ICES Fisheries and Plankton Acoustics Symposium

From Echosounders to the Cloud: Transforming Acoustic Data to Information

27-30 March 2023
Portland, Maine USA
#ICESAcoustics50

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2021 2030 United Nations Decade of Ocean Science for Sustainable Development

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Organism detection: models, measures, and classification

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Data Integration: Application to ecosystem, conservation, and society

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Schedule

Time	Sunday - 26 March	Time	Monday - 27 March	Session
16:00 to 19:00	Registration and Check-in	7:00	Registration and Check-in	Symposium
		9:00	Welcome	
		9:05	ICES Welcome	
		9:10	Conveners Welcome	
		9:25	Transition	
		9:30	Chair Overview	Models & Measures Session
		9:35	Wieczorek et al.: A comparison of acoustic, catch and video data to investigate and monitor grenadier abundance in the Ross Sea	
		9:50	Maslov et al.: North-west atlantic cetaceans detecting algorithm based on spectrogram classification using fastai machine learning model	
		10:05	Dunn et al.: Model-informed classification of broadband acoustic backscattering from zooplankton in an in situ mesocosm	
		10:20	Schaber et al.: The acoustic backscattering of spurdog / spiny dogfish (Squalus acanthias) – in situ, ex situ measurements and modelling	
		10:35	**Break**	
		11:00	Kashindye et al.: Identification of mesopelagic fish species using multi-frequency acoustic approaches – implications for biomass estimation	
		11:15	Loranger et al.: Acoustic species identification, length distribution and biomass estimation of a mixed species aggregation in an oceanographic frontal region	
		11:30	Grados et al.: Acoustic identification of the Northern Humboldt Current System's pelagic community using machine learning	
		11:45	Berges et al.: Modelled and measured broadband acoustic target strength comparison for fish with and without a swimbladder	

		12:00	Khodabandeloo et al.: Investigation of broadband acoustic to resolve and identify nearby targets using different pulse durations	
		12:15	**Lunch**	
		13:45	Matt et al.: Building a robust machine learning tool for discriminating between bottom schooling fish and the bottom echo	
		14:00	Lucca et al.: One size does not fit all: experimental target strength measurements of pteropods and shrimp emphasize the importance of scattering model inputs	
		14:15	Zytko et al.: Development of a hydroacoustic technique for determination of the orientation of aggregated Baltic herring	
		14:30	Kang et al.: Acoustic target strength with growth stage of fish: comparison of juvenile and adult Japanese anchovy (Engraulis japonicus)	
		14:45	Macaulay et al.: Target strength of mesopelagic organisms derived from computed tomography scans	
		15:00	Vohra et al.: Computer Vision-Based Echogram Annotation Methods for Acoustic Classification with Deep Learning Systems	
		15:15	**Break**	
		15:40	Barbin et al.: Micronekton repartition in western tropical Pacific from wideband profiler and hull-mounted narrowband acoustics	
		15:55	Gastauer et al.: Towards a better understanding of broadband scattering properties of single fish and zooplankton targets	
		16:10	Santivanez-Yuffra et al.: In situ target strength measurements of Peruvian anchovy (Engraulis ringens) from data collected with a commercial echosounder during fishing operations	
		16:25	Chacate et al.: A multifrequency acoustic algorithm to classify mesopelagic organisms within deep Sound Scattering Layers (SSL) in oligotrophic Indian Ocean	
		16:40	Whitman et al.: Utilization of a paired eDNA and acoustic survey for assessing assemblages in the Gulf of Maine	
		16:55	Lightning Talks Session 1: 15@2.5 minutes; Poster #s M1-M14 and A1	
		17:35	**Adjourn**	
		19:00	Welcome Reception	

Time	Tuesday - 28 March	Session
8:00	Registration and Check-in	Symposium
9:00	Daily Remarks	
9:05	Keynote - Andy Lipsky, A call to science—understanding fisheries, wildlife and ecosystem impacts in a new Era of Offshore Wind Development	
10:05	**Transition**	
10:10	Perez-Arjona et al.: Acoustical simulation of the target strength of Atlantic bluefin tuna using 3D computed tomographical images	Models & Measures Session
10:25	**Break**	
10:50	Hentati-Sundberg et al.: Target strength modelling of small pelagics in the Baltic Sea using the Kirchoff Ray Mode Model	
11:05	Yang et al.: Broadband acoustic scattering simulation and in-situ observation of dagaa (Rastrineobola argentea) in Lake Victoria, East Africa	
11:20	Mangeni et al.: Improving accuracy of dagaa acoustic biomass estimation in Lake Victoria using school analysis and geostatistics for Ecosystem based Fisheries Management	
11:35	Saavedra et al.: Do fish swim faster in the horizontal direction than up-down?. Study case: two small pelagic fish and two demersal fish	
11:50	**Lunch**	
13:20	Chair Overview	Analytics Session
13:25	Lee et al.: Building an open-source software toolbox for cloud-native processing of fisheries and plankton acoustic data	
13:40	Steig et al.: Using Artificial Intelligence for Identification of an Acoustic Signal	
13:55	Korneliussen et al.: Estimation and removal of noise in broadband echosounders	
14:10	Staneva et al.: Semantic Segmentation of Pacific Hake Aggregations in Water Column Echograms	
14:25	Annasawmy et al.: Micronekton multifrequency backscatter classification within an eddy dipole of the Mozambique Channel, South West Indian Ocean	
14:40	Wall et al.: Towards a cloud optimized data lake for archived water column sonar data	
14:55	**Break**	
15:20	Lightning Talks Session 2: 15@2.5 minutes; Poster #s A2-A5 and E1-E11	

16:00	Duskey et al.: Spatial tug of war: kriging spline model residuals of fish abundance in a Bayesian framework	
16:15	Handegard et al.: A story about data extraction and deep learning applied to fishery acoustic data	
16:30	Berges et al.: Impact of echosounder calibration errors on an international acoustic survey (HERAS)	
16:45	Valdez et al.: Using mixture Gaussian models for characterization of ispi (*Orestias ispi*) in Lake Titicaca, Peru - Bolivia	
17:00	McReynolds et al.: Classification of acoustically-similar pelagic forage fishes: combining ecological knowledge with machine learning	
17:15	Kalkhoran et al.: Real-time underwater acoustic data acquisition and processing with a large aperture 160-element coherent hydrophone array	
17:30	Lightning Talks Session 3: 13@2.5 minutes; Poster #s E12-E13 and T1-T11	
18:00	**Adjourn**	
18:30	Posters	

Time	**Wednesday - 29 March**	**Session**
8:00	Registration and Check-in	Symposium
9:00	Daily Remarks	
9:05	Keynote - Mike Fogarty, The Systems Approach to Fisheries Management: Concepts, Data Needs, and Strategies for Implementation	
10:05	Transition	
10:10	Chair Overview	Technology Session
10:15	Dornan et al.: Temporal patterns in South Georgia zooplankton: insights from a moored echosounder	
10:30	**Break**	
10:55	Milne et al.: Integrating Split-beam, Multibeam and Bio-telemetric Surveys to Estimate Fish Abundance: A New Approach to an Old Problem	
11:10	Geoffroy et al.: Pelagic organisms avoid white, blue, green, and red artificial light from scientific instruments	
11:25	Godo et al.: Industry based autonomous acoustic systems in near real time monitoring of marine ecosystems	

11:40	Le Bouffant et al.: Using seafloor backscatter for single beam echosounder calibration	
11:55	**Lunch**	
13:25	Silva et al.: Target strength measurements of deep scattering mesopelagic layers	
13:40	Johnsen et al.: Towards a multi-platform armada strategy for ecosystem based marine surveys	
13:55	Scoulding et al.: Monitoring snapper aggregations using recreational fish finders and aerial drones	
14:10	De Robertis et al.: Use of uncrewed surface vehicles in tandem with NOAA vessels to increase survey efficiency	
14:25	Benoit-Bird et al.: Echo Sounding atop the Wave of Oceanography's Robot Revolution	
14:40	Smith et al.: Shelf-based mooring reveals seasonally variable benthic behaviour of Antarctic krill	
14:55	**Break**	
15:20	T. Ryan et al.: Long range acoustic detection of gas seeps in a shallow water coastal environment	
15:35	Imaizumi et al.: Estimating splendid alfonsino (Beryx splendens) abundance using a low-frequency broadband quantitative echo sounder	
15:50	M. Pena et al.: Recording acoustic data from the surface to 4500 m depth with an AZFP attached to the rosette	
16:05	Campanella et al.: Plankton dynamics observed using fisheries acoustics from an autonomous vehicle	
16:20	Diachok et al.: Derivation of lengths and depths of anchovies and observations of schooling behavior from Bio-acoustic Attenuation Spectroscopy (BAS) measurements	
16:35	Sunnarborg et al.: Pairing environmental DNA with acoustic monitoring of anadromous fish in the Penobscot River, Maine	
16:50	Horne et al.: IoT Acoustic Monitoring of Tonle Sap River Fish Migration and Mortality for Cambodian Fisheries Management	
17:05	Doray et al.: Uncrewed Surface Vehicle (USV) for acoustic mapping of common dolphin and their small pelagic preys	
17:20	Chair Overview	Ecosystem Session
17:25	Zwolinski et al.: The school trap hypothesis predicts the spatial distribution and environmental preferences of the collapsed Pacific Sardine	
17:40	Hemed et al.: Biomass and geographical distribution of seven small pelagic fish species in relation to environmental condition in Mauritanian waters	

17:55	Thorvaldson et al.: They move in mysterious ways: Spatial behaviour of individual Calanus finmarchicus quantified by using broad-band target tracking	
18:10	**Adjourn**	
19:00	Banquet	

Time	**Thursday - 30 March**	**Session**
8:00	Registration and Check-in	Symposium
9:00	Daily Remarks	
9:05	Keynote - Kathy Mills, Advancing resilient marine ecosystems and fisheries in changing oceans	
10:05	Transition	
10:10	Ens et al.: Geographic variability in the seasonality of euphausiid diel vertical migrations among three locations in coastal British Columbia, Canada	Ecosystem Session
10:25	**Break**	
10:50	Ongore et al.: Acoustic estimation of haplochromine biomass in Lake Victoria: A novel approach to the estimation of pelagic biomass with precision	
11:05	Blanluet et al.: Fishing for answers: are there more tuna inside a blue-water marine reserve?	
11:20	Receveur et al.: Mesoscale oceanic eddies are not oases for mesopelagic organisms at global scale	
11:35	Klevjer et al.: The Mesopelagic and Beyond: High-Latitude Boundaries and Global Patterns in Vertical Connectivity of the Deep Ocean	
11:50	**Lunch**	
13:20	Copeland et al.: Linking Organisms from the Surface to the Seafloor Through Acoustic Analysis	
13:35	Diogoul et al.: Pelagic Sound Scattering Layer distribution and behavior across North Est Atlantic and Equatorial Pacific	
13:50	Priou et al.: Using autonomous surface vehicles for long-term environmental monitoring for the offshore industry	
14:05	Urmy et al.: Estimating uncertainty in acoustic-trawl surveys with a semi-parametric spatial bootstrapping procedure	
14:20	Fernandes et al.: Fish density around decommissioned oil and gas platforms: evidence for “rigs to reefs”?	
14:35	Salvetat et al.: Combining video and acoustics to describe fish assemblages distribution in coastal and oceanic tropical ecosystems	
14:50	Kloser et al.: Sounding the twilight zone life and its changes	
15:05	**Break**	

15:30	Renfree et al.: Relationships between mesopelagic assemblages and the surrounding ecosystem derived from long-term deployments of autonomous echosounders on stationary platforms off California	
15:45	Ariza et al.: Acoustics for global pelagic fauna assessments: advances and challenges	
16:00	Dudeck et al.: Distribution of Deep-Scattering Layers and Vertical Migration along transects crossing the central and southeastern Atlantic	
16:15	Demer et al.: Foresight, in hindsight: a retrospective analysis of a unique sardine-stock forecast	
16:30	Sibley et al.: Seeing with sound: the potential of imaging sonar for quantifying reef fish abundance and diversity	
16:45	Eager et al.: Fish responses to regional and sub-mesoscale flow-topographic interactions over a tropical seamount	
17:00	Robinson et al.: Hydroacoustic surveys evidenced decline of biological backscattering layers during 2013–2018 anomalous low Chl-a concentration and warm temperatures at the east coast of the Gulf of California	
17:15	Ramasco et al.: Using acoustics from a USV to monitor behavioural effects of fish during an industrial seismic survey	
17:30	Menkes et al.: Tuna ecosystems in the tropical Pacific. An interdisciplinary approach from physics to micronekton using sea experiments and ecosystem modelling	
17:45	**Adjourn**	

Table of Contents

Katherine E. Mills

Organism Detection: Models, Measures, and Classification

Micronekton repartition in western tropical Pacific from wideband profiler and hull-mounted narrowband acoustics

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

Modelled and measured broadband acoustic target strength comparison for fish with and without a swimbladder

Benoit Berges[1], Sven Gastauer[2], Serdar Sakinan[1], Rokas Kubilius[3], Gavin Macaulay[3,4]

Assessing the size spectra of fish communities with hydroacoustics: Examining the challenges of abundant schools, diverse assemblages, and variable orientations

Derek G. Bolser[1], Jack P. Egerton[2], Philip M. Souza, Jr.[3], Kevin M. Boswell[4], Brad E. Erisman[5]

Relative index abundance for jellyfish (*Chrysaora plocamia*) in The northern Humboldt Current System

G. Cuadros[1], R. Castillo[1], L. La Cruz[2], C. Valdez[1], D. Grados[1], M. Pozada[1], J. Quiñones[1], and R. Cornejo[1]

Target Strength in-situ and ex-situ of anchoveta (*Engraulis ringens*) in the Southeastern Pacific

J. Castillo[11]; A. Saavedra[1,2]; J. Legua[1,3] and F. Leiva[1,4]

A multifrequency acoustic algorithm to classify mesopelagic organisms within deep Sound Scattering Layers (SSL) in oligotrophic Indian Ocean

O.E. Chacate[1,4], J.C. Coetzee[1,2] and B.E. Axelsen[3]

Broadband discrimination of the target strength spectra from three co-occurring Arctic species: *Boreogadus saida*, *Pandalus borealis*, and *Gadus morhua*

M. Dunn[1,2], G. Pedersen[3], S. Falk-Petersen[1], M. Daase[4,5], J. Berge[4], E. Venables[4], S. L. Basedow[4], L. Camus[1] & M. Geoffroy[2,4].

Model-informed classification of broadband acoustic backscattering from zooplankton in an *in situ* mesocosm

M. Dunn[1,2]*, C. McGowan-Yallop[3]*, G. Pedersen[4], S. Falk-Petersen[1], M. Daase[5,6], K. Last[3], T. J. Langbehn[7], S. Fielding[8], A. S. Brierley[9], F. Cottier[3,5], S. L. Basedow[5], L. Camus[1] & M. Geoffroy[2,5].

Assessing fish avoidance to motorized acoustic survey vessels using quiet autonomous Saildrones in the Great Lakes

T. M. Evans[1], L. G. Rudstam[2], S. A. Sethi[3], D. L. Yule[4], S. D. Hanson[5], B. Turschak[6], D. M. Warner[7], S. A. Farha[8], T. P. O'Brien[9], K. N. McDonnell[10], J. M. Watkins[11], M. R. Dufour[12], A. R. Barnard[13], S. E. Wells[14], S. R. Koproski[15], P. M. Dieter[16], E. Kocher[17], J. J. Roberts[18], J. D. Swain[19], P. C. Esselman[20]

Towards a better understanding of broadband scattering properties of single fish and zooplankton targets

Sven Gastauer[1,2], Rokas Kubilius[3], Egil Ona[3], Gavin Macaulay[4], Edmundo F. Lavia[5], Dezhang Chu

Acoustic identification of the Northern Humboldt Current System's pelagic community using machine learning

D. Grados[1], A. Paz[2], R. Castillo[1], L. La Cruz[1,3], R. Cornejo[1], C. Valdez[1], G. Cuadros[1], M. Pozada-Herrera[1] and P. G. Fernandes[4]

Acoustic biomass estimation of overwintering Atlantic Menhaden using a Simrad ES80 echosounder

C.W.D. Gurshin[1], G. M. Nesslage[2], J. Gartland[3], R.J. Latour[4], D. Liang[5], D. Gregg[6], and J.M. Jech[7]

Target strength modelling of small pelagics in the Baltic Sea using the Kirchoff Ray Mode Model

Jonas Hentati-Sundberg[1], Astrid Carlsen[1], Hans Nilsson[1] and Sven Gastauer[2,3]

Identification of mesopelagic fish species using multi-frequency acoustic approaches – implications for biomass estimation

B. B. Kashindye[1,4], J.C. Coetzee[1,2] and B.E. Axelsen[3]

Investigation of broadband acoustic to resolve and identify nearby targets using different pulse durations

B. Khodabandeloo[1], G. Pedersen[2], T. Nesse Forland[3], R. J. Korneliussen[4] and N.O. Handegard[5]

Acoustic target strength with growth stage of fish: comparison of juvenile and adult Japanese anchovy (*Engraulis japonicus*)

Hansoo Kim[1], Mira Kim[1], Sungho Cho[1], and Donhyug Kang[1]

Weakly-supervised classification of acoustic echotraces in a multispecific pelagic environment

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

Acoustic species identification, length distribution and biomass estimation of a mixed species aggregation in an oceanographic frontal region

S. Loranger[1,2], J.M. Jech [3], and A. C. Lavery[1]

One size does not fit all: experimental target strength measurements of pteropods and shrimp emphasize the importance of scattering model inputs

B. M. Lucca[1] and J. D. Warren[2]

Target strength of mesopelagic organisms derived from computed tomography scans

Gavin J. Macaulay[1], Ryan Downie[2], and Ben Scoulding[2]

Improving accuracy of dagaa acoustic biomass estimation in Lake Victoria using school analysis and geostatistics for Ecosystem based Fisheries Management

Richard Mangeni-Sande[1,2], Roland Proud[1], Chrisphine S. Nyamweya[3], Robert J. Kayanda[4], , Anthony Taabu-Munyaho[4], and Andrew S. Brierley[1]

North-west atlantic cetaceans detecting algorithm based on spectrogram classification using fastai machine learning model

D. Maslov[1], A. Bio[1]

Building a robust machine learning tool for discriminating between bottom schooling fish and the bottom echo

Geoff Matt, Stuart Orchard, Tim Ryan and Haris Kunnath

Investigating right whale prey distribution and quantity in southern New England

C.D. Orphanides[1], G. Diaz[2], H.J. Walsh[3], J.M. Jech[4]

Characterization of Sprat acoustic backscatter and its implication on biomass estimates

A. Palermino1[1,2], A. De Felice2[1], I. Biagiotti3[1], G. Canduci4[1], I. Costantini5[1] and I. Leonori6[1]

Classifying fish with broadband acoustics; behaviour and platform dependent broadband backscattering by physostomous fish (*Clupea harengus* L.)

Geir Pedersen[1], Nils Olav Handegard[1], Babak Khodabandeloo[1], Espen Johnsen[1]

Acoustical simulation of the target strength of Atlantic bluefin tuna using 3D computed tomographical images

I.Pérez-Arjona, A. Ladino, V. Puig-Pons, V. Espinosa

Visualizing classified bottom habitat in Echoview: an aid in species discrimination

R. E. Thomas[1], A. A. Billings[2], J. E. Clemons[2],

Do fish swim faster in the horizontal direction than up-down?. Study case: two small pelagic fish and two demersal fish

A. Saavedra[1.1]; J. Castillo[12];

In situ target strength measurements of Peruvian anchovy (*Engraulis ringens*) from data collected with a commercial echosounder during fishing operations

M. Santivañez-Yuffra[1,2,3], N. Pereira-Letona[1,2], and C. Vasquez-Paredes[1,2]

The acoustic backscattering of spurdog / spiny dogfish (*Squalus acanthias*) – in situ, ex situ measurements and modelling

Matthias Schaber[1], Mike Jech[2], Susan Lusseau[3], Martin Riis[4], Sven Gastauer[1,5]

Detection, spatial and source level characterization of coastal cod vocalizations using eight-element hydrophone array

Sai Geetha Seri,[1] Matthew Edward Schinault,[1] Seth Michael Penna,[1] Lise Doksæter Sivle,[2] Karen de Jong,[2] Nils Olav Handegard, [2] and Purnima Ratilal[1]

Computer Vision-Based Echogram Annotation Methods for Acoustic Classification with Deep Learning Systems

R. Vohra*[1], F. Senjaliya*[1], M. Cote[1], A. Branzan Albu[1], J. Chawarski[2], S. Pearce[2], A. Dash[1,2], and K. Ersahin[2]

Species specific material property measurements improve the agreement of experimental measurements and scattering model predictions of krill Target Strength

J.D. Warren[1] and B.M. Lucca[1]

Utilization of a paired eDNA and acoustic survey for assessing assemblages in the Gulf of Maine

A. Whitman[1], G. Sherwood[1], and M. Kinnison[2]

A comparison of acoustic, catch and video data to investigate and monitor grenadier abundance in the Ross Sea

A. M. Wieczorek[1], Y. Ladroit[1], J. A. Devine[2], M. H. Pinkerton[1], P. C. Escobar-Flores[1], B. R. Moore[2], A. Hart[2] and R. L. O'Driscoll[1]

Assessing spatial and temporal abundance and distribution of Mueller's pearlside (*Maurolicus muelleri*) in the Northeast Atlantic

A. M. Wieczorek[1,2], T. Cariou[2], M. O'Malley[2] C. O'Donnell[2] and D. G. Reid[2]

Broadband acoustic scattering simulation and in-situ observation of dagaa (*Rastrineobola argentea*) in Lake Victoria, East Africa

Yang Yang[1], Sven Gastauer[2,3], Richard Mangeni-Sande[1,4], Inigo Everson[1,5], Roland Proud[1], Robert J Kayanda[6], Andrew S Brierley[1]

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]

Data Integration: Analytics

Field comparison of Antarctic krill (*Euphausia superba*) backscatter and aggregation types using Nortek and SIMRAD echosounders

P. Annasawmy[1], J. K. Horne[1], C. S. Reiss[2], G. R. Cutter[2] and G. J. Macaulay[3]

Micronekton multifrequency backscatter classification within an eddy dipole of the Mozambique Channel, South West Indian Ocean

P. Annasawmy[1], G. Roudaut[1], and A. Lebourges Dhaussy[1]

Impact of echosounder calibration errors on an international acoustic survey (HERAS)

Benoit Berges[1], Serdar Sakinan[1]

Understanding the impact of ping interval on acoustically based abundances

G. Boyra[1], I. Paradinas[1,2], I. Rico[1], U. Martinez[1] and E. Nogueira[3]

Spatial tug of war: kriging spline model residuals of fish abundance in a Bayesian framework

E. Duskey[1,2], D. R. Hart[3], J.-H. Chang[4], and P. J. Sullivan[5]

A story about data extraction and deep learning applied to fishery acoustic data

Nils Olav Handegard[1], Leif Edvard Bildøy[2], Olav Brautaset[3], Tomasz Furmanek[1], Arne Johannes Holmin[1], Ingrid Utseth[3], Sindre Vatnehol[1], Ketil Malde[1]

Real-time underwater acoustic data acquisition and processing with a large aperture 160-element coherent hydrophone array

H. Mohebbi-Kalkhoran[2,1], M. E. Schinault[1], N. C. Makris[2], P. Ratilal[1]

Estimation and removal of noise in broadband echosounders

Rolf. J. Korneliussen[1], Inge. K. Eliassen[2], and Yngve. Heggelund[3]

Building an open-source software toolbox for cloud-native processing of fisheries and plankton acoustic data

W.-J. Lee[1], E. Mayorga[1], V. Staneva[2], L. Setiawan[2], B. C. Reyes[1]

Classification of acoustically-similar pelagic forage fishes: combining ecological knowledge with machine learning

A.T. McReynolds[1], B. Pientka[2], J. M. Jech[3], L. G. Rudstam[4], J. E. Marsden[5], J. D. Stockwell[6]

Multifaceted Study with the Aris Imaging Sonar and Acoustic Tags Using AI Techniques for Fish Identification at White Rock Dam

J. P. Quirion[1], T. W. Steig[2]

Semantic Segmentation of Pacific Hake Aggregations in Water Column Echograms

V. Staneva[1], W.-J. Lee[2], and Z. Miao[3]

Using Artificial Intelligence for Identification of an Acoustic Signal

T. W. Steig[1], J. P. Quirion[2]

Effects of net-sampling methods, timing, and effort on biomass estimates from acoustic-trawl-method surveys

K.L. Stierhoff[1], S.H. Dolan[2], D.A. Demer[1]

Using mixture Gaussian models for characterization of ispi (*Orestias ispi*) in Lake Titicaca, Peru – Bolivia

C. Valdez[1], D. Grados[1], M. Gutierrez[2]

Towards a cloud optimized data lake for archived water column sonar data

C. C. Wall[1], R. Klucik[1], C. Slater[1], C. Anderson[1], V. Martinez[1]

Advancements in acoustic devices, platforms, and combined technologies

Echo Sounding atop the Wave of Oceanography's Robot Revolution

K. J. Benoit-Bird[1]

SONAR-netCDF4 convention and open source software for reproducible and versatile sonar data processing

L. Berger[1], C. Poncelet[1], N. Le Bouffant[1], M. Doray[2]

Correction of athwart distortion induced by beam overlap in multibeam sonars

G. Boyra[1],U. Martinez[1], J. Uranga[1], G. Moreno[2], and H. Peña[3]

Plankton dynamics observed using fisheries acoustics from an autonomous vehicle

Fabio Campanella[1], Angus Atkinson[2], Martina Bristow[3], and Jeroen van der Kooij[1]

Use of uncrewed surface vehicles in tandem with NOAA vessels to increase survey efficiency

Alex De Robertis[1], Michael Gallagher[2], Rob Downs[3], Don Jones[4], Scott Furnish[5], Val Schmidt[6], Rick Towler[7], Benjamin LaCour[8], and Sandra Parker-Stetter[9]

Derivation of lengths and depths of anchovies and observations of schooling behavior from Bio-acoustic Attenuation Spectroscopy (BAS) measurements

O. Diachok

Uncrewed Surface Vehicle (USV) for acoustic mapping of common dolphin and their small pelagic preys

M. Doray[1], M. Cambreling[1], A. Ariza[1], E. Veit[2], L. Berger[2], C. Poncelet[2], N. Le Bouffant[2]

Temporal patterns in South Georgia zooplankton: insights from a moored echosounder
T. Dornan[1], S. Fielding[1], G.A. Tarling[1]

Pelagic organisms avoid white, blue, green, and red artificial light from scientific instruments
M. Geoffroy[1,2*], T. J. Langbehn[3], D. McKee[2,4], E. Sandbank[1], M. Daase[2], D. Vogedes[2], P. Priou[1,5], A. LeBris[1], J.A.D. Fisher[1], J. Cohen[6], Ø. Varpe[3], G. Johnsen[7], & J. Berge[2,]

Industry based autonomous acoustic systems in near real time monitoring of marine ecosystems
O.R. Godø[1], R. Patel[2], T. Torkelsen[3], M.S. Ybema[4], and R. Øyerhamn[5]

IoT Acoustic Monitoring of Tonle Sap River Fish Migration and Mortality for Cambodian Fisheries Management
J. K. Horne[1], J. A. Swan[1], T. J. Tracy II[2], and G. W. Holtgrieve[1]

Estimating splendid alfonsino (*Beryx splendens*) abundance using a low-frequency broadband quantitative echo sounder
Tomohito Imaizumi, Tomohiko Matsuura, Yoshiaki Fukuda, Kouichi Sawada

Towards a multi-platform armada strategy for ecosystem based marine surveys
E. Johnsen1[1], N. O. Handegard2[1], and G. Huse3[1]

Chasing noise and counting Orange Roughy
Y. Ladroit[1,2], P.C. Escobar-Flores[1], C. Ray[1], and R.L. O'Driscoll[1]

Elevated fish densities adjacent to oil platforms surveyed with an uncrewed surface vehicle
J. M. Lawrence[1,2] and P. G. Fernandes[1,3]

Using seafloor backscatter for single beam echosounder calibration
N. Le Bouffant[1] , L. Berger[1], R. Fezzani[1]

Mills cross multi split-beam processing for assessment of target strengths
Guillaume Matte[1], Tehei Gauthier[1], Jean Guillard[2], Marie Lamouret[1], Olivier Lerda[1], Benoit Tallon[3], Philippe Roux[4], Frederic Mosca[1].

Integrating Split-beam, Multibeam and Bio-telemetric Surveys to Estimate Fish Abundance: A New Approach to an Old Problem
B. J. Shuter[1], S. W. Milne[2], L. E. Hrenchuk[3], D. T. deKerckhove[4] and M. D. Rennie[5]

Performance of a glider-mounted multi-frequency echosounder for detecting dense mesozooplankton layers *in situ*
D. S. Mossman[1], N. Hynes[2], K. Davies[3]

Direct measurements of the migration speed of spawning herring
Egil Ona[1], Guosong Zhang[1], Sindre Vatnehol[1], Sverre Berg[2], and Lars N. Andersen[2], Nils Olav Handegard[1]

Biomass estimates of spawning Atlantic Bluefin tuna schools using omnidirectional fisheries sonars
H. Peña[1], V. Puig[2], I. Pérez-Arjona[3], V. Espinosa[4] and G. J. Macaulay[5]

Recording acoustic data from the surface to 4500 m depth with an AZFP attached to the rosette

M. Peña[1], S. Hernández-León[2]

Long range acoustic detection of gas bubbles in a shallow water coastal environment

T.E. Ryan[1], B. Scoulding[1]. B and R.J. Kloser[1]

Development of A Large-Aperture 160-Element Coherent Hydrophone Array System for Instantaneous Wide Area Ocean Acoustic Sensing

M. E. Schinault[1], S. Seri[1], M. K. Radermacher[1], H. Mohebbi-Kalkhoran[1], C. Zhu[2], N. C. Makris[2], P. Ratilal[1]

Passive sensing instrumentation, the past, present and future of technology

M. E. Schinault[1], P. Ratilal[1]

Monitoring snapper aggregations using recreational fish finders and aerial drones

B. Scoulding[1], D. V. Fairclough[2], and G. Jackson[2]

Development of an unmanned research vessel for economical commercial fishing and multipurpose research

E. Sepp[1], M. Vetemaa[2], V. Peedimaa[3] and T. Raid[4]

Target strength measurements of deep scattering mesopelagic layers

Teresa Silva[1], Sigurður T. Jonsson[1], Birkir Bardarson[1], Arnþór B. Kristjansson[1], Björn Sigurðarson[1] and Klara Jakobsdóttir[1]

Shelf-based mooring reveals seasonally variable benthic behaviour of Antarctic krill

A. J. R. Smith[1], G. R. Cutter[2], G. J. Macaulay[3], B. Hutton[4], R. King[5], S. Kawaguchi[5] and M. J. Cox[5]

Pairing environmental DNA with acoustic monitoring of anadromous fish in the Penobscot River, Maine

J. Sunnarborg[1], J. R. Stevens[2], K. Cammen[1,4], M. Kinnison[3,4]

Techniques for the Characterization of Aquatic Ecosystem ----- How Life Works in a Wetland Pond

W. M, Tian[1]

Data Integration: Application to Ecosystem, Conservation, and Society

Characterizing Antarctic air-breathing predator dive patterns on a common prey base from stationary echosounders

P. Annasawmy[1], J. K. Horne[1], C. S. Reiss[2], and G. J. Macaulay[3]

Acoustics for global pelagic fauna assessments: advances and challenges

Alejandro Ariza[1,2*], Matthieu Lengaigne[1], Christophe Menkes[3], Anne Lebourges-Dhaussy[4], Aurore Receveur[5], Thomas Gorgues[6], Jérémie Habasque[4], Mariano Gutiérrez[7], Olivier Maury[1] and Arnaud Bertrand[1]

Investigation of pelagic fish communities in Offshore Wind Farms using bottom mounted echosounders with a combination of narrowband and broadband acoustics

Benoit Berges[1], Jeroen Hubert[2], Fien Demuynck[2], Elisabeth Debusschere[3], Carlota Muñiz[3], Hans Slabbekoorn[2]

Fishing for answers: are there more tuna inside a blue-water marine reserve?
A. Blanluet[1,2]; E. T. Game[2], J. Everett[1,5], K. Pollock[3], N. H. Wolf[4], A. J. Richardson[1,5]

Linking Organisms from the Surface to the Seafloor Through Acoustic Analysis
Adrienne Copeland[1], Emily Speciale[2], and Carrie C. Wall[3]

Foresight, in hindsight: a retrospective analysis of a unique sardine-stock forecast
D. A. Demer[1] and J. P. Zwolinski[1,2]

Pelagic Sound Scattering Layer distribution and behavior across North Est Atlantic and Equatorial Pacific
N. Diogoul[1], B. QUACK[2], and P. BREHMER[3]

Seamount effects on micronekton at a subtropical central Pacific seamount
R. Domokos

Distribution of Deep-Scattering Layers and Vertical Migration along transects crossing the central and southeastern Atlantic
T. Dudeck[1], A. Rommel[2], and W. Ekau[1]

Fish responses to regional and sub-mesoscale flow-topographic interactions over a tropical seamount
D. Eager[1], E. Robinson[1], B. J. Williamson[2], P. Hosegood[1], C. B. Embling[1]

Geographic variability in the seasonality of euphausiid diel vertical migrations among three locations in coastal British Columbia, Canada
N. J. Ens[1], J. F. Dower[1, 2], and S. Gauthier[1, 3]

FishLAT (Fisheries Location Assessment Technology): Approaching the Offshore Energy Transition from a Fisheries Perspective
A. G. Everett[1], E. Hazelwood[1], and A. Sparks[1]

Fish density around decommissioned oil and gas platforms: evidence for “rigs to reefs”?
P. G. Fernandes[1], J. D. Lawrence[1]

Biomass and geographical distribution of seven small pelagic fish species in relation to environmental condition in Mauritanian waters
S. A. HEMED[1], Anna H. Olafsdottir[2]

Study of the ecology of Atlantic wolffish in the Bay of Fundy marine ecosystem, New Brunswick, Canada
A. Jayawardane1[1], C. M. Stairs2[2] and C. F. Sacobie3[3]

The Mesopelagic and Beyond: High-Latitude Boundaries and Global Patterns in Vertical Connectivity of the Deep Ocean
T.A. Klevjer[1], J. Chawarski[2], M. Geoffroy[2,3], D. Coté[4], C. Richards[5], S. Kaartvedt[5]

Sounding the twilight zone life and its changes
R. J. Kloser[1], H. Kunnath[1],

Tuna ecosystems in the tropical Pacific. An interdisciplinary approach from physics to micronekton using sea experiments and ecosystem modelling

C. E. Menkes[1], V. Allain[2], A. Lebourges-Dhaussy[3], L. Barbin[1,2,3], J. Habasque[3], A. Ariza[4,8], P. Lehodey[2,9], A. Receveur[6], I. Senina[3], S. Albernhe[7,5], A. Conchon[5], T. Gorgues[7], G. Roudaut[3], M. Lengaigne[4], and S. Nicol[3]

Acoustic estimation of haplochromine biomass in Lake Victoria: A novel approach to the estimation of pelagic biomass with precision

C. O. Ongore1[1,2], R. Proud2[1], and A. S. Brierley3[1]

Ecology and behavior of tuna and non-tuna species at drifting fish aggregating devices (DFADs) in the Indian Ocean using fishers' echo-sounder buoys

B. Orue[1]

Spatial distribution of zooplankton acoustic biomass in the Gerlache Strait, Antarctica

J. Paramo[1], J. Salon[2]

Monitoring the state of Peruvian anchovy (*Engraulis ringes*) population by using data entirely collected by fishing vessels

S. Peraltilla1[1], M. Gutierrez 2[1], G. Cuadros,3[1], L. La Cruz4[1], A. Aliaga 5[1] C, Vasquez 5[2] C Juarez 5[3] M. Santivañez 6[1] A. Ramirez 7[1], S. Montero 8[1], C. and C. Vsquez6[2]

Does variation in Pacific hake diet reflect changes in the prey community?

E. M. Phillips[1], A. Billings[2], J. Clemons[2]

Using autonomous surface vehicles for long-term environmental monitoring for the offshore industry

P. Priou[1,2], V. Ramasco[1], G. Pedersen[3], M. Thorstensen[1], and L. Camus[1]

Using acoustics from a USV to monitor behavioural effects of fish during an industrial seismic survey

V. Ramasco[1], P. Priou[1,2], G. Pedersen[3], Karen de Jong[3], Anne Christine Utne Palm[3], and L. Camus[1].

Mesoscale eddies are not oases for mesopelagic organisms at global scale

A. Receveur[1], C. Menkes[2], M. Lengaigne[3], A. Ariza[4], C. Dutheil[5], A. Bertrand[3], S. Cravatte[6], V. Allain[7], L. Barbin[2,8], A. Lebourges-Dhaussy[8], P. Lehodey[7], S. Nicol[7]

Relationships between mesopelagic assemblages and the surrounding ecosystem derived from long-term deployments of autonomous echosounders on stationary platforms off California

J. S. Renfree[1] and D. A. Demer[1]

Hydroacoustic surveys evidenced decline of biological backscattering layers during 2013–2018 anomalous low Chl-*a* concentration and warm temperatures at the east coast of the Gulf of California

Carlos Robinson

Potential for siphonophores to influence global acoustic estimates of mesopelagic fish biomass

A. C. M. Rommel[1], R. Proud[1], P. G. Fernandes[2] and A. S. Brierley[1]

Combining video and acoustics to describe fish assemblages distribution in coastal and oceanic tropical ecosystems

Julie Salvetat[1,2], Nicolas Bez[2], Jéremie Habasque[3], Anne Lebourges-Dhaussy[3], Gildas Roudaut[3], Monique Simier[2], Paulo Travassos[1], Gary Vargas[1] and Arnaud Bertrand[1,2,4]

Seeing with sound: the potential of imaging sonar for quantifying reef fish abundance and diversity

Edward C. P. Sibley[1,2], Alethea S. Madgett[2], Joshua M. Lawrence[3], Paul G. Fernandes[3]

They move in mysterious ways: Spatial behaviour of individual *Calanus finmarchicus* quantified by using broad-band target tracking

K. G. Thorvaldsen, S. Neuenfeldt[1], Helena Hauss[2], P. Mariani[1], and J.R Nielsen[1]

From FAD acoustics to tropical tuna abundance indicators

Jon Uranga[1], Jon Lopez[2], Maitane Grande[1], Cleridy E. Lennert-Cody[2], Iñaki Quincoces[1], Guillermo Boyra[1], Mark N. Maunder[2], Alexandre Aires-da-Silva[2], Gorka Merino[1], Hilario Murua[3], Josu Santiago[1]

Estimating uncertainty in acoustic-trawl surveys with a semi-parametric spatial bootstrapping procedure

S. S. Urmy[1], P. Ressler[1], A. De Robertis[1]

Bubble trouble and fishy findings: challenges for hydroacoustic studies of fish at tidal energy sites

H. A. Viehman[1], D. J. Hasselman[2]

The school trap hypothesis predicts the spatial distribution and environmental preferences of the collapsed Pacific Sardine

J. P. Zwolinski1[1,2], D. A. Demer2[2]

Keynote Speakers

A call to science—understanding fisheries, wildlife and ecosystem impacts in a new Era of Offshore Wind Development and global marine Industrialization.

Andrew Lipsky

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To meet state and federal renewable energy targets offshore wind development is rapidly expanding in the Northwest Atlantic, Gulf Of Mexico, and Pacific regions of the United States. By 2030 to meet U.S. national goal of 30 gigawatts of energy, the Northeast large marine ecosystem will be occupied by over 2.4 million acres of leases, 3400 turbines, and 10,000 miles of submarine cables with an additional 18.87 million acres under consideration for further development (BOEM, 2022a, BOEM, 2022b). Offshore wind development is also scheduled for the U.S. Pacific coast and the Gulf Mexico. At a global scale, Europe, Asia, and North and South America will add over 177 gigawatts of cumulative offshore wind development over the next five years (U.S Department of Energy , 2022). This development will consist of a 3.5 fold increase in fixed turbine technologies in waters less than 60 meters and 68 fold increase of first of its kind floating offshore wind technologies in waters over 1,000+ meters in depth. This change may likely represent the greatest single marine industrialization event across our global oceans.The pace, scale, and scope of this development creates scientific demands for regulatory and scientific missions at NOAA Fisheries and our international partners. Addressing the interaction of wind on fisheries, fishing communities, wildlife, marine habitats, and ecosystems requires deepening our collaborations and for the international scientific community to urgently increase our scientific capabilities and to move to ecosystem based approaches if we are to be successful in meeting our mandates. This presentation will provide an overview of these scientific needs and how fishing communities, academic partners, managers and international scientific community can work together to meet them.

The Systems Approach to Fisheries Management: Concepts, Data Needs, and Strategies for Implementation

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Management of marine fisheries has traditionally focused on individual species. Existing national and international management organizations have largely retained this orientation. Marine fisheries, however, have long been recognized as coupled social-ecological systems

characterized by dominant interactions within and between human and 'natural' subsystems. Optimal management requires joint consideration of these interactions; the increasingly dominant role of environmental change affecting these systems; and an assessment of the expanded information and analytical needs to make a transition to Ecosystem-Based Fisheries Management (EBFM).

The apparent complexity of marine fishery ecosystems has been an impediment to adopting a more holistic management approach. Perhaps paradoxically, however, adopting a systems perspective can potentially provide avenues for simplification of management by focusing on higher levels of ecological organization than individual species or stocks. The dynamic properties of a system are not the same as those of its parts. Indeed, system-level elements such as functional groups can be more stable and predictable than the trajectories of individual species comprising these assemblages.

Advancing resilient marine ecosystems and fisheries in changing oceans

Katherine E. Mills

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Climate change is altering oceans and marine ecosystems around the world, pushing physical conditions beyond recent analogues, driving biological changes, and creating impacts that cascade through social-ecological systems. The Northeast U.S. Shelf has experienced rapid warming of ocean temperatures, recurring marine heatwaves, and an exceptionally warm temperature regime over the past decade. Fish and invertebrate populations across the region are being affected in a variety of ways, including changes in distribution, growth, phenology, and productivity. Moreover, changing ocean uses that can support climate adaptation and mitigation are also affecting marine ecosystems and fisheries. Changes in both environmental conditions and ocean use patterns also influence our ability to effectively monitor organisms, understand their responses to change, and produce information that is needed for fisheries management and other decisions. Advances in our monitoring systems, analytical approaches, and science-to-management processes will be important for providing the scientific basis for supporting resilient marine ecosystems and sustainable fisheries in the context of future novelty and uncertainty.

Organism Detection: Models, Measures, and Classification

Micronekton repartition in western tropical Pacific from wideband profiler and hull-mounted narrowband acoustics

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The pelagic ecosystems in the tropical Pacific contain a high diversity of mixed micronekton species such as crustaceans, gelatinous or mesopelagic fish. Total abundance and biomass of micronekton species remain uncertain although they are critical to understand ecosystem functioning. Trawls and hull-mounted acoustics are often used together to provide abundance estimates, but both methods have their own biases, especially in regions with high species diversity. Here, we used a statistical classification method applied on EK60-38 kHz acoustic vertical profiles across the western tropical Pacific from the WARMALIS 1 survey to define ecoregions with similar vertical distributions. To complement the quantification of organisms, wideband acoustic profiles acquired during night-time with a profiler (WBAT) were added to calculate vertical organisms' density with a target strength (TS) based echo-counting algorithm by ecoregion at depths where single targets can be isolated. The average TS distribution of the density profiles informs about the TS composition of the scattering layers and provides a tool to understand the mean backscattered energy measured with the hull-mounted sounder. On a wide latitudinal scale, WBAT shows the spatial and vertical variability of micronekton density at stations and the fine resolution of wideband data allows to consider all reflectors, including weak ones.
Keywords: Micronekton distribution, Broadband acoustics, Tropical Pacific ocean, Ecosystem, Clustering

Modelled and measured broadband acoustic target strength comparison for fish with and without a swimbladder

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Acoustic scattering properties of targets underwater underpin any application of active acoustics. For fisheries acoustics, it is paramount to understand acoustic scattering properties of pelagic marine organisms (e.g., fish, plankton) as it allows to model and interpret the response of marine organisms to ensonification by echosounders. Consequently, it is important to improve scattering models but also to compare them against a range of data sets to understand the applications and limitations of those models.
In 2018 and 2019, three fish species were ensonified using broadband acoustics in a controlled manner while tethered in a rotating suspension apparatus. In that context, an experimental data set is used to compare target strength models against measurements at various ensonification angles. The data set consists of dead tethered fish (saithe, pollck, and mackerel) that were rotated and ensonified with broadband pulses (45-90kHz, 160-260kHz) at broadside aspect. This data set yields accurate measurement of target strength at different ensonifying angles. Scattering models (e.g. KRM) are tuned to the characteristics of each individual fish using x-ray image data. Modelled and measured individual target strengths at varied incidence angles and across 45-90kHz and 160-260kHz are then compared.
Keywords: scattering model, target strength, broadband acoustics

Assessing the size spectra of fish communities with hydroacoustics: Examining the challenges of abundant schools, diverse assemblages, and variable orientations

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Assessing the size spectra of fish communities with acoustics is challenging given diverse assemblages and behaviors. To examine challenges quantitatively, we conducted 51 optic-acoustic surveys of fish communities around petroleum platforms throughout the U.S. Gulf of Mexico and estimated size spectra. We compared acoustic size spectra with those estimated from simulated communities (based on species composition) and published fish community censuses at platforms (i.e., 'reference datasets'). We also conducted sensitivity analyses to quantify the impact of acoustic data processing choices on size spectra. When *in situ* target strength (*TS;* dB re 1 m^2) distributions were used to scale the volumetric backscatter (*Sv;* dB re 1 m^{-1}) of schools, lengths and size spectra slopes were significantly smaller than those derived from reference datasets. However, acoustic slopes were comparable to reference slopes when simulated *TS* values (based on species composition) were used to scale school *Sv*. Orientation was not a useful predictor of slope or *TS,* yet the effect of orientation on the *in situ TS* of fishes adjacent to schools may explain why unreasonable results were produced when those data were used to scale school *Sv*. This study is an early step towards using acoustic size spectra metrics for ecological inferences.

Keywords: acoustic

Relative index abundance for jellyfish (*Chrysaora plocamia*) in The northern Humboldt Current System

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In recent years, there has been an increase in the frequency of jellyfish blooms in the world impacting on fisheries productivity, reducing recruitment of other fish and interfering with fishing activities. The presence of this jellyfish is usually associated with regime changes and ENSO events. The present study aims to quantify the jellyfish in the northern Humboldt Current System (NHCS) between february and march 2022. Acoustic and biological data were collected from pelagic scientific survey, using Simrad EK-80 echo sounder with five frequencies (18, 38, 70, 120 and 200 kHz) and a pelagic trawl.
Jellyfish aggregations were identified and quantified by eco-integration-multifrequency methods. Post-processing and analysis were performed with Echoview and R softwares. Our results show a high abundance (NASC average, relative index abundance) of jellyfish in the coastal and oceanic zone, interacting with patches of peruvian anchovy and red squat lobster (múnida) in an environmental scenario of neutral conditions. This work contributes to on-going efforts to monitor and detect changes in the NHCS.
Keywords: Relative index, multifrequency, hydroacoustic, abundance, jellyfish.

Target Strength in-situ and ex-situ of anchoveta (*Engraulis ringens*) in the Southeastern Pacific

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Anchoveta is a pelagic fish widely distributed alongside the Humboldt Current of the Southeast Pacific coast. Southward parallel 18°20'S (Chile) there are three Demographic Units (DU) whose stocks are evaluated by acoustic methods during its main recruitment period. This study analyzes target strength (TS) in-situ data, collected in 26 hydroacoustic assessment cruises conducted between 2008-2022 on board of the RV Abate Molina. For each DU, TS-Length equations are fitted and compared with each other. SIMRAD EK60 ® echo sounders calibrated with 38B and 120-7c Khz split beam transducers were used, biological samples were collected with a midwater trawl. Results indicate no differences between the TS-Length equations for each DU. The global TS-in situ-L equations were:

- $TS_{in\ situ}$(38 khz) = 18.134 Log (L) – 71.352 (r2=0.93; n=24 p<0.05); b20 = -73.34 dB;
- $TS_{in\ situ}$ (120 khz) =18.543 Log (L) -72.388 (R2= 0.87; n=71 p<0.0; b20=-73.95.

It was determined that depth affected the anchoveta TS according to Boylle's Law, fitting a preliminary TS- Length-Z(depth) equation by each frequency:

- $TS_{38Khz}\,(L,\gamma,z) = 20log_{10}(L) - 4{,}199log_{10}\left(1+\frac{z}{10}\right) - 71{,}3807$
- $TS_{120Khz}\,(L,\gamma,z) = 20log_{10}(L) - 4{,}274log_{10}\left(1+\frac{z}{10}\right) - 71{,}6710$

$TS_{ex\text{-}situ}$ measurements were also made with a small cubic cage of 0.5 m side.

Keywords: *Engraulis ringens*, pelagic fish, Humboldt Current, target strength

A multifrequency acoustic algorithm to classify mesopelagic organisms within deep Sound Scattering Layers (SSL) in oligotrophic Indian Ocean

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Sound Scattering Layers (SSL) in oligotrophic systems are typically comprised of a variety of organisms at low densities, complicating acoustic classification. Here, two acoustic classification algorithms (ACA) were tested to identify mesopelagic organisms within the deep SSL in the Indian Ocean. The first approach, which was developed in the Atlantic Ocean for higher productivity systems, uses mean volume backscattering strength differences (ΔSv) between 18 and 38 kHz to categorise targets into crustaceans, small non-swimbladder fish, large non-swimbladder fish, swimbladder fish, or 'unclassified' (cephalopods, pteropods and gelatinous zooplankton). The second ACA tested was developed from *in situ* data collected by the R/V "Dr Fridtjof Nansen" in 2018 using 18, 38 and 70 kHz data. ΔSv pairs were combined to identify 3 broad groups: mesopelagic fish, krill/ tunicates/plankton or squid/others. In oligotrophic conditions the first ACA classified fewer targets to mesopelagic fish than indicated by trawl catches, whereas classification of mesopelagic fish was much improved by the *in situ* approach. The results indicate that the SSL is broadly dominated by mesopelagic fish, with average regional densities ranging from 0.3 (±0.02) to 1.1 (±0.1) $g.m^{-3}$, and average proportions of the acoustic backscatter (NASC) attributed to mesopelagic fish from 0.2 (±0.04) to 0.3 (±0.05).

Keywords: SSL classification, mesopelagic fish density, Indian Ocean, multi-frequency acoustics, frequency response

Broadband discrimination of the target strength spectra from three co-occurring Arctic species: *Boreogadus saida*, *Pandalus borealis*, and *Gadus morhua*

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The Northern shrimp (*Pandalus borealis*) fishery, a valuable commercial fishery in both the North Atlantic and Barents Sea, reports large amounts of by-catch of Arctic cod (*Boreogadus saida*), a key forage fish species. Furthermore, the spatial distribution of Atlantic cod (*Gadus morhua*) is expanding northward and increasingly overlaps spatially with Northern shrimp and Arctic cod, both prey of large Atlantic cod. Acoustic discrimination between Arctic cod, Atlantic cod and Northern shrimp could provide more information on the risk of cod by-catch in the Northern shrimp fishery and the spatial dynamics of these three species. In January 2023, we conducted a series of single-species mesocosm experiments for target strength measurements of Arctic cod, Atlantic cod and shrimp to assess the potential for discrimination of their target spectra. The fish and shrimps were trawled from Billefjorden and Kongsfjorden, Svalbard, and transferred alive to an *in situ* mesocosm deployed from a wharf in Ny-Ålesund. Acoustic backscattering measurements were collected with a Wideband Autonomous Transceiver (WBAT) at frequencies ranging from 90 to 255 kHz. Thereafter, we tested the applicability of the mesocosm measurements of target spectra at discriminating between Arctic cod, Atlantic cod and shrimp in a mixed assemblage by lowering a WBAT probe in a sound scattering layer at the trawling sites.
Keywords: Broadband acoustics, mesocosm, Artic cod, Northern shrimp.

Model-informed classification of broadband acoustic backscattering from zooplankton in an *in situ* mesocosm

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Classification of zooplankton with broadband echosounder data could increase the taxonomic resolution of hydroacoustic surveys and reduce the dependence on trawing. Yet, supervised classification with broadband echosounder data is limited by the acquisition of validated acoustic signals required to train classifiers. We tested the hypothesis that acoustic scattering models could be used to train machine learning algorithms ('classifiers') to improve zooplankton classification. Three classifiers were trained with data from scattering models of four fluid-like Arctic zooplankton (copepods, euphausiids, chaetognaths, and hydrozoans). We compared predictions from the classifiers with observations of a zooplankton community in a submerged purpose-built mesocosm (12 m^3) insonified with a broadband signal (185 to 255 kHz). The mesocosm was deployed from a wharf in Ny-Ålesund, Svalbard, during the Arctic polar night in January 2022. We collected 38,192 single target detections over three hours. The best-performing classifier as evaluated on the modelled data had a class-weighted F1 score of 0.68. Class-specific F1 scores varied from 0.92 for copepods to 0.48 for chaetognaths. The classifiers were unable to differentiate euphausiids, chaetognaths and hydrozoans reliably due to the overlap in their modelled spectra, and only 30% of measured targets were classified as the same taxa by all three algorithms. Results suggest that more complex scattering models are needed for classification of taxa with similar gross anatomical properties and size distributions.
Keywords: Machine learning, zooplankton, classification, broadband acoustics, mesocosm

Assessing fish avoidance to motorized acoustic survey vessels using quiet autonomous Saildrones in the Great Lakes

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Acoustic surveys assess spatially extensive stocks and are widely used to evaluate prey fish throughout the Great Lakes. However, a major assumption of these surveys is that fish do not avoid vessels which, if avoidance does occur, could bias survey estimates. If fish do avoid boats, it is presumably because of engine noise radiated in the water column. We used quiet uncrewed surface vehicles (Saildrone) to test fish responses to conventional motorized survey ships on the Great Lakes. The Great Lakes provide an ideal region to test fish avoidance because surveys are conducted by numerous vessels on differing fish communities. Saildrones were equipped with a 120 kHz Simrad EK80 transducer and deployed in Lakes Huron and Michigan in the summer of 2021, and Lake Superior in the summer of 2022. Saildrones were overtaken by eight different motorized survey vessels, and we compared the differences in average target depth, target strength, and acoustic back-scattering over 2km transects. We also tested for a fish behavioral response by fitting regression smoothers to Saildrone acoustic data as motorized vessels approached. This work informs interpretation of acoustic data in the Great Lakes and provides the largest scale testing of fish avoidance to acoustic surveys to date.
Keywords: Autonomous drone, survey bias, vessel noise, silent vessel

Towards a better understanding of broadband scattering properties of single fish and zooplankton targets

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Broadband acoustic data collection is becoming routine and a full understanding of broadband scattering is important. Much uncertainty remains over how broadband scattering is determined by the target behaviour, size, shape, and internal boundary transitions between body parts. Acoustic scattering models are a useful tool to understand such influences on the expected backscatter. Here we present recommendations and limitations of several commonly used scattering models. We discuss the performance of selected models using realistic real-world parametrisations. We introduce freely available, open source tools, which simplify the use of acoustic scattering models and allow for quick model parametrisations. We demonstrate how

some of the presented tools can help with the interpretation of collected broadband data, comparing model outputs with ex situ and in situ recordings.
Keywords: scattering model, target strength, broadband acoustics

Acoustic identification of the Northern Humboldt Current System's pelagic community using machine learning

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Famed as an oceanic upwelling region, the Northern Humboldt Current System (NHCS), off the west coast of South America, comprises 0.1% of the worlds ocean surface, but produces 10% of global fish catch. Catches are dominated by the Peruvian anchovy (*Engraulis ringens*), which has a biomass ~8MT, but two other species are also abundant: the red squad lobster (*Pleuroncodes monodon,* biomass ~3MT) and the mesopelagic lightfish (*Vinciguerria lucetia* ~7MT). Acoustic surveys of these resources, vital for sustainable management, are conducted annually, but differentiating the echotraces of these three species is a significant challenge. Here, we implement a Random Forest (RF) machine learning algorithm to classify the echotraces detected on an acoustic survey. We labelled echotraces from previous acoustic surveys (5 years, 2016-2019) to construct the RF. The final algorithm had an accuracy of 94% and volume backscattering at 38 kHz and 70 kHz were the most important variables. We applied the model to the 2019 survey and found the species distribution to be spatially coherent. Finally, we implement a replicable routine in the statistical computer language R, combined with signal processing software (Echoview R), to show how such a model can be used by the broader scientific community.
Keywords: Peruvian anchovy, Northern Humboldt Current System, Random Forest

Acoustic biomass estimation of overwintering Atlantic Menhaden using a Simrad ES80 echosounder

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This cooperative research used industry-grade acoustics and midwater trawls to estimate stock biomass of the overwintering resident stock of Atlantic Menhaden offshore New Jersey. The goals of this study are to address industry's need for collection of novel scientific data to support enhancing sustainable development of the winter bait fishery, expand the use of cooperative science, and promote scientifically-informed fisheries management of Atlantic Menhaden. The primary bait fishery region 24–80 km offshore between the Hudson Canyon and the Delaware border was surveyed over 8 days starting in late February 2022 by the 49-m commercial midwater trawling vessel, F/V Dyrsten, equipped with a recordable 38-kHz Simrad ES80 split-beam echosounder and a Furuno FSV25S omnidirectional sonar. Six transects perpendicular to the coast and spaced 23 km apart (~400 km total) were systematically sampled. The omnidirectional sonar informed when and where to adaptively collect biological samples from trawling and collect acoustic data before, during and after trawling. This survey generated ~850 GB of echosounder data and caught 523 mt of Atlantic Menhaden from 5 ensonified schools. Several echogram processing techniques were used to overcome data challenges to provide acoustic biomass estimates.

Keywords: Industry acoustics, cooperative research, noise removal

Target strength modelling of small pelagics in the Baltic Sea using the Kirchoff Ray Mode Model

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Good estimates of species specific Target strength (TS) at length are crucial for abundance estimates in hydroacoustic surveys. In the brackish semi-enclosed Baltic Sea, European sprat (*Sprattus sprattus)* and herring (*Clupea harengus*) were the dominating pelagic species for decades, but recent years have seen a massive increase in three-spined stickleback (*Gasterosteus aculeatus*). A lack of specific knowledge on TS for the three species has led to the use of a generic TS-L equations for the three species. During acoustic surveys in 2020 – 2022, 221 specimens of the three species were frozen whole, cut and photographed. General shape models for the three species as a function of length have been established using General Additive Modelling (GAM). KRM was used to model TS-L at 14 - 380 kHz. Modelled TS at 38kHz for an average size stickleback, sprat and herring was -53.1, -44.5 and -39.8 dB which is 3.1, 5.7 and 7.4 dB stronger than currently applied values. These estimates correspond better to empirical measurements of TS distribution during acoustic surveys in the Baltic Sea. A flatter TS ~ frequency curve for stickleback than the other two species suggests that remote acoustic classification is possible, with potential implications for future survey design.

Keywords: scattering model, target strength, broadband acoustics

Identification of mesopelagic fish species using multi-frequency acoustic approaches – implications for biomass estimation

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Mesopelagic fish are of the least studied components of the ocean ecosystem, with major uncertainties about their biomass. The high diversity of fish, plankton, and other sound scattering organisms in the Benguela region makes acoustic identification of species difficult. Multi-frequency acoustic techniques were used to distinguish between mesopelagic fish aggregations and other major co-occurring sound-scatterers such as krill, plankton and jellyfish. Frequency responses were extracted from acoustic data collected by R/V "Dr Fridtjof Nansen" off Namibia during April-May 2019. Acoustic targets were verified with an in-trawl camera system (Deep Vision). The acoustic classification algorithm (ACA) developed was applied to data collected during two surveys in the northern Benguela in 2017 and 2019.
Mesopelagic fish biomass estimates were computed using four different approaches to evaluate diurnal effects and the reliance of the estimates on independent target verification. Depending on the approach used, the biomass of mesopelagic fish varied from 900 000t to 1 300 000t in 2017, and was in 2019 estimated at 1 200 000t based solely only on the ACA. This study demonstrates that the ACA developed reliably classifies mesopelagic fish, krill, and plankton and can be successfully applied in the absence of trawl data.
Keywords: Species identification, mesopelagic fish biomass, Benguela, multi-frequency acoustics, frequency response, Deep Vision

Investigation of broadband acoustic to resolve and identify nearby targets using different pulse durations

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Frequency modulated broadband signals provide frequency response over a frequency interval and improve range resolution by pulse compression. These features have made broadband acoustics a favorable tool in several applications in fisheries. However, being able to resolve nearby targets does not assure the signals of the targets are unaffected of each other. To collect correct target strength (TS) using broadband echosounders, several parameters should be assigned properly. These parameters include, among others, frequency range, transmit power, pulse duration, signal modulation, and tapering. Here, we have studied the effects of pulse duration on compressed pulse signal of two adjacent targets and Fourier window length on the TS frequency response estimation using modelling and measurements. Calibration spheres are used as target since their backscattering is known and orientation independent. Acoustic

backscattering of two similar (WC38.1 mm) and two different (WC20 and WC57.2 mm) calibration spheres with different spacing were measured. Acoustic interaction between the targets is not included in the modelling while it is inherent in the measurements. Using both measurements and modelling enables decoupling the effects of for example side-lobe overlaps and the acoustic interaction - such as shadowing and multiple scattering - on the TS estimation.
Keywords:broadband, pulse duration, Fourier window length, adjacent targets, pulse compression

Acoustic target strength with growth stage of fish: comparison of juvenile and adult Japanese anchovy (*Engraulis japonicus*)

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Japanese anchovy (*Engraulis japonicus*) is one of the important commercial species around coastal waters of the northwestern Pacific Ocean. For various acoustic surveys on spawning or fishing ground, there is necessary to understand target strength (*TS,* dB) with growth stage of the fishes. However, little is known about *TS* information of juvenile fishes. This paper presents measures of *TS* and models for juvenile Japanese anchovy and describes *TS* difference between young and adult anchovy. The measurements were conducted at 38, 120 and 200 kHz transducers with live 21 individual anchovy (total length; 3.13 to 9.85 cm). For juvenile stage of the anchovy, the *TS* models were suggested with frequency, respectively. As a result, the mean *TS* values of young and adult anchovy are very similar to those of previous *TS* studies (Kang *et al*., 2009), whereas those of juvenile anchovy were significantly very low. These results show that it is difficult to apply the acoustic characteristics of the anchovy with growth stages as a *TS* function, especially juvenile anchovy. From this studies, we might be suggested that suitable Japanese anchovy *TS* equation according to growth stages must be adopted for data analysis of acoustic surveys on spawn and fishing ground.
Keyword: Acoustic survey, growth stage, Japanese anchovy (*Engraulis japonicus*), Target strength,

Weakly-supervised classification of acoustic echotraces in a multispecific pelagic environment

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Automatic echo-trace classification models may contribute to increasing the vertical resolution of species allocation and providing complementary information on specific structural and aggregation patterns. Here, we applied a weakly supervised model to deal with habitual multispecific trawl catch information in diverse pelagic ecosystems. Trawl catch proportions were interpreted as the probability of each school to belong to a species and they were used to develop a multiple-output model. Our results indicate that at school-level we can expect an accuracy of 76 % out-of-sample at labeled data. When considering both labeled and unlabeled data the model

performance could not be established at the school level but at the haul level by comparing species proportions. Then, the out-of-sample accuracy increased to 80%. Based on the probabilistic output of the model, we developed a metric to measure the confidence of the model for each school assignation. Higher confidence provided higher accuracy, hence showing the validity of the metric. The automatic classification tool developed in this study, are meant to be applied extensively to trawl-acoustic surveys to gain information about the structure and behavior of such aggregations to study temporal shifts in a large 3-D scenario.
Keywords: Machine learning, weak-supervision, poor-labelling, school processing, fisheries acoustics, gradient boosting machine

Acoustic species identification, length distribution and biomass estimation of a mixed species aggregation in an oceanographic frontal region

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During the Office of Naval Research Sediment Characterization Experiment in 2017, a dense aggregation of scatterers was discovered at the New England Shelf break. In this unique environment the cold, less saline water of the New England Shelf meets the warmer saltier slope waters to form an oceanographic front. While mapping the front, an aggregation of scatterers was observed at the northern most extent of the slope water wedge. Combining Northeast Fisheries Science Center bottom trawl data with data from narrowband (18 and 38 kHz) and broadband (70-280 kHz) shipboard echo sounders, it was possible to identify the species in the aggregation as longfin squid (*Doryteuthis pealeii*) and mackerel (*Scomber scombrus*). A mixed species scattering model was developed to estimate the length distribution of each species as well as the total biomass. The mean length of squid and mackerel, respectively, using the new mixed species scattering method was 4.45 ± 1.00 and 20.25 ± 1.25 cm compared with 6.17 ± 2.58 and 22.76 ± 1.50 cm from the trawl data. The estimated total biomass of the aggregation was a factor of 1.64 times larger when using the length distribution estimated by the new mixed species scattering method compared to the trawl length distribution.
Keywords: Species Identification, broadband, backscatter, biomass

One size does not fit all: experimental target strength measurements of pteropods and shrimp emphasize the importance of scattering model inputs

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Shrimp and pteropods can produce significant amounts of water column backscatter that may overlap with survey target species. Few studies have experimentally measured both target

strength (TS) and scattering model inputs for individual shelled pteropods and shrimp, especially from the meso- and bathypelagic. We captured animals from net trawls throughout the northeast Pacific and northwest Atlantic continental shelves between 2016 and 2020. We measured morphology, density and soundspeed contrasts, and broadband TS (35 – 75, 110 – 230 kHz) from tethered individuals at sea and on land in scientific aquaria. Experimental TS was used to examine model sensitivity and performance. Mean length-to-radius ratios and density contrasts of epipelagic shrimp species (10 to 13 and 1.02 to 1.03) significantly differed from their mesopelagic counterparts (8 to 9 and 1.04 to 1.05). Shrimp TS model predictions (averaged over measurement bandwidth) were within 2 dB of measurements despite these differences. Conversely, pteropod TS model predictions differed from measurements (by more than 4 dB), with species with elongated shapes having larger differences. These discrepancies are likely due to shell shape and uncertainty surrounding material properties. Widely used models may significantly underestimate uncertainty in TS and may not adequately represent other specific species.

Keywords: Target strength, modeling, pteropod, shrimp, epipelagic, mesopelagic

Target strength of mesopelagic organisms derived from computed tomography scans

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Changes in catch rates of Patagonian toothfish (*Dissostichus eleginoides*) in the Heard Island and McDonald Islands (HIMI) fishery in the southern Indian Ocean have been observed in recent years but areas of decreasing catch rates are not thought to be related to stock decline. Rather, changes in the biophysical environment are suspected of affecting the availability of toothfish to the fishery, such as the micronekton community that toothfish forage on. To quantify the temporal and spatial aspects of this community and explore links to toothfish catchability, existing vessel echosounder data will be used to produce population metrics of the micronekton community. To obtain biologically meaningful outputs from echosounder data, robust length to target strength relationships for the main species or species groups are generally required. These were not available for several of the species/species groups found in the HIMI region, so a semi-automated procedure was developed to transform computed-tomography (CT) scans of large numbers of micronekton species into realistic three-dimensional datasets suitable for use in boundary element method and the phase-tracking distorted wave Born approximation backscattering models. Length to target strength relationships for nine species/species groups were then estimated from CT scans of 439 specimens and compared to existing relationships and datasets, where available.

Keywords: acoustic

Improving accuracy of dagaa acoustic biomass estimation in Lake Victoria using school analysis and geostatