, CNRS, Ifremer, LEMAR, Campus UCAD-IRD de Hann, Dakar, Senegal*

[3]*IRD, Univ. Brest, CNRS, Ifremer, LEMAR, DR Ouest, Plouzané, France*

[4]*Institute of Marine Research IMR, Pelagic Fish, P.O. Box 1870 Nordnes, 5817 Bergen, Norway*

[5]*Institut National de Recherche Halieutique INRH, Agadir, Morocco*

[6]*Institut Sénégalais de Recherches agricoles ISRA, Centre de Recherches Océanographiques de Dakar-Thiaroye (CRODT), BP 2221 Dakar, Senegal*

Understanding the relationship between sound scattering layers (SSLs) and pelagic habitat characteristics is a substantial step to apprehend ecosystem dynamics. SSLs are detected on echo sounders representing aggregated marine pelagic organisms. In this study, SSL characteristics of zooplankton and micronekton were identified during an upwelling event in two contrasting areas of the Senegalese continental shelf. Here a cold upwelling-influenced inshore area was sharply separated by a strong thermal boundary from a deeper, warmer, stratified offshore area. Mean SSL thickness and SSL vertical depth increased with the shelf depth. The thickest and deepest SSLs were observed in the offshore part of the shelf. Hence, zooplankton and micronekton seem to occur more frequently in stratified water conditions rather than in fresh upwelled water. Diel vertical and horizontal migrations of SSLs were observed in the study area. Diel period and physicochemical water characteristics influenced SSL depth and SSL thickness. Although chlorophyll-a concentration insignificantly affected SSL characteristics, the peak of chlorophyll a was always located above or in the middle of the SSLs, regularly matching with the peak of SSL biomass. Such observations indicate trophic relationships, suggesting SSLs to be mainly composed of phytoplanktivorous zooplankton and micronekton. Despite local hypoxia, below 30m depth, distribution patterns of SSLs indicate no vertical migration boundary. The results increase the understanding of the spatial organization of mid-trophic species and migration patterns of zooplankton and micronekton, and they will also improve dispersal models for organisms in upwelling regions.

Applying Acoustic Scattering Layer Descriptors to Depict Mid-Trophic Pelagic Organisation: The Case of Atlantic African Large Marine Ecosystems Continental Shelf

Anne Mouget[1,2], Patrice Brehmer[1,3], Yannick Perrot[1], Uatjavi Uanivi[4], Ndague Diogoul[1,5], Salahedine El Ayoubi[6], Mohamed Ahmed Jeyid[7], Abdoulaye Sarré[5], Nolwenn Béhagle[1], and Aka Marcel Kouassi[8]

[1]*IRD, Univ Brest, CNRS, Ifremer, Lemar, Délégation régionale IRD ouest France, 29280, Plouzané, France*

[2]*Unité Biologie des organismes et écosystèmes aquatiques (BOREA), CNRS, IRD, Museum National d'Histoire Naturelle, Sorbonne Université, Université de Caen Normandie, Université des Antilles, 38, rue du port Blanc, 35800 Dinard, France*

[3]*Commission Sous Régional des Pêches, CSRP, SRFC, Dakar, Sénégal*

[4]*Ministry of Fisheries and Marine Resources (MFMR), P.O. Box 912 Swakopmund, Namibia*

[5]*Institut Sénégalais de Recherche Agricole (ISRA), Centre de Recherche Océanographique de Dakar Thiaroye (CRODT), Pôle de recherche de Hann, Dakar, Sénégal*

[6]*Institut National de Recherche Halieutique (INRH), Casablanca, Maroc*

[7]*Institut Mauritanien de Recherche Océanographique et des Pêches (IMROP), BP 22, Nouadhibou, Mauritania*

[8]*Centre de Recherches Océanologiques (CRO), BP V 18 Abidjan, Côte d'Ivoire*

Hydroacoustic is a reliable and often used tool to monitor and study marine ecosystems. This study focus on acoustic scattered layers, which are the echosounder detection of pelagic marine organism of low trophic level, important in ecosystems functioning. Data have been recorded at 38 kHz in the three Atlantic African Large Marine Ecosystems (AA LME). To describe parsimoniously ecosystems, compare them and understand the difference, 14 descriptors have been used. Some of them are based on already used descriptors and others are new. The aim of this study is to ensure that these descriptors are relevant to monitor and compare systems. So, we first explore spatial (intra- and inter-LME comparisons) and then temporal dimension (interannual variability). For such purpose, we use a large acoustic database collected over 15 years in the three AA LME: Canary Current LME, Guinea Current LME and Benguela Current LME. Our methodology is innovative, introducing original new descriptors to monitor pelagic compartment of each LME and should be efficiently used for environmental monitoring in case of perturbation as overfishing, climate change or marine pollution. Indeed the acoustic scattered layer are mainly composed of macrozooplankton and ichtyoplankton which are sensitive to environmental change.

Spatial functionnal analysis application on fisheries acoustics data coupled with fine scale environmental data

Yoba Kande[1,2,3], Sophie Dabo-Niang[2], Ndague Diogoul[1,3], and Patrice Brehmer[1,3,4]

[1]*ISRA, Centre de Recherches Océanographiques de Dakar-Thiaroye, CRODT, BP 2241, Dakar, Sénégal ;*

[2]*University of Lille, Laboratory PAINLEVE UMR 8524;*

[3]*IRD, Univ Brest, CNRS, Ifremer, LEMAR, Dakar, Sénégal ; 4IRD, CSRP / SRFC, Dakar, Sénégal*

In this work, we were interested in the application of functional, spatial data analysis (FSDA) on coupling acoustic (*Sv*) and environmental (water temperature, fluorescence, salinity and turbidity) data. To do this we use data from an acoustics fisheries surveys (R/V Thalassa, Ifremer, AWA campaign) carry out in West African waters using multifrequency echosounder (18, 38, 70, 120, 333 kHz) and a scanfish (high performance towed undulator). FSDA were compared to classical statistical methods namely multivariate functional principal component analysis, classical principal component analysis, classification on principal component scores, classical additive model, spatial functional additive model. The interest to improve such statistical analysis is appliedhere to the study the effect at fine scale of environmental parameters on the distribution of coastal sound scattered layers. We first considered an aggregated analysis of the environmental data then we considered a more complete analysis of the data via their functional characters.

Annex 4: WGFAST Response to WGIPS

Recommendation from WGIPS to WGFAST

The Working Group on International Pelagic Surveys (WGIPS) acknowledges that acoustic backscatter values collected during surveys coordinated by the group and used to calculate biomass estimates for stock assessments, may be affected by acoustic shadowing when very dense schools are encountered, thereby potentially adversely impacting the quality of the stock assessment. While a handful of papers report on shadowing, to the best of our knowledge, there are currently no standardized guidelines in the peer review literature on how to robustly test for the occurrence of shadowing, to quantify it, or to correct for these biases. The group seeks advice from WGFAST on standardized methods to identify, measure and correct for acoustic shadowing.

WGFAST Response

Rolf Korneliussen, Sven Gastauer, and Michael Jech provided a response to this request as follows.

Response from Rolf Korneliussen *(This is an excerpt of an e-mail from Rolf)*

Regarding the shadowing effect, I would claim that quite much is done there:

- Foote (1983): Theory (after measuring)
- Toresen (1991; some new measurements)
- Foote, Ona, Toresen (1992), Theory and measurements
- Zhao & Ona (2003) improvements in correction methods (with the help from Gorska).
- Utne & Ona (2006) ICES paper: Measurements with bottom fixed transducers: Same result at 2! On mean ext cross section, much meter data.
- Martha Uumati et al. (2010), on single schools from Marocco. Method development using BEI etc.

Both Foote (1983) and Zhao & Ona (2003) methods were implemented in the Bergen Echo Integrator (BEI). These assumed a known, measured mean extinction cross section that was provided by R. Korneliussen. The Foote (1983) theory is approximate and potentially inaccurate depending on how measurements are made available. Implementation in LSSS would be easy. The problems are similar for sonar. I have myself collected data for this for MS70, and so have others at IMR.

The Foote (1983) theory resulted in a Taylor expansion. The expansion was an approximation that relied on high resolution in the data to be accurate. The Zhao & Ona (2003) theory was accurate and did not need high vertical resolution of the data. When herring data were stored at a vertical resolution of 1 m, the Zhao & One (2003) and Foote (1983) theories gave the same result. The extinction cross section was necessary for both theories for the estimation of extinction.

Background

The conversion of echo intensity to abundance estimates is a major goal of acoustic surveys of living marine and freshwater resources. Because these estimates are a (if not “the”) fundamental product of acoustic surveys, considerable effort has been dedicated to quantifying the relationship between echo intensity and fish density when using echo integration (Foote, 1999). Ideally, that relationship is linear over the range of animal densities encountered during a survey, and indeed that relationship is indeed linear for most aggregations of animals. For example, Foote (1983) found a linear relationship for fish densities up to 40 pollack (*Pollachius pollachius*) and Atlantic herring (*Clupea harengus*) per m^3. We take linearity for granted now, but in the course of determining that relationship, dense aggregations were found to have measured echo intensities that were not linearly proportional to their number densities. For example, early measurements of caged saithe (*Pollachius virens*) and sprat (*Sprattus sprattus*) by Røttingen (1976) suggested a linear relationship of echo intensity to fish density of up to 100 saithe m^{-3} and 2000 sprat m^{-3}, and up to 120 saithe m^{-3} and 2500 sprat m^{-3} at 38 and 120 kHz, respectively, but echo intensity deviated from linear at higher fish densities.

As the transmitted sound interacts with targets, a proportion of the acoustic energy is absorbed and scattered by each target. The combined effect of absorption and scattering by a target is called extinction and the extinction cross section of a target is denoted as σ_e (m^2). In addition, the scattered sound can interact with the other targets before it travels back to the receiver. This is called multiple scattering, and is often considered a second-order term because it has been shown to be of lesser magnitude than extinction (a first order term) under common survey conditions (Stanton, 1983), and is often assumed to be negligible when compared to the effects of extinction (Foote, 1983; Zhao and Ona, 2003). For the purposes of this response, we assume multiple scattering to be negligible.

When the relationship between echo intensity and fish density is linear, σ_e is negligible and the resulting estimates of fish density $(\rho, \#\ m^{-3})$ are calculated directly using echo integration. As fish density increases, more of the acoustic energy is scattered and absorbed, and increased levels of extinction will reduce the measured acoustic energy at proportionally greater magnitude. In this case, the measured acoustic energy is less than what it should be at the transducer. In terms of volume backscattering $(s_v\ , m^2\ m^{-3})$, the measured volume backscatter $(\hat{s}_v)$ is reduced by a factor of $exp(2\rho\sigma_e\Delta z)$, i.e. $\widehat{s_v} \sim s_v exp(2\rho\sigma_e\Delta z)$, where s_v is the true density, Δz is the vertical extent of the integration layer, and the factor 2 accounts for two-way travel (Foote, 1990). Excess extinction is often called acoustic shadowing (Zhao and Ona, 2003).

To estimate the level of acoustic shadowing, we need to know or estimate the density of scatterers and the extinction cross section of those scatterers. Unfortunately, these are not easy to obtain directly, so methods have been developed to estimate them. The next two sections review methods to identify and correct for acoustic shadowing when there is a reference target and when there is no reference target available.

Corrections for Acoustic Shadowing Using a Reference Target

The effect of acoustic shadowing in an aggregation can be estimated by comparing the echo intensities of a reference target with and without an intervening aggregation in the acoustic beam. A decline in the echo intensity of the reference target when an aggregation is present is proportional to the extinction cross section of that aggregation (Foote et al., 1992), and this information can be used to derive a ratio between the measured acoustic energy from an aggregation and what that energy would be without shadowing, such as the extinction coefficient $\left(\frac{\sigma_e}{\sigma_b}\right)$ where σ_b is the acoustic backscatter cross section $\left(TS = \frac{\sigma_b}{4\pi}, dB\ re\ m^2\right)$ (Foote et al., 1992), or the acoustic shadowing coefficient $\beta = \frac{(s_A - \widehat{s_A})}{s_A}$, where s_A is true areal backscatter $\left(s_A = 4\pi 1852^2 \int_{z1}^{z2} s_v dz, m^2 nmi^{-2}\right)$ without shadowing and $\widehat{s_A}$ is the measured areal backscatter, potentially with shadowing (Zhao and Ona, 2003). The seabed is most commonly used as the reference target (e.g. Toresen, 1991; Foote et al., 1992; Zhao and Ona, 2003; Uumati et al., 2010), but a calibration sphere could be used when stationary, or the sea surface (Utne and Ona, 2006) works for upward-looking transducers.

Zhao and Ona (2003) built on Foote et al. (1992) to provide methods to estimate the level of acoustic shadowing and subsequently correct for it. For this response, we assume an aggregation with homogeneous density and extinction cross sections. We leave the cases of inhomogeneous densities and extinction cross sections for the reader to pursue. The areal backscatter of a reference target without an intervening aggregation (s_{ARo}) and with an intervening aggregation (s_{ARf}) are used to estimate the shadow coefficient $(\hat{\beta})$ by

$$\hat{\beta} = \frac{s_{ARo} - s_{ARf}}{s_{ARo}} = K\frac{\sigma_e}{\sigma_b}\widehat{s_A},$$

where the constant $K = \frac{2}{1852^2}$ accounts for 2-way travel and conversion from SI units to nautical mile squared $(1\ nmi = 1852\ m)$. This equation eliminates the need to estimate ρ within the aggregation, but still requires estimates of σ_e and σ_b. Foote et al. (1992) derived a method to estimate the ratio of σ_e and σ_b ($\gamma = \frac{\sigma_e}{\sigma_b}$ using Zhao and Ona (2003) notation) by using the coefficients of the regression between s_{ARo} and s_{ARf}

$$s_{ARo} = \alpha' + \beta' s_{ARf.}$$

α' and β' are used to define γ as

$$\gamma = \frac{\sigma_e}{\sigma_b} = \frac{-1852^2\widehat{\beta\prime}}{2\widehat{\alpha\prime}},$$

where $\widehat{\beta}'$ and $\widehat{\alpha}'$ are the estimated regression coefficients derived from survey data. Higher values of γ indicate greater acoustic shadowing. Zhao and Ona (2003) provide a correction factor (CF) for acoustic shadowing:

$$CF = \frac{1}{K\gamma\widehat{s_A}} \cdot ln\left(\frac{1}{1 - K\gamma\widehat{s_A}}\right)$$

Table 1 and Figure 1 show that at γ values less than 3, $\widehat{s_A}$ values need to be greater than 100,000 $m^2\ nmi^{-2}$ to have correction factors greater than 10%. The R-code to generate Table 1 and Figure 1 is provided at the end of the response.

Table 1. Measured s_A (x1000 m2 nmi-2) ($\widehat{s_A}$), and correction factors (CF) at γ = 1, 2, and 3. The bold and underlined values represent the 10% correction factor where $\widehat{s_A}$ values less than that require less than 10% correction and $\widehat{s_A}$ values above that require greater than 10% correction. NAN represents CF values that are invalid (see Foote (1990) and Zhao and Ona (2003) for causes). The R-code to generate this table is provided at the end of this document.

$\widehat{s_A}$	CF:γ=1	CF:γ=2	CF: γ=3
1	1.000	1.001	1.001
5	1.001	1.003	1.004
10	1.003	1.006	1.009
15	1.004	1.009	1.013
20	1.006	1.012	1.018
25	1.007	1.015	1.023
30	1.009	1.018	1.027
35	1.010	1.021	1.032
40	1.012	1.024	1.037
45	1.013	1.027	1.042

50	1.015	1.030	1.046
55	1.016	1.034	1.051
60	1.018	1.037	1.056
65	1.019	1.040	1.062
70	1.021	1.043	1.067
75	1.023	1.046	1.072
80	1.024	1.050	1.077
85	1.026	1.053	1.083
90	1.027	1.056	1.088
95	1.029	1.060	1.094
100	1.030	1.063	**1.099**
150	1.046	**1.099**	1.160
200	1.063	1.139	1.231
250	1.081	1.182	1.315
300	**1.099**	1.231	1.418
350	1.118	1.285	1.547
400	1.139	1.347	1.719
450	1.160	1.418	1.966
500	1.182	1.500	2.374
550	1.206	1.599	3.402
600	1.231	1.719	NaN
650	1.257	1.872	NaN
700	1.285	2.076	NaN
750	1.315	2.374	NaN
800	1.347	2.897	NaN
850	1.381	4.784	NaN
900	1.418	NaN	NaN
950	1.457	NaN	NaN
1000	1.500	NaN	NaN

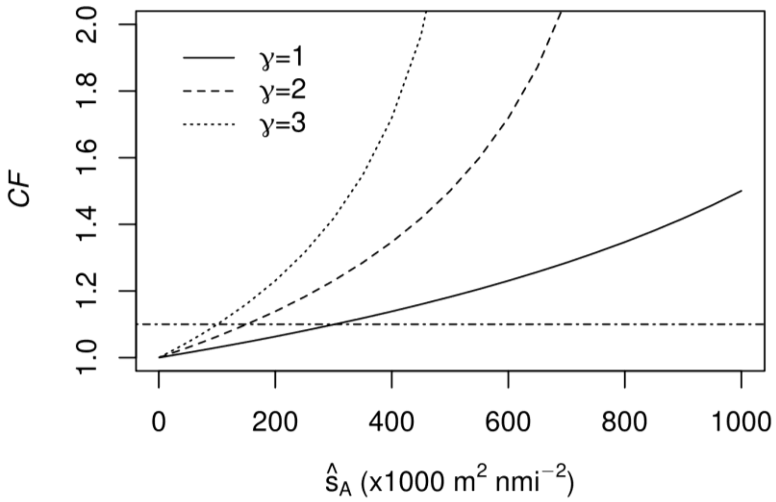

Figure 1. Correction factor (CF) as a function of (s_A) ̂ for three different γ values. The horizontal dash-dot is at the 10% correction level. The R-code to generate this figure is provided at the end of this document.

A limitation to using a reference target, such as the seabed echo, is that measurements of that seabed echo must be obtained without the intervening aggregations. This may be difficult under survey conditions, so additional resources may be required to survey the seabed.

Corrections for Acoustic Shadowing Without a Reference Target

In instances where the seabed echo is not recorded, e.g. when the target species is located where the water depth is much deeper than the depth of the target species, using the seabed as a reference target is not possible.

In the absence of a reference target, the correction factor developed by Zhao and Ona (2003) uses γ as a proxy for animal density and extinction coefficient, thus estimates of γ may be used to indicate the magnitude of correction. Foote et al. (1992) provide ranges of γ for measurements of Atlantic herring at 38 kHz found in their study as well as from the literature from 1.17 to 3.3 (Foote et al., 1992). For these γ values, correction factors can range from approximately 3 to 10% for aggregations with $\widehat{s_A}$ of 100,000 m^2 nmi^{-2} or from about 14 to 70% for aggregations with $\widehat{s_A}$ of 400,000 m^2 nmi^{-2} (Table 1). Thus, it is up to the analyst to decide what level of estimation they are comfortable with.

Software

Echoview currently does not have a dedicated module/virtual variable to identify and correct acoustic extinction by fish schools, but the user can build their own process using their virtual variables to do this.

BEI (Bergen Echo Integrator) that is not used anymore did have a processing module to correct for extinction of herring. There is no similar implementation for LSSS, although the code for BEI is available so that implementing correction for extinction would be relatively easy.

Recommendations

1. Inspect historical data for the prevalence of aggregations that may be affected by acoustic shadowing (e.g. $\widehat{s_A}$ values greater than 100,000 m^2 nmi^{-2}), and develop metrics to estimate the magnitude of the effects. Metrics include percentage of aggregations with acoustic shadowing, magnitude of acoustic shadowing, and effects on abundance estimates.
2. If acoustic shadowing is determined to be significant, devote resources to develop survey protocols and collecting additional data.

References

Foote, K. G. 1983. Linearity of fisheries acoustics, with addition theorems. Journal of the Acoustical Society of America, 73(6): 1932-1940. doi.org/10.1121/1.389583.

Foote, K. G. 1990. Correcting acoustic measurements of scatterer density for extinction. Journal of the Acoustical Society of America, 88(3): 1543-1546, doi.org/10.1121/1.400312.

Foote, K. G. 1999. Extinction cross-section of Norwegian spring-spawning herring. ICES Journal of Marine Science, 56: 606–612, doi.org/10.1006/jmsc.1999.0479

Foote, K. G., Ona, E., Toresen, R. 1992. Determining the extinction cross section of aggregating fish. Journal of the Acoustical Society of America, 91(4):1983-1989. doi.org/10.1121/1.403682.

Raveau, M., and Feuillade, C., 2015. Sound extinction by fish schools: Forward scattering theory and data analysis. Journal of the Acoustical Society of America, 137:539, https://doi.org/10.1121/1.4906172

Røttingen, I. 1976. On the relation between echo intensity and fish density. FiskDir. Skr.Ser.HavUnders., 16: 301-314.

Stanton, T. K. 1983. Multiple scattering with applications to fish-echo processing. Journal of the Acoustical Society of America, 73(4): 1164-1169. doi.org/10.1121/1.389287.

Toresen, R. 1991. Absorption of acoustic energy in dense herring schools studied by the attenuation in the bottom echo signal. Fisheries Research, 10(3-4): 317-327. doi.org/10.1016/0165-7836(91)90083-R

Utne, K. R., Ona, E. 2006. Acoustic extinction in dense herring layers, measured from a bottom-mounted transducer. ICES CM 2006/I:10.

Uumati, M., Ona, E., Hjellvik, V. 2010., "Correction for shadowing within sardine schools," OCEANS 2010 MTS/IEEE SEATTLE, 2010, pp. 1-8, doi: 10.1109/OCEANS.2010.5664456.

Zhao, X., Ona, E. 2003. Estimation and compensation models for the shadowing effects in dense fish aggregations. ICES Journal of Marine Science. 60: 155-163. doi.org/10.1006/jmsc.2002.1319

R-Code

```
###########################
# Acoustic-Shadow.R
# calculate acoustic shadow correction factors using Zhao and Ona (2003)
# "Estimation and compensation models for the shadowing effect in dense fish
# aggregations", ICES JMS, 60:155-163.
#
# jech
# source('Acoustic-Shadow.R')

# start with clean slate
rm(list=ls(all=TRUE))

# generate areal backscatter values. These simulate those used in Fig. 2 of
# Zhao and Ona
```

```
sA = c(seq(0, 100, by=5), seq(150, 1000, by=50))
sA[1] = 1
# scale to typical NASC values of aggregations
sA = sA*1000
# the K constant
K = 2/1852^2

# output plot to a .png file with 300 dpi resolution
png('test.png', bg='white', res=300, width=5, height=4, units='in')
# gamma value, ratio of sigma-e and sigma-b, sigma-e/sigma-b
d = 1
# the correction factor (C), equation 27
cf = (1/(K*d*sA))*log(1/(1-K*d*sA))
plot(sA/1000, cf, pch=20, ylim=c(1,2), lty=1, type='l',
              xlab=expression(paste(hat(s)[A], ' (x1000 ', m^2, ' ',nmi^-2,')')),
              ylab=expression(italic('CF')))
abline(h=1.1, lty=4)

# calculate and plot C for gamma values 2 & 3
for (d in 2:3) {
  tmp = (1/(K*d*sA))*log(1/(1-K*d*sA))
  lines(sA/1000, tmp, pch=20, lty=d)
  cf = cbind(cf, tmp)
}

legend(0, 2, lty=c(1,2,3), box.col='white',
              legend=c(expression(paste(gamma,'=1')),
              expression(paste(gamma,'=2')),
              expression(paste(gamma,'=3'))))
dev.off()

# print the values
cat('Measured sA', '\t\t', ' CF:d=1', '\t\t', ' CF:d=2', '\t\t',
              ' CF:d=3', '\n')
for (i in 1:length(sA)) {
  cat(sprintf('%.0f', sA[i]/1000), '\t\t',
              sprintf('%.3f', cf[i,1]), '\t\t',
              sprintf('%.3f', cf[i,2]), '\t\t',
              sprintf('%.3f', cf[i,3]), '\t\t',
              '\n')
}
```

Annex 5: Report on WGAST Resource Surveys

Country	Institute	Survey name	Target stock(s)	Species [latin names]	Area	Survey date [month(s)]	Output(s)
Australia	CSIRO	NZ orange roughy	Orange roughy	*Hoplostethus atlanticus*	New Zealand Chatham Rise	June/July 2021	Biomass estimate
Australia	CSIRO	Southern Ocean Time Series (SOTS)	Mesopelagics	Multiple	Southern Ocean	April 2021, April 2021, May 2022,	Census of mesopelagic species using optics and acoustics, behavioural observations in response to platform
Australia	CSIRO	Cascade Plateau orange roughy surveys	Orange roughy	*Hoplostethus atlanticus*	Southeast Tasmanian, Australia	June 2021, June 2022	Observations of fish schools, distribution and bheavious, biomass estimates of spawning aggregations
Australia	CSIRO	Tasmanian West Coast Blue grenadier surveys	Blue grenadier	Macruronus novaezelandiae	West Coast, Tasmania, Australia	June-August 2020,2021, 2022	Biomass estimates based on opportunistic transect surveys carried out during fish processing time. Season-long detection of schools to produce metrics of abundance
Australia	CSIRO	IMOS Bioacoustics sub-Facility	Pelagic and mesopelagics to 1000 m	Multiple	Indian Ocean, Southern Ocean, Tasman Sea, Pacific Ocean	2020-2022 opportunistic collection of bioacoustic data from 10 vessels	NetCDF of quality controlled echointegration data of ocean-basin scale acoustic backscatter posted to a public repository (https://portal.aodn.org.au/search?uuid=8edf509b-1481-48fd-b9c5-b95b42247f82)
Brazil	Insititut de Recherche pour le Développement (IRD) Universidade Federal de Pernambuco (UFPE)	ABRAÇOS 2 (Acoustic Along the Brazilian Coast) http://dx.doi.org/10.17600/17004100	Ecosystem	Multiple	Northeast Brazil	April-May 2017	Comprehensive three-dimensional characterization of the demersal and pelagic ecosystems in Northeast Brazil

	Universidade Federal Rural de Pernambuco (UFRPE)						
Brazil	Insititut de Recherche pour le Développement (IRD) ; Universidade Federal de Pernambuco (UFPE) ; Universidade Federal Rural de Pernambuco (UFRPE)	AMAZOMIX	Multiple	Multiple including *Melichtys niger* *Canthidermis sufflamen* *Sphyraena barracuda*	Amazon shelf off French Guiana and Northeast Brazil	August-October 2021	Demersal and pelagic ecosystems and oceanography in Northeast Brazil
Cabo Verde	Instituto do Mar (IMar) / Sea Institute	CABO VERDE ECOSYSTEM SURVEY			Around the Cape Verde islands The survey covered waters from shallow depths (about 20 m depth) to upper slope (about 1000 m depth)	20 November - 15 December, 2021	Assess the demersal and pelagic resources of the continental shelf and upper slope by determining their distribution and abundance, while also studying the oceanographic conditions, distribution of microplastics and marine debris, and measure nutrient and contaminant levels in commercial fish
Cabo Verde	Instituto do Mar (IMar) / Sea Institute in coloboration with GEOMAR	MSM106 Wascal Floating University			St. Luzia (Marine Reserve), Nola Seamount and Eddy in the north of São Vicente to the site CVOO	26 February to 19 March 2022	Echosystemic approach
Canada	DFO Institute of Ocean Sciences	Joint U.S.-Canada Pacific hake survey	Pacific hake	*Merluccius productus*	West coast of North America	June-September 2021	Index of abundance-at-age (age 2+), age-1 index.

Canada	DFO Institute of Ocean Sciences	Joint U.S.-Canada Pacific hake survey	Pacific hake	*Merluccius productus*	West coast of North America	August-September 2020	Research on Pacific Hake migration
Canada	DFO Institute of Ocean Sciences	La Perouse zooplankton surveys	Zooplankton	Multiple	West coast Vancouver Island	May and September 2020, 2021	Index of zooplankton abundance
Canada	DFO Pacific Biological Station	Strait of Georgia juvenile herring survey	Pacific herring and other pelagics	Multiple	Strait of Georgia	September 2020, 2021	Index of abundance for juvenile herring and pelagic species
Canada	DFO Pacific Biological Station	Seamounts surveys	Zooplankton and pelagic species	Multiple	Offshore West coast of Canada	June 2021	Abundance and distribution of pelagic species in seamounts areas of interest
Canada	DFO Institute of Ocean Sciences	Line P survey	Zooplankton and pelagic species	Multiple	West coast Canada	May, September, and February 2020, 2021	Long time-series of zooplankton and fish abundance
Canada	Fisheries and Marine Institute of Memorial University/Université Laval/Fisheries and oceans Canada	ArcticNet and Amundsen Science	Polar cod, zooplankton, and mesopelagic species	*Boreogadus saida, Benthosema glaciale, and others*	Canadian Arctic and Labrador Sea	Annual survey (summer-autumn) between 2004 and 2022	Index of abundance (age-0 and age-1+). Target Strength. Long time-series of zooplankton and fish abundance
Canada	DFO Maurice Lamontagne Institute	nGSL herring acoustic survey	Atlantic herring	Multiple	Northern Gulf of St. Lawrence	July 2019-present; November 2009-present	Age-stratified herring abundance index
Canada	DFO Maurice Lamontagne Institute	nGSL bottom-trawl multispecies survey	Redfish, Atlantic cod, herring and capelin	Multiple	Northern Gulf of St. Lawrence	August 2012-present	Index of abundance
Canada	DFO Newfoundland Region	Northeast coast Newfoundland herring	Newfoundland NE coast Atlanic herring	*Clupea harengus harengus*	NE coast of NL	October-November, 2020-2022	Biomass index

Canada	DFO Newfoundland Region	South coast Newfoundland herring	Newfoundland South coast Atlanic herring	*Clupea harengus harengus*	Placentia and Fortune Bays	February-March 2020,2022	Biomass index
Canada	DFO Newfoundland Region	Spring capelin	NAFO Divsions 2J3KL capelin	*Mallotus villosus*	NAFO Division 3L	May 2020-2022	Biomass index
Canada	DFO Newfoundland Region	Capelin/Arctic Cod Reserach	NAFO Divsions 2J3KL capelin	*Mallotus villosus / Boregogadus saida*	NAFO Division 2J3K	Jan 2023	CW and FM species response curves
Denmark Germany Ireland Netherlands Norway UK (Scotland)	DTU-Aqua (DK), Thünen-Institute of Sea Fisheries (GER), Marine Institute Ireland (IRL), WMR-Wageningen Marine Research (NL), IMR - Institute of Marine Research (NOR), Marine Scotland Science (UK-SCO)	The ICES Coordinated Acoustic Survey in the Skagerrak and Kattegat, the North Sea, West of Scotland and the Malin Shelf area (HERAS)	North Sea Autumn Spawning Herring NSAS, Western Baltic Spring Spawning Herring WBSS, West of Scotland autumn spawning Herring (VIa N), Malin Shelf Herring (MSHAS); North Sea Sprat (Subarea 4); Sprat in Div3a.	*Clupea harengus, Sprattus sprattus, (Engraulis encrasicolus, Sardina pilchardus)*	Continental shelf of North Sea north of 52°N incl. West of Scotland and Ireland to northern limit of 62°N	June/July	Biomass Index Abundanxe Index Age structure Mean weight at age Maturity
Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia, Sweden	Danish Technical University, National Institute of Aquatic Resources; University of Tartu, Estonian Marine Institute; Natural Resources Institute Finland;	BIAS (Baltic International Acoustic Survey)	Baltic sprat and herring (spr.27.22-32, her.27.20-24, her.27.25-2932)	*Clupea harengus membras, sprattus sprattus*	Baltic Sea (IIIb-d)	September/October	Age stratified index of abundance

	Thünen-Institute of Baltic Sea Fisheries; Institute of Food Safety, Animal Health and Environment (BIOR), Fish Resources Research Department; Marine Research Institute Klaipeda University; National Marine Fisheries Research Institute; AtlantNIRO; Swedish University of Agricultural Sciences, Department of Aquatic Resources						
Estonia, Germany, Latvia, Lithuania, Poland, Russia, Sweden	University of Tartu, Estonian Marine Institute; Thünen-Institute of Baltic Sea Fisheries; Institute of Food Safety, Animal Health and Environment (BIOR), Fish Resources Research Department;	BASS (Baltic Acoustic Spring Survey)	Baltic sprat stock (spr.27.22-32)	*Sprattus sprattus*	Baltic Sea (IIIb-d)	May/June	Age stratified index of abundance

	Marine Research Institute Klaipeda University; National Marine Fisheries Research Institute; AtlantNIRO; Swedish University of Agricultural Sciences, Department of Aquatic Resources						
Estonia, Latvia	University of Tartu, Estonian Marine Institute; Institute of Food Safety, Animal Health and Environment (BIOR)	GRAHS (Gulf of Riga Acoustic Herring Survey)	Gulf of Riga herring stock (her.27.28.1)	*Clupea harengus membras*	Gulf of Riga in Baltic Sea (ICES SD 28.1)	July/August	Age stratified index of abundance
France	Ifremer	PELGAS	Anchovy,sardine	*Engraulis encrasicolus, Sardina Pilchardus,*	Bay of Biscay	May, annually	Age stratified index of abundance, distribution
France	Ifremer	PELGAS	Horse mackerel, mackerel, sprat, boarfish	*Trachurus trachurus, Sprattus sprattus*	Bay of Biscay	May, annually	Abundance index, distribution
France	Ifremer	PELMED	Anchovy,sardine,	*Engraulis encrasicolus, Sardina Pilchardus,*	Gulf of Lion	July, annually	Age stratified index of abundance
France	Ifremer	PELMED	Horse mackerel,sprat	*Trachurus trachurus, Sprattus sprattus*	Gulf of Lion	July, annually	Abundance index, distribution

France	Ifremer	ESSDRIX	Multiple		Gulf of Lion	November	Technical assessment of abundance index measured by USV compared to Research Vessel
Germany	Thünen-Institute of Sea Fisheries/Thünen-Institute of Baltic Sea Fisheries	German Acoustic Autumn Survey (GERAS)	Western Baltic Spring Spawning Herring WBSS, Central Baltic Herring CBH, Baltic Sea Sprat (SD22-32)	*Clupea harengus, Sprattus sprattus, (Engraulis encrasicolus)*	Kattegat, Western Baltic Sea, Öresound (ICES SD 21-24)	October	Biomass Index Abundanxe Index Age structure Mean weight at age Maturity
Greece	Hellenic Centre for Marine Research (HCMR)	MEDIAS (GSA 20 and 22)	European anchovy and Sardine	*Engraulis encrasicolus* *Sardina pilchardus*	Aegean Sea & eastern Ionian Sea	Jun-Jul (Aegean Sea) Sep-Oct (east. Ionian Sea)	Index of abundance-at-age
Iceland	Marine and freshwater research institute	International ecosystem survey in Norwegian Sea (IESNS)	Norwegian spring-spawning herring	*Clupea harengus*	Norwegian Sea	May 2020 May 2021 May 2022	Index of abundance
Iceland	Marine and freshwater research institute	International ecosystem survey in Norwegian Sea (IESNS)	Norwegian spring-spawning herring	*Clupea harengus*	Norwegian Sea	May 2020 May 2021 May 2022	Index of abundance
Iceland	Marine and freshwater research institute	Herring survey	Icelandic summer-sp. herring	*Clupea harengus*	Icelandic shelf (in E, S and W)	November-December and March	Index of abundance
Iceland	Marine and freshwater research institute	Capelin autumn survey	Icelandic capelin	*Mallotus villosus*	Irminger Sea, Greenland Sea, Iceland Sea and Denmark Strait	September-October 2020 September-October 2021 September-October 2022	Biomass estimate

Iceland	Marine and freshwater research institute	Capelin winter survey	Icelandic capelin	*Mallotus villosus*	Icelandic Waters	January-February 2020 January-February 2021 January-February 2022	Biomass estimate
Iceland	Marine and freshwater research institute	International ecosystem summer survey in Nordic Seas (IESSNS)	Norwegian spring-spawning herring and blue whiting	*Clupea harengus* and *Micromesistius poutassou*	Nordic Seas	July 2020 July 2021 July 2022	Indices of abundance
Iceland	Marine and freshwater research institute	Icelandic Spring survey	Krill	*Meganyctiphanes norvegica* and *Thysanoessa inermis*	Icelandic Waters	May 2020 May 2021 May 2022	Index of abundance
Iceland	Marine and freshwater research institute	Mapping of the seabed	N/A	*N/A*	Within Iceland's EEZ	June 2020 August 2020 June 2021 August 2021	Multibeam bathymetry Backscatter (applies to all surveys)
Italy	CNR-National Research Council, IRBIM-Institute for Marine Biological Resources and Biotechnologies	MEDIAS (FAO GSAs 17 and 18)	European anchovy and Sardine	*Engraulis encrasicolus* *Sardina pilchardus*	Western Adriatic Sea	June-July, annually	Biomass index Abundance index Age structure Spatial distribution
Italy	CNR-National Research Council, IRBIM-Institute for Marine Biological Resources	MarE-Albania (FAO GSA18)	European anchovy and Sardine	*Engraulis encrasicolus* *Sardina pilchardus*	Southeastern Adriatic Sea (Albania)	May 2021	Biomass index Abundance index Age structure Spatial distribution

	and Biotechnologies						
Italy	CNR-National Research Council, IRBIM-Institute for Marine Biological Resources and Biotechnologies	ROSSKRILL	Antarctic krill, crystal krill	krill *(Euphausia superba, Euphasia crystallorophias)*	Ross Sea, Antarctica	January 2022	Biomass index Abundance index Spatial distribution
Ireland	Marine Institute	Celtic Sea herring acoustic survey (CSHAS)	HER, SPR	Herring (*Clupea harengus*) Sprat (*Sprattus sprattus*)	Celtic Sea, Ireland	October, annually	Age stratified index of abundance
Ireland	Marine Institute	International blue whiting spawning stock survey (IBWSS)	WHB, Mesopelagic spp	Blue whiting (*Micromesistius poutassou*)	W of Ireland & Scotland	March-April, annually	Age stratified index of abundance
Ireland	Marine Institute	Western European Shelf Pelagic Acoustic Survey (WESPAS)	HER, BOC,HOM(W)	Herring (*Clupea harengus*), Boarfish (*Capros aper*), Horse mackerel (*Trachurus trachurus*)	W of Ireland & Celtic Sea	June-July, annually	Age stratified index of abundance
Ireland and UK (Scotland)	Marine Institute and Marine Scotland Science	6a7bc herring industry survey	HER	Herring (*Clupea harengus*)	W of Ireland & Scotland	Aug/Sept (autumn spawning) and Oct/Jan (winter spawning) annually	Age stratified index of abundance
Netherlands	Wageningen Marine Research	International blue whiting spawning stock survey (IBWSS)	WHB, Mesopelagic spp	Blue whiting (*Micromesistius poutassou*)	W of Ireland & Scotland	March-April, annually	Age stratified index of abundance

New Zealand	National institute of Water & Atmospheric Research Ltd	Cook Strait hoki	HOK1	*Macruronus novaezelandiae*	Cook Strait, New Zealand	July-August 2021	Index of abundance
New Zealand	National institute of Water & Atmospheric Research Ltd	West coast South Island middle depths trawl survey	HOK1, LIN7, HAK7	*Macruronus novaezelandiae, Genypterus blacodes,* *Merluccius australis,* Mesopelagic spp.	West coast South Island, New Zealand	August 2021	Index of abundance-at-age (trawl) Index (acoustics)
New Zealand	National institute of Water & Atmospheric Research Ltd	Campbell southern blue whiting	SBW6I	*Micromestius australis*	Campbell Plateau, New Zealand	August-September 2022	Index of abundance-at-age
New Zealand	National institute of Water & Atmospheric Research Ltd	Bounty southern blue whiting	SBW6B	*Micromestius australis*	Bounty Plateau, New Zealand	August 2020, 2021, 2022	Index of abundance
New Zealand	National Institute of Water and Atmospheric Research Limited	Chatham Rise middle depths trawl survey	HOK1, LIN3/4, HAK1/4	*Macruronus novaezelandiae, Genypterus blacodes,* *Merluccius australis,* Mesopelagic spp.	Chatham Rise, New Zealand	January 2020, 2022	Index of abundance-at-age (trawl) Index (acoustics)
New Zealand	National Institute of Water and Atmospheric Research Limited	Subantarctic middle depths trawl survey	HOK1, LIN5/6, HAK1	*Macruronus novaezelandiae, Genypterus blacodes,* *Merluccius australis,*	Southland and Subantarctic, New Zealand	November-December 2020, 2022	Index of abundance-at-age (trawl) Index (acoustics)

				Mesopelagic spp.			
New Zealand	National Institute of Water and Atmospheric Research Limited	Ross Sea Marine Protected Area monitoring		*Pleuragramma antarctica*, *Macrourus caml*, *Euphausia superba*	Ross Sea, Antarctica	Jan-Feb 2021	Index, distribution
New Zealand	National Institute of Water and Atmospheric Research Limited	Acoustic survey of orange roughy in ORH Mid-east Coast	ORH 2A, 2B, and 3A	*Hoplostethus atlanticus*	New Zealand Mid East Coast	June 2021	Index of abundance
New Zealand	National Institute of Water and Atmospheric Research Limited	Acoustic assessment of perch in Lake Rototoa		*Perca fluviatilis*	Lake Rototoa, Auckland	June 2021	Index of abundance, echo-counting
Norway	Institute of Marine Research	WGIPS (2019831)	Blue whiting	*Micromesistius poutassou*	Atlantic Ocean, west of Ireland	March-April	Index of abundance
Norway	Institute of Marine Research	HERAS-NORACU (2019207)	Herring	*Clupea harengus*	North Sea	May-June	Index of abundance
Norway	Institute of Marine Research	Sandeel survey (2019847)	Sandeel	*Ammodytes marinus*	North Sea, Norwegian EEZ	April-May	Index of abundance
Norway	Institute of Marine Research	Ecosystem survey Barents Sea (2019209)	Capelin	*Mallotus Villosus*	Barents Sea	September	Index of abundance
Norway	Institute of Marine Research	2019809	Capelin	*Mallotus villosus*	Barents Sea, Finnmark coast	March	Spawning biomass
Norway	Institute of Marine Research	WGIPS (2019107)	Herring	*Clupea harengus*	Norwegian Sea	May-June	Index of abundance
Norway	Institute of Marine Research	Spawning survey	Herring	*Clupea harengus*	Norwegian Coast	February	Spawning biomass

		NVG herring (2019840, 841, 842)					
Peru	Peruvian Marine Research Institute	Pelagic fishes	Small Pelagic species (e.g. anchovy)	*Engraulis ringens*	Northern Humboldt Current System	All years: February to April, August to September, October to November	index of abundance and distribution
Peru	Peruvian Marine Research Institute	Demersal fishes	Demersal species (e.g. hake)	*Merlucius gayii*	Northern Humboldt Current System	All years: May to June	index of abundance and distribution
Peru	Peruvian Marine Research Institute	Coastal fishes	Coastal species (e.g. Chilean silverside)	*Odonthestes regia*	Northern Humboldt Current System	All years: August	index of abundance and distribution
Peru	Peruvian Marine Research Institute	Giant squid	Giant squid	*Dosidicus gigas*	Northern Humboldt Current System	All years: December to January	index of abundance and distribution
Peru	Peruvian Marine Research Institute	Antarctic krill	Antarctic krill	*Euphasia superba*	Bransfield Strait, Area 48, Antarctica	All years: January	index of abundance and distribution
Peru	Peruvian Marine Research Institute	Freshwater fishes	Freshwater species (e.g. Ispi)	*Orestias mooni*	Titicaca Lake	All years: May	index of abundance and distribution
Senegal	ISRA / CRODT	A22	Small Pelagic	*Scomber scolias, Sardinelle aurita, S. madarensis,Trachurus trachurus, T. trecae*	Senegal shelf	July 2022	index of abundance and distribution
Senegal Mauritania Gambia	ISRA / CRODT with FAO	Nansen	Small Pelagic	*Sardina pilchardus, En-graulis encrasicolus , Scomber scolias, Sardinelle aurita, S.*	SRFC area	Oct. 2022	Transboundary pelagic survey off Northwest Africa

Guinea Bissau				*madarensis,Trachurus trachurus, T. trecae*			
Senegal Mauritania Gambia Guinea Bissau	ISRA / CRODT with FAO	Nansen	Small Pelagic	*Sardina pilchardus, En-graulis encrasicolus , Scomber scolias, Sardinelle aurita, S. madarensis,Trachurus trachurus, T. trecae*	SRFC area Mauritania, Snegl, Gambie, Guinea Bissau	Oct. 2021	Transboundary pelagic survey off Northwest Africa
Senegal Mauritania Gambia Guinea Bissau	ISRA / CRODT with FAO	Nansen	Demersal fish	*Epinephelus aeneus, Pagellus bellottii, Sparus caeruleostictus, Galeoides decadactylus,*	SRFC area Mauritania, Snegl, Gambie, Guinea Bissau	Feb-March 2022	Transboundary demersal survey off Northwest Africa
Spain	AZTI	JUVENA (Acoustic survey for juvenile anchovy)	Bay of Biscay Anchovy	*Engraulis encrasicholus*	Bay of Biscay	August/September	Age stratified index of abundance
Spain	AZTI	BFTIndex	Atlantic Bluefin tuna	*Thunnus thynnus*	Bay of Biscay	June/July	Relative abundance index
Spain	IEO		Bluefin tuna larval survey	*Thunnus thynnus*	Balearic Sea	June/July	Relative abundance index
UK	MASTS (Marine Alliance for Science & Technology Scotland), University of Aberdeen	North Sea Mackerel acoustic survey	NEA mackerel	*Scomber sombrus*	Northern North Sea	Oct	In situ TS, tilt angle distributions, Broadband measurementsAbundance index (in prep)
UK	Cefas	PELTIC Pelagic Ecosystem Survey	English Channel (ICES area 7e)	*Sprattus sprattus, Sardina pilchardus, Engraulis Encrasicolus*	Celtic Sea and Western	Q4	Age stratified index of abundance for sprat, sardine, anchovy, ecosystem

			sprat, sardine, anchovy	(*Trachurus trachurus, Scomber scombrus, Capros aper*)	Channel, ICES area 7d,e,f		indicators (phytoplankton, eutrophication)
UK	Cefas	IBTS North Sea	Specifically North Sea Mackerel	*Scomber scombrus*	ICES area 4	August	Opportunistic: Biomass estomates (R&D)
UK	Cefas	Discovery Seamount survey	Mesopelagics	Many *(Maurolicus muelleri)*	S. Atlantic Tristan de Cunha & St Helena	March / April	Biomass estimates; predator prey
UK	Marine Scotland Science	Herring Acoustic survey	North Sea herring	*Clupea harengus*	ICES area IV	July	Index at age for herring
UK	MASTS (Marine Alliance for Science & Technology Scotland), University of St Andrews	Lake Victoria acoustic survey	Nile perch and dagaa	*Lates niloticus* *Rastrineobola argentea*	Entire Lake Victoria	?	Biomass estimates
UK (Scotland)	Marine Scotland Science	West of Scotland Sprat	Sprat	*Sprattus sprattus*	W of Scotland	October	Biomass index for the fish species and krill
UK (Scotland)	Scottish Pelagic Fisheries Association & Marine Scotland Science	6aN herring -industry survey	Herring	*Clupea harengus,*	West of Scotland		Age-disaggregated estimate of biomass. Stock identity separation (morphometrics & genetics). Commercial catch age composition.
UK Scotland	University of Aberdeen	Dee estuary surveys	Clupeids (herring and sprat)	*Clupea harengus, Sprattus sprattus*	Dee estuary, Merseyside, England, UK	March 2021–Dec 2022 seasonal	Biomass and biomass at length estimates
United States	NOAA Alaska Fisheries Science Center	Winter acoustic-trawl survey of the Shumagin Islands area	Walleye pollock	*Gadus chalcogrammus*	Gulf of Alaska	February 2020	Index of abundance

United States	NOAA Alaska Fisheries Science Center	Winter acoustic-trawl survey of the southeast Aleutian Basin near Bogoslof Island	Walleye pollock	*Gadus chalcogrammus*	Bering Sea	February-March 2020	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Winter acoustic-trawl survey of Shelikof Strait	Walleye pollock	*Gadus chalcogrammus*	Gulf of Alaska	March 2020	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Uncrewed surface vehicle (USV) survey in response to the cancellation of a ship-based survey	Walleye pollock	*Gadus chalcogrammus*	Bering Sea	July-August 2020	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Winter acoustic-trawl survey of Shelikof Strait and Marmot Bay	Walleye pollock	*Gadus chalcogrammus*	Gulf of Alaska	March 2021	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Summer acoustic-trawl survey of the Gulf of Alaska	Walleye pollock, euphausiids	*Gadus chalcogrammus, Thysanoessa spp.*	Gulf of Alaska	June-July 2021	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Acoustic vessels of opportunity (AVO) index of midwater pollock abundance	Walleye pollock	*Gadus chalcogrammus*	Bering Sea	June-August 2021	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Winter acoustic-trawl survey of Shelikof Strait	Walleye pollock	*Gadus chalcogrammus*	Gulf of Alaska	March 2022	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Summer acoustic-trawl survey of the eastern Bering Sea	Walleye pollock, euphausiids	*Gadus chalcogrammus, Thysanoessa spp.*	Bering Sea	May-August 2022	Index of abundance
United States	NOAA Alaska Fisheries Science Center	Acoustic vessels of opportunity (AVO) index of midwater pollock abundance	Walleye pollock	*Gadus chalcogrammus, Thysanoessa spp.*	Bering Sea	June-August 2022	Index of abundance
United States	NOAA Northeast Fisheries Science Center	Annual autumn bottom-trawl survey	Atlantic herring	*Clupea harengus*	Gulf of Maine	September-November 2021-2022	Index of abundance

United States	NOAA Northeast Fisheries Science Center	Deep-See mesopelagic exploration	Numerous	Multiple	Oceanic waters of the US mid-Atlantic and New England	July-August 2022	
United States and Canada	NOAA Northwest Fisheries Science Center	Joint U.S.-Canada Pacific hake survey	Pacific hake	*Merluccius productus*	West coast of North America	June-September 2021	Index of abundance-at-age (age 2+), age-1 index.

Annex 6: Report on WGAST Research Activities

COUNTRY	INSTITUTE	BEHAVIOUR	EMERGING TECHNOLOGIES, METHODOLOGIES AND PROTOCOLS	ACOUSTIC PROPERTIES OF MARINE ORGANISMS	APPLICATIONS OF ACOUSTIC METHODS TO CHARACTERIZE ECOSYSTEMS
Australia	Commonwealth Scientific Industrial Research Organisation		Multi-frequency characterization of open-ocean pelagic ecosystem through use of vertically deployed profiling acoustic-optical system. Development of acoustic systems for detection and monitoring fugitive CO_2 and methane gas releases	TS of commercial fish species combining in-situ acoustic measurements with concurrent stereo optical images and model based estimates	Australia's Integrated Marine Observing System, Biological Ship of Opportunity Program (IMOS BASOOP) – distribution and abundance of mesopelagics at ocean basin scale Biomass of commercial deep water fish species using vessel-based and deployed acoustic systems
Brazil	Insititut de Recherche pour le Développement (IRD) Universidade Federal de Pernambuco (UFPE) Universidade Federal Rural de Pernambuco (UFPE)	Diel behaviour of pelagic and demersal communities	Combination of multifrequency acoustics and a variety of optical methods (tawd video, ROV-mounted video, stereo-video)	Fish TS and multifrequency discrimination of scatters (gelatinous, etc.); Physical properties: extraction of the thermohaline structure from multifrequency echograms	Comprehensive three-dimensional characterization of multiple ecosystem components from physics to apex predators
Canada	Fisheries and Marine Institute of Memorial University / Université Laval / Fisheries and Oceans Canada	Diel behaviour of pelagic species in the Arctic and Labrador ea	Applications of bottom-moored, ice-tethered echosounders, and acoustic probes. Classification of fish and zooplankton species using broadband echosounder data. Use of machine learning to classify acoustic data.	Target-strength measurements. Broadband characterization of polar cod, Atlantic cod, and mesopelagic species.	Assesment of interannual and seasonal changes in abundance and distribution of pelagic and mesopelagic fish in the Canadian Arctic and the Labrador Sea.

Canada	DFO Institute of Ocean Sciences	Migration behaviour and movement of stocks and its implication for fisheries surveys.	Develop methodologies to conduct fisheries acoustic surveys using Unmamed Surface Vessels (USVs), Saildrones and estimate biomass of pacific hake. Classification of fish and zooplankton species using broadband echosounder data. Use of machine learning to classify acoustic data. Development of optical methods and imaging techniques to assist in the interpretation of fisheries acoustics data.	In situ target-strength measurements. Broadband characterization of pelagic species.	Echosystem-based acoustic surveys on pelagic-demeral fish (pacific hake), rockfish, zooplankton, and mesopelagic species. Environmental impacts on fish/zooplankton ecology. Salmon migration and effects of aquaculture on wild stocks. Predator-prey interactions.
Canada	Fisheries and Oceans Canada (Institut Maurice Lamontagne)	Diel behaviour of pelagic and demersal communities	Use of bottom-moored echosounders. Use of underwater cameras in acoustic surveys. Development of machine learning methods for acoustic classification.	In-situ measurements of average fish length using school-based multi-frequency analysis	Ecosystem-based acoustic surveys for herring, redfish and capelin stocks.
Cabo Verde	Instituto do Mar (IMar) / Sea Institute		Use of different platforms, such as Wave Glider, Saildrone and Echosounder EK80, for echosystemic approach and stock assessent study around the Cape Verde islands.		acoustic studies for ecosystem approach and fish stock assessment
France	Ifremer	Study of small pelagic fish aggregative behaviour based on multibeam echosounder three-dimensional schools	Fish biomass assessment with horizontal beaming echosounders. Development of EchoR R package for fish biomass acoustic assessment.	In situ measurements of European anchovy and sardine, mesozooplankton and micronekton TS Modelling fish TS	Multidisciplinary integrated surveys to monitor pelagic ecosystems. Small pelagic fish habitat and ecosystem mapping, ecosystem state indices

			Geostatistics for mapping fish distributions in space and time. Applications of bottom-moored and shipborne broadband echosounders to monitor coastal pelagic ecosystems and assess the impact of marine renewable energy. Use of Unmanned Surface Vehicules to complete pelagic ecosystems monitoring		
France	IRD with MNHN	Application of acoustics to ultracoastal waters Combination of scuba diver observations with active acoustics	Combining vertical multibeam sonar and broadband acoustics in shallow coastal waters Development of broadband analysis in Matecho		Use of SSL as ecostsemic indocator of change in large marine Ecosystem
Greece	Hellenic Centre for Marine Research	Diurnal migration patterns of small pelagic species Diurnal migration patterns of mesopelagic species Habittat compression induced by dissolved oxygen stratification		In situ TS estimation of small pelagic and mesopelagic fish	Annual assesment of the abundance and distribution of small pelagic fish in GSA 20 and 22 (east. Mediterranean) as part of the MEDIAS. Habitat modelling for the spatio-temporal study of the anchovy and sardine biomass distribution. Surveys for the seasonal study of mesopelagic assemblages at specific locations of eastern Mediterranean Sea.

Iceland	Marine and Freswater Research Institute	Sudies of spatial and temporal dynamics of capelin	Development and use of underwater cameras for observations of fish, and other organisms, as well as habitats.	Concurrent acoustic and optic observations of euphausiids, aiming at estimation of in situ average target strength. In situ target-strength measurements of pelagic and mesopelagic fish	Marine ecosystem acoustic surveys in fjords and open ocean Mapping the seafloor
Ireland	Marine Institute	Behaviour and interactions of SPF to survey sampling gear (trawls). Spatial and temporal dynamics of SPF during key life hisotry stages	Development of a dedicated sampling trawl for mesopelagic species and optical systens for monitoring interactions with trawl gear		Multi-disiplinary ecosystem monitirng surveys
Italy	CNR-National Research Council, IRBIM-Institute for Marine Biological Resources and Biotechnologies			Studies on target strength of pelagic fishes throught in-situ, ex-situ experiments and backscattering models	Annual assesment of the biomass and distribution of small pelagic fishes in the Adriatic Sea, GSAs 17 and 18 (Mediterranean Sea) in the framework of MEDIAS Project. Pelagic ecosystem monitoring of the key species of Middle Trophic Level in the Ross Sea Marine Protected Area, Antarctica.
Mauritania	IMROP with IRD	Spatial shift of small pelagic vs. climate Diel vertical migration of SSL			Use of SSL as ecosystemic indicator of change in large marine Ecosystem Fish stock assessment
New Zealand	National institute of Water & Atmospheric Research Ltd	Observation of migration with bottom-moored echosounders.	Applications of bottom-moored echosounders. Optical/acoustic surveys including trawl cameras.	In situ measurements of fish tilt angle and TS using cameras and deep-towed systems.	Using acoustics to evaluate and predict abundance of mid-trophic level organisms for ecosystem modelling.

		Characterization of diurnal migration of mesopelagic fish.	Acoustic deployments on sea ice. Acoustic characterization of gas seeps. Estimation of uncertainty for acoustic indices in Bayesian assessments. Development of ESP3 analysis software. Calibration and comparison of FCV30 and EK60 echosounders. Implementation of resonace scattering models. Protocols and methodologies for automated classification of acoustic data. Echo-counting.		Monitoring Ross Sea Marine Protected Area using vessels of opportunity, sea iced based deployments, and moorings.
Norway	Instutute of Marine Research	Observations of cod spawning migration with bottom mounted observatory (Love) Direct measurement of blind zone problem and fish avoidance during pelagic fish surveys Measuring behaviour of schools in the catch situation, before and after purse sein catching Measuring the behaviour of spawning cod during sounds from seismic air gun sounds.	Bottom mounted systems. Acoustic probes using broadband echosounders. Development and trials of new multibeam sonar systems. Trial of acoustics from drone systems, like KayakDrone, saildrone and Hugin. Further development of broadband analysis in LSSS postprosessing software. Comparing FM and CW surveying results	Experiments with wideband measurements on single targets for understanding the backscattered spectrum. In situ measurements of mean target strength in lateral aspect. (to convert sonar school measurements to biomass). TS measurements of mesopelagic fish.	Ecosystem acoustic surveys in Arctic, Antarctic areas, as well as within Norwegain EEZ. Ecosystem surveys within African waters. Development of direct photographic system in codend: DeepVision system, and interfacing this with LSSS interpretation system.

Norway	UiT The Arctic University of Norway	Diel behaviour of pelagic species in the Arctic. Artificial light avoidance.	Applications of bottom-moored, ice-tethered, and USV-mounted echosounders.	Broadband characterization of polar cod, Atlantic cod, and zooplankton	Assesment of seasonal changes in abundance and distribution of pelagic and mesopelagic fish in the European Arctic.
Panamá	Albor Tecnologico (peruvian company)		Develop methodologies to evaluate acoustic in line using satellite comunicaction Geostatistics for mapping fish distributions in space and time.	Fish TS at the panama bay: herring (Opisthonema libertate y Opisthonema medirastre) and Anchovy (Cetengraulis mysticetus)	Annual Marine acoustic surveys on pelagic fish in panama bay. In 2022 Stock evaluation and estimation of quota Annual assesment of the abundance and distribution of small pelagic fish
Peru	Peruvian Marine Research Institute (IMARPE)	Characterization of diurnal migration of mesopelagic fish Characterization of the relationship between mesopelagic organisms (e.g. predator-prey)	Echocounting experiments using a IxBlue Seapix multibeam sonar	In situ measurements of fish tilt angle and TS	Using acoustics to evaluate the abundance of low trophic level organisms for ecosystem modelling. Characterization of the interaction between biotic (oxycline) and abiotic (biological fields) parameter
Peru	Federico Villarreal University (UNFV)		Acoustic characterization of gas seeps.		
Peru	Humboldt Institute of Marine and Aquaculture Research (IHMA) - UNFV				Protocol for estimating fish and zooplankton abundance using industry vessels' acoustic data. Relationship between sea surface level anomaly, vorticity, internal waves and acoustic abundance of organism.

					Indentification of convergence and divergence processes based on the acoustic detection of the minimun oxygen zone.
Poland	Institute of Oceanology Polish Academy of Sciencies IO PAS	Tilt angle distribution of Baltic herring Characteristic features of spatial distribution of fish in the Gulf of Gdańsk and its temporal variation. Characterization of diel vertical migration of fish in the Gulf of Gdańsk		Modelling of Baltic herring TS Multifrequency discrimination of Baltic scattering organisms	
Senegal	ISRA / CRODT with IRD	Spatial shift of small pelagic vs. climate Diel vertical migration of SSL	Correction of active acoustics data for the water colum vs. sound celerity profile in Matecho		Bi-frequency method to estimate coppepods Use of SSL as ecosystemic indocator of change in large marine Ecosystem Fish stock assessment
Spain	AZTI	Tilt angle distribution of anchovy	Size discrimination of tuna based on Kongsberg M3 Size discrimination of tuna based on broadband acoustics. Influence of ping rate on the error of abundance estimations. Distortion correction of across-beam dimensions measured with multibeam sonars.	In situ TS of European anchovy In situ TS of Maurolicus muelleri. Swimbladder behavior with pressure in Maurolicus muelleri. In situ TS of Bluefin tuna. In situ acoustic properties of salp.	Multidisciplinary oceanographic surveys to study the pelagic ecosystem.
Spain	IEO. Centro de Baleares.	Characterization of diurnal migration of mesopelagic	AZFP & EK80, horizontal beaming, rosette	Mesopelagic species modelling	Mesopelagic and bathypelagic ecosystem.

		fish. Avoidance reactions of mesopelagic fish. Identification of acoustic layers with avoidance.	deployment. Using machine learning and AI to perform species identification.		
UK	MASTS (Marine Alliance for Science & Technology Scotland), University of Aberdeen	Tilt angle distribution of mackerel	Low frequency broadband scattering of fish Geostatistical conditional simulations for error propagation in acoustic surveys Optical methods for alterntive evidence ofr species identification Mesopelagic fish biomass estimation using an acoustic-driven and observation-based open-ocean biomass framework. Using machine learning and AI to perform species identification.	In situ measurements of fish TS Modelling fish TS	Predator prey relationships in a heavily exploited ecosystem Deep scattering layer in the Antarctic Prey surveys around foraging whale sharks. Global mesoepalgic biogeography based on deep scattering layers. Fine-scale vertical structure of mesopelagic communities and links to deep-diving predators. Linking echosounder observations to ecological models.
UK	Cefas (Centre for Fisheries and Aquatic Sciences)	Observations of plankton behaviour and patchiness using surface gliders; vertical and horizontal migration and stock structure of pelagic fish and meso pelagic fish using gliders and RV	Wavegliders as platfroms for echsounders		Habitat selection in foraging seabirds, cetaceans and bluefin tuna; Predator prey habitat use in subtropical reefs; predator-prey habitat use in seamounts
UK	SPFA (Scottish Pelagic Fishermens Association)				Herring survey to distinguish stock structure of European western herring

UK	Queen's University Belfast		M3 multibeam sonar imaging of marine fauna. ADCP, AZFP & EK80 (broadband), deployments (bottom-mounted and mobile surveys) in high-flow environments to discriminate physics (e.g. bubbles) from biological targets.		Foraging habitat of seabirds, marine mammals and sharks (fine-scale)
UK	Bangor University	Understanding the depth distribution of fish schools and its drivers in high current areas. Reponses of fish schools to operating marine renewable energy devices.			Combined use of bottom mounted upward looking and vessel mounted downward looking echosounders to characterize water column use in high current areas.
UK	University of Aberdeen & Greenland Institute of Natural Resources & DTU-aqua Denmark	Depth distribution of Greenland cod	Small vessel deployments close to shore	Broadband TS of Greenland cod	Estimates of abundance and biomass of Greenland cod in fjords Comparison of echocounting methods
UK	University of Aberdeen		Comparing imaging sonar with optics for counting fish near man made marine structures		Effects of decomissioning oil and gas platform on fish
UK	University of Aberdeen		USV surveys near oil and gas platforms and through windfarms		Effects of decomissioning oil and gas platform on fish
US	NOAA Alaska Fisheries Science Center, Midwater Assessment and Conservation Engineering (MACE) Program	Investigation of fish capture processes, migration and overwinter behavior of fish stocks, fish response to underwater lights and instrumentation packages.	USV deployments to provide survey information after cancellation of ship-based surveys due to COVID pandemic.	Data mining observations of target strength of walleye pollock (*Gadus chalcogrammus*), target strength from historical survey data. Development of probabilistic inversion	Improvement to methods for stock assessment surveys, particularly studies of trawl selectivity, methods for allocation of backscatter among species,

			Evaluation of new echosounder instrumentation (EK60/EK80). Use of moored echosounders to study fish migrations and Arctic fishes during periods of ice cover. Development and use of underwater stereo cameras for observations of fish, zooplankton, and habitat.	methods for backscatter species classification.	echosounder comparisons (EK80/EK60). Catchability of rockfish (Sebastes spp.) using split beam, multibeam, and underwater camera observations. Use of survey products (krill abundance index) in ecosystem approach to fisheries management
US	NOAA National Centers for Coastal Ocean Science Florida International Univeristy	Reef fish spawning aggregations; predator/prey interactions Spatial and temporal dynamics of spawning aggregations of subtropical reef fish	Echosounders in ocean gliders Application of narrowband, broadband and imaging sonar methodologies for quantifying spawning aggregations in coastal reefs	Broadband modelling and field observations for differentiating diverse fish communities In situ tilt angle, scattering properties, modelling orientation specific fish TS	Marine ecosystem acoustic surveys in marine sanctuaries and marine reserves; multi-trophic level surveys of fish and zooplankton over coral reefs; seafloor habitat mapping Enhance fisheries independent survey methodologies for reef fish management in Southeast US.
US	NOAA Northwest Fisheries Science Center, Fisheries Engineering and Acoustic Technologies (FEAT) Team	Spactial and temporal distribution of important fish and zooplankton species off the west coasts of US and Canada	Develop methodologies to conduct fisheries acoustic surveys using Unmamed Surface Vessels (USVs), Saildrones and estimate biomass of pacific hake Classification of fish and zooplankton species using	Shipboard measurements of acoustic properties of zooplankton (g & h) Develop scattering models of a variety of fish and zooplankton species	Echosystem-based acoustic surveys on pelagic-demeral fish (pacific hake), rockfish, zooplankton, and mesopelagic species Environmental impacts on fish/zooplankton ecology

			broadband echosounder data		
US	NOAA Northeast Fisheries Science Center	Diel behaviour of mesopelagic species	Wideband acoustic (1-500 kHz) and optical (cameras, holographic imaging) characterization of the deep scattering layers. Development of open-source code for processing and analysing acoustic data.	Development and application of acoustic scattering models for abundance and biomass estimates of marine organisms.	Investigation of the catchability and selectivity of pelagic trawls for the mesopelagic community. Investigation of Atlantic herring consumption on krill. Integration of acoustic estimates of krill abundance and biomass in ecosystem models.
US	NOAA Northeast Fisheries Science Center	Distribution of animals and seabed characterization in and around offshore wind development areas and "wind farms"			Surveys and monitoring of proposed offshore wind development areas prior to construction, and surveys of existing wind farms to study the effects of wind energy on pelagic and demersal species, and address benthic habitat effects.
US	NOAA Pacific Islands Fisheries Science Center				Assessment of the effects of the environment (e.g. temp, oxy) on the distribution, composition, and relative biomass on micronekton in the Central North Pacific.

Annex 7: Report on WGFAST Interactions with other ICES Expert Groups

Country	Institute	Name	Expert Group	Comment
Poland	Institute of Oceanology Polish Academy of Sciences	Natalia Gorska	Baltic International Fish Survey Working Group	Cooperation with Sea Fisheries Institute in Gdynia reasponsible for hydroacoustic surveys in Polish part of the Baltic Sea
Ireland	Marine Institute	Ciaran O'Donnell	WGIPS	WG International Pelagic Surveys
Ireland	Marine Institute	Ciaran O'Donnell	WGACEGG	Working Group on Acoustic and Egg Surveys for small pelagic fish in NE Atlantic
Ireland	Marine Institute	Ciaran O'Donnell	WGAcousticGov	ICES Trawl acoustic Database Governance Group
Netherlands	Wageningen Marine Research	Bram Couperus	WGIPS	WG International Pelagic Surveys
Netherlands	Wageningen Marine Research	Bram Couperus	WGAcousticGov	ICES Trawl acoustic Database Governance Group
Netherlands	Wageningen Marine Research	Serdar Sakinan	WKEVUT	Workshop to Evaluate the Utility of Industry-derived data for enhancing scientific knowledge and providing data for stock assessments
Iceland	Marine and Freshwater Research Institute	Teresa Silva	WGZE	ICES Working group on Zooplankton Ecology
Estonia	Estonian Marine Institute	Elor Sepp	WGBIFS	Baltic International Fish Survey Working Group
Estonia	Estonian Marine Institute	Elor Sepp	WGAcousticGov	ICES Trawl acoustic Database Governance Group
Estonia	Estonian Marine Institute	Elor Sepp	WGOWDF	Working Group on Offshore Wind Development and Fisheries

US	NOAA Northeast Fisheries Science Center	Michael Jech	WGAcousticGov	ICES Trawl acoustic Database Governance Group
US	NOAA Northeast Fisheries Science Center	Michael Jech	WGChairs	Working group for expert group chairs.

Annex 8: List of WGFAST Publications

Accola, K.L., J.K. Horne, J.R. Cordell, and J.D. Toft. 2022. Acoustic characterization of juvenile Pacific Salmon distributions along an eco-engineered seawall. Marine Ecology Progress Series 682: 207-220 (doi: 10.3354/meps13917).

Accola, K.L., J.K. Horne, J.R. Cordell, and J.D. Toft. 2022. Nocturnal distributions of juvenile Pacific salmon along an eco-engineered marine shoreline. Marine Ecology Progress Series 687: 113-123 (doi:10.3354/meps14006).

Bassett, C., De Robertis, A., and C.D. Wilson, C. D. 2017. Broadband echosounder measurements of the frequency response of fishes and euphausiids in the Gulf of Alaska. – ICES Journal of Marine Science, doi:10.1093/icesjms/fsx204.

Bolser, D.G., J.P. Egerton, P.M. Souza, K.M. Boswell, B.E. Erisman. 2022. Assessing the size spectra of marine fish communities with hydroacoustics: Examining the challenges of abundant schools, diverse assemblages, and variable orientations. Canadian Journal of Fisheries and Aquatic Sciences. https://doi.org/10.1139/cjfas-2021-0189

Boswell, K.M., G. Pedersen, J.C. Taylor, S. Labua, W.F. Patterson, III. 2020. Morphological variation and broadband scattering responses of reef-associated fishes from the Southeast United States. Fisheries Research. 10.1016/j.fishres.2020.105590

Boswell, K.M., [P]M.A. D'Elia, M. Johnston, T.T. Sutton, A. Cook, J. Mohan, J.D. Warren, R.J.D. Wells. 2020. Oceanographic Structure and Light Levels Drive Patterns of Sound Scattering Layers in a Low-Latitude Oceanic System. Frontiers in Marine Science, 7:51. doi:10.3389/fmars.2020.00051

Bouchard, C., Chawarski, J., Geoffroy, M., Klasmeier, A., Møller, E.F., Mohn, C. and Agersted, M.D., 2022. Resource partitioning may limit interspecific competition among Arctic fish species during early life. Elementa Science of the Anthropocene, 10: 00038. https://doi.org/10.1525/elementa.2021.00038

Cammen, K., Marafino, G., Burton, S., Dow, J., Dullaert, E., Jorge, M., Macolini, L., McGarry, L., Tremblay, C., Jansujwicz, J., Johnson, T., Ross, L., and Zydlewski, G., 2021. Interdisciplinary research collaborative trains students to see through turbulent systems. Oceanography 34(1), https://doi.org/10.5670/oceanog.2021.102

Chu, D., Ostrovsky, I., and Homma, H. 2021. "Acoustic observation and evaluation of gas-bearing cyanobacterium Microcystis sp. biomass with echosounders at multiple frequencies: acoustic modeling and in situ measurements," Sci. Total Environ. 794 (2021) 148573. https://doi.org/10.1016/j.scitotenv.2021.148573

Cook, A.B., K. Boswell, D. English, T. Richards, M. Johnston, N. Pruzinsky, R.J. Milligan, B. Penta, I. Romero, S deRada, C. Lembke, H. Judkins, H. Bracken-Grissom, T. Frank, M. Weber, R. Eytan, A. Bernard, M. Vecchione, C. Hu, J. Quinlan, and T.T. Sutton. 2020. A Multidisciplinary Approach to Investigate Deep-Pelagic Ecosystem Dynamics in the Gulf of Mexico following Deepwater Horizon has been approved for production and accepted for publication in Frontiers in Marine Science, section Deep-Sea Environments and Ecology. *Frontiers in Marine Science, doi: 10.3389/fmars.2020.548880*

Couto, A. S., and Fernandes, P. 2021. Tidal streams, fish and seabirds: understanding the linkages between mobile predators, prey, and hydrodynamics. Ecosphere. Wiley.

De Robertis, A., Levine, M., Lauffenberger, N., Honkalehto, T., Ianelli, J., Monnahan, C., Towler, R., Jones, D., Steinessen, S. and McKelvey, D., 2021. Uncrewed surface vehicle (USV) survey of walleye pollock, Gadus chalcogrammus, in response to the cancellation of ship-based surveys. ICES Journal of Marine Science, 78: 2797-2808. https://doi.org/10.1093/icesjms/fsab155

Dmitrenko, I.A., Petrusevich, V.Y., Kosobokova, K., Komarov, A.S., Bouchard, C., Geoffroy, M., Koldunov, N.V., Babb, D.G., Kirillov, S.A. and Barber, D.G., 2021. Coastal Polynya Disrupts the Acoustic Backscatter Diurnal Signal Over the Eastern Laptev Sea Shelf. Frontiers in Marine Science. 8: 791096. https://doi.org/10.3389/fmars.2021.791096

Domokos, R. 2021. On the development of acoustic descriptors for semi-demersal fish identification to support monitoring stocks. ICES JMS., doi:10.1093/icesjms/fsaa232

Doray, M., Boyra, G., and van der Kooij, J. (Eds). 2021. ICES Survey Protocols – Manual for Acoustic Surveys Coordinated under the ICES Working Group on Acoustic and Egg Surveys for Small Pelagic Fish (WGACEGG). ICES Techniques in Marine Environmental Sciences Vol. 64. 100 pp.

Dunn, M., & Zedel, L. (2022). Evaluation of discrete target detection with an acoustic Doppler current profiler. Limnology and Oceanography: Methods.Domokos, R. 2021. On the development of acoustic descriptors for semi-demersal fish identification to support monitoring stocks. ICES JMS., doi:10.1093/icesjms/fsaa232

Easson, C.G., K.M. Boswell, [F]N. Tucker, J.D. Warren, J.V. Lopez. 2020. Combined E-DNA and Acoustics Analysis Reflects Diel Vertical Migration of Mixed Consortia in the Gulf of Mexico. *Frontiers in Marine Science. https://doi.org/10.3389/fmars.2020.00552*

Escobar-Flores, P. C.; O'Driscoll, R. L.; Montgomery, J. C.; Ladroit, Y.; Jendersie, S. (2020). Estimates of density of mesopelagic fish in the Southern Ocean derived from bulk acoustic data collected by ships of opportunity. Polar Biology 43: 43-61.

Fernández Castro, B.; Peña, M.; Nogueira, E.; Gilcoto, M.; Broullón, E.; Comesaña, A.; Bouffard, D.; Naveira Garabato, Alberto C. & Mouriño-Carballido, B. Intense ocean mixing in fish spawning aggregations. Nature geosciences, 2022, 15 (4), 1-6

Garner, S.B., Ahrens, R., Boswell, K.M., Campbell, M.D., Correa, D., Tarnecki, J.H. and Patterson III, W.F., 2022. A multidisciplinary approach to estimating red snapper, *Lutjanus campechanus*, behavioral response to mobile camera and sonar sampling gears. *Fisheries Research*, *246*, p.106155.

Geoffroy, M., Langbehn, T., Priou, P., Varpe, Ø., Johnsen, G., Le Bris, A., Fisher, J.A., Daase, M., McKee, D., Cohen, J. and Berge, J., 2021. Pelagic organisms avoid white, blue, and red artificial light from scientific instruments. Scientific Reports, 11: 1-13. https://doi.org/10.1038/s41598-021-94355-6

Gíslason Á, Jakobsdóttir K, Guðmundsson K, Egilsdóttir S and Silva T (2021) Sampling for the MEESO project during the International Ecosystem Summer Survey in Nordic Seas on the R/V Arni Fridriksson in July 2020. Haf- og vatnarannsóknir. HV2021-22. 26 pp.

Gíslason Á, Reynisson P, Karlsson H, Hreinsson E, Silva T and Jóakimsson K (2021). Ljósáta í Ísafjarðardjúpi – nýtanleg auðlind? / Euphausiids in Ísafjarðardjúp - a harvestable resource? Haf- og vatnarannsóknir. HV2021-52. 43 pp.

Gonzalez, S. J.K. Horne, and S.L. Danielson. 2021. Multi-scale temporal variability in biological-physical associations in the NE Chukchi Sea. Polar Biology 44: 837-855 (doi: 10.1007/s00300-021-02844-1).

Gorska N., J. Idczak. 2022. *On Baltic herring morphometry and its impact on the backscattering properties.* Oceanologia, 64(1): 198-211. https://doi.org/10.1016/j.oceano.2021.10.001

Govindarajan, A. F., R. D. Francolini, J. M. Jech, A. C. Lavery, J. K. Llopiz, P. H. Wiebe, W. Zhang. 2021. Exploring the use of environmental DNA (eDNA) to detect animal taxa in the mesopelagic zone. Frontiers in Ecology and Evolution. doi: 10.3389/fevo.2021.574877

Greer, A.T., J.C. Lehrter, B.M. Binder, A.R. Nayak, R. Barua, A.E. Rice, J. Cohen, M. McFarland, A. Hagemeyer, N.D. Stockley, K.M. Boswell, I. Shulman, S. deRada, B. Penta. 2020. High-resolution sampling of a broad marine life size spectrum in relation to shelf biophysical characteristics. *Frontiers in Marine Science, doi: 10.3389/fmars.2020.542701*

Hjartarson, Á., Erlendsson, Ö., Hersir, G.P., Richter, B., Hagalínsson, G., Óðinsson, D.Þ. (2020). Exploring Offshore Geothermal Fields Around Iceland. Proceedings World Geothermal Congress 2020+1. https://pangea.stanford.edu/ERE/db/WGC/papers/WGC/2020/11126.pdf

Idczak J., A. Brodecka-Goluch, K. Łukawska-Matuszewska, B. Graca, N. Gorska, Z. Klusek, P. D. Pezacki, J. Bolałek. 2020. A geophysical, geochemical and microbiological study of a newly discovered pockmark with active gas seepage and submarine groundwater discharge (MET1-BH, central Gulf of Gdańsk, southern Baltic Sea). Science of The Total Environment, 742, 140306. https://doi.org/10.1016/j.scitotenv.2020.140306

Jech, J. M., J. J. Johnson, M. Lutcavage, A. S. M. Vanderlaan, Y. Rzhanov, D. LeRoi. 2020. Measurements of juvenile Atlantic bluefin tuna (Thunnus thynnus) size using an unmanned aerial system. Journal of Unmanned Vehicle Systems, 8: 140-160. DOI:10.1139/juvs-2018-0039.

Jech, J.M, M. Schaber, M. Cox, P. Escobar-Flores, S. Gastauer, K. Haris, J. Horne, T. Jarvis, Y. Ladroit, R. O'Driscoll, G. Pedersen, M. Pena, T. Ryan, S. Sakinan, R. Thomas, H. Viehman, C. Wall, and T. Whitton. 2021. Collecting quality echosounder data in inclement weather. ICES Cooperative Research Report, Vol. 352. 108 pp. (doi: 10.17895/ices.pub.7539).

Ladroit, Y.; Escobar-Flores, P. C.; Schimel, A. C. G.; O'Driscoll, R. L. 2020. ESP3: An open-source software for the quantitative processing of hydro-acoustic data. SoftwareX 12: 100581-100581.

Lawrence, J. M., and Fernandes, P. G. 2021. A switch in species dominance of a recovering pelagic ecosystem. Current Biology, 31: 4354-4360.e3. Elsevier.

Levine, R. M., De Robertis, A., Grünbaum, D., Woodgate, R., Mordy, C. W., Mueter, F., Cokelet, E., Mueter, F., Cokelet, E., Lawrence-Slavas, N., and Tabisola, H. 2021. Autonomous vehicle surveys indicate that flow reversals retain juvenile fishes in a highly advective high-latitude ecosystem. Limnology and Oceanography, 66: 1139-1154. https://aslopubs.onlinelibrary.wiley.com/doi/full/10.1002/lno.11671

Lowe, S.C., McGarry, L.P., Douglas, J., Newport, J., Oore, S., Whidden, C., and Hasselman, D.J. Echofilter: A Deep Learning Segmentation Model Improves the Automation, Standardization, and Timeliness for Post-Processing Echosounder Data in Tidal Energy Streams. In revision at Frontiers in Marine Science special issue Novel Technologies for Assessing the Environmental and Ecological Impacts of Marine Renewable Energy Systems

Lucca, B.M., Ressler, P.H., Harvey, H.R., and Warren, J.D. 2021. Individual variability in sub-Arctic krill material properties, lipid composition, and other scattering model inputs affect acoustic estimates of their population, ICES Journal of Marine Science, Volume 78(4): 1470–1484, https://doi.org/10.1093/icesjms/fsab045

Marques, T.P., Cote, M., Rezvanifar, A., Albu, A., Ersahin, K., Mudge, T., and Gauthier, S. 2021. Instance Segmentation-based Identification of Pelagic Species in Acoustic Backscatter Data. Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR) Workshops, 2021, pp. 4378-4387.

McGowan, D.W., E. Goldstein, M. Arimitsu, A. Deary, O. Ormseth, A. De Robertis, J.K. Horne, L.A. Rogers, M.T. Wilson, K.O. Coyle, K. Holderied, J.F. Piatt, W.T. Stockhausen, and S. Zador. 2020. Spatial and temporal dynamics of Pacific capelin Mallotus catervarius in the Gulf of Alaska: implications for ecosystem-based fisheries management. Marine Ecology Progress Series 637: 117-140. (doi: 10.3354/meps13211).

McKenzie, T.L., M. Twardowski, N. Briggs, A.R. Nayak, K.M. Boswell, F. Dalgleish. 2020. Three-dimensional imaging lidar for characterizing particle fields and organisms in the mesopelagic zone. *Frontiers in Marine Science, doi: 10.3389/fmars.2020.558745*

Moriarty, P.E., T.E. Essington, J.K. Horne, J.E. Keister, L. Li, S.L. Parker-Stetter, and M. Sato. 2020. Unexpected food web responses to low dissolved oxygen in an estuarine fjord. Ecological Applications 30: e02204 (doi: 10.1002/eap.2204).

Óðinsson, D.Þ., Ólafsdóttir, S.H., & Burgos, J.M. (2020). Characterization of the geomorphology and biotopes of the Háfadjúp canyon system, south Iceland. Editor(s): Peter T. Harris, Elaine Baker, Seafloor Geomorphology as Benthic Habitat (Second Edition), Elsevier, pp. 753-767. https://doi.org/10.1016/B978-0-12-814960-7.00045-2.

Pałgan, D., Tylmann, K., Devey, C.W., Óðinsson, D.Þ., & Le Saout, M. (2020). The extent of the ice sheet in the area of the Reykjanes Ridge at maximum of the last glaciation: new insights.

EGU General Assembly 2020. EGU2020-8539. https://doi.org/10.5194/egusphere-egu2020-8539

Parada, C., Ernst, B., Cornejo-Guzman, S., Santa Cruz, F., Sandoval Belmar, M., Rivara, P., Tapia, B. Gauthier, S., Pino-Aiguilera, J., Escribano, R., Morales, C.E. 2021. Local and remote physical processes driving variability of the planktonic system in the Juan Fernández Archipelago: A multidisciplinary framework providing conservation insights. Aquatic Conservation Marine and Freshwater Ecosystems 31 (2): 253-272. https://doi.org/10.1002/aqc.3499

Peña, M. Full customization of colour maps for fisheries acoustics: visualizing every target. Fisheries research, 2021, 240, 105949

Peña, M., Munuera-Fernandez, I., Nogueira, E. & Gonzalez-Quiros, R. First recording of a bathypelagic deep scattering layer in the Bay of Biscay. Progress in oceanography, 2021, 198, 102669

Peña, M.; Cabrera-Gámez, J. & Domínguez-Brito, A. C. Multi-frequency and light-avoiding characteristics of deep acoustic layers in the North Atlantic. Marine Environmental Research, 2020, 154

Phillips, E.M., J.K. Horne, and J.E. Zamon. 2021. Characterizing juvenile salmon predation risk during early marine residence. PlosOne 16: e0247241 (doi: 0.5061/dryad.z8w9ghxbk).

Phillips, E.M., Chu, D., Gauthier, S., Parker-Stetter, S.L., Shelton, A.O., and Thomas, R.E. 2022. Spatiotemporal variability of euphausiids in the California Current Ecosystem: insights from a recently developed time series. ICES Journal of Marine Science: fsac055. doi:10.1093/icesjms/fsac055.

Post S, Jónasdóttir SH, Andreasen H, Ólafsdóttir AH, Jansen T (2021) Blue whiting Micromesistius poutassou diel feeding behaviour in the Irminger Sea. Mar Ecol Prog Ser 678:1-16. https://doi.org/10.3354/meps13918

Priou, P., Nikolopoulos, A., Flores, H., Gradinger, R., Kunisch, E., Katlein, C., Castellani, G., Linders, T., Berge, J., Fisher, J.A. and Geoffroy, M., 2021. Dense mesopelagic sound scattering layer and vertical segregation of pelagic organisms at the Arctic-Atlantic gateway during the midnight sun. Progress in Oceanography, 196: 102611. https://doi.org/10.1016/j.pocean.2021.102611

Proud, R., Le Guen, C., Sherley, R. B., Kato, A., Ropert-Coudert, Y., Ratcliffe, N., Jarman, S., et al. 2021. Using Predicted Patterns of 3D Prey Distribution to Map King Penguin Foraging Habitat. Frontiers in Marine Science, 8: 1681.

Rodriguez-Pinto, I., N.O. Handegard, G. Rieucau, K.M. Boswell. 2020. Environmental context elicits behavioral modification of collective state in schooling fish. *Animal Behavior,* 165:107-116. https://doi.org/10.1016/j.anbehav.2020.05.002

Rodriguez-Pinto, I., G. Rieucau, N.O. Handegard, M.E. Kimball, K.M. *2021*. Anthropogenic Marsh Impoundments Alter Collective Tendency in Schooling Fish. *Estuaries and Coasts*. 10.1007/s12237-021-00961-y.

Rousseau, S., Gauthier, S., Neville, C., Johnson, S. and Trudel, M. (2020). A multi-frequency acoustic method to estimate mean standard length of juvenile salmon in the Discovery Islands, British Columbia. Fisheries Research, 227. https://doi.org/10.1016/j.fishres.2020.105536.

Sarmiento-Lezcano, A.; Olivar, P.; Peña, M.; Landeira, J.; Armengol, L.; Medina-Suárez, I.; Manfrida, D.; Castellón, A. & Hernández-León, S. Carbon remineralization by small mesopelagic and bathypelagic Stomiforms in the Northeast Atlantic Ocean. Progress in Oceanography, 2022, 203(4), 102787

Sato, M., Trites, A.W., and Gauthier, S. 2021. Southern resident killer whales encounter higher prey densities than northern resident killer whales during summer. Canadian Journal of Fisheries and Aquatic Sciences. 78(11): 1732-1743. https://doi.org/10.1139/cjfas-2020-0445

Schaber, M.; Gastauer, S.; Cisewski, B.; Hielscher, N.; Janke, M.; Peña, M.; Sakinan, S. & Thorburn, J. Extensive Oceanic Mesopelagic Habitat Use of a Migratory Coastal and Continental Shark Species Scientific reports, 2022, 12, 2047

Shelton, A. O., Ramón-Laca, A., Wells, A., Clemons, J., Chu, D., Feist, B. E., Kelly, R. P., Parker-Stetter, S. L., Thomas, R., Nichols, K. M., and Park, L. 2022. "Environmental DNA provides quantitative estimates of Pacific hake abundance and distribution in the open ocean," Proc. R. Soc. B 289: 20212613. https://doi.org/10.1098/rspb.2021.2613 .

Sobradillo, B., Boyra, G., Pérez-Arjona, I., Martinez, U., and Espinosa, V. 2021. Ex situ and in situ target strength measurements of European anchovy in the Bay of Biscay. ICES Journal of Marine Science, 78: 782–796.

Stevens, J. R., Jech, J. M., Zydlewski, G. B., Brady, D. C. Estimating target strength of estuarine pelagic fish assemblages using fisheries survey data. Journal of the Acoustical Society of America. 150(4): 2553-2565. https://doi.org/10.1121/10.0006449

Stienessen, S.C., Rooper, C.N., Weber, T.C., Jones, D.T., Pirtle, J.L., Wilson, C.D. 2021. Comparison of model types for prediction of seafloor trawlability in the Gulf of Alaska by using multibeam sonar data. Fish Bull. 119: 184-196. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/fish-bull/stienessen_0.pdf

White, A.L., W.F. Patterson, K.M. Boswell. *2022*. Distribution of habitat-specific backscatter associated with natural and artificial reefs in the northeastern Gulf of Mexico. *Fisheries Research. https://doi.org/10.1016/j.fishres.2021.106199*

Zhang, Y., Wall, C., Jech, J. M., Liu, Q. Automated identification of Atlantic herring schools from multifrequency echosounder data using semi-supervised machine learning. In review to ICES Journal of Marine Science.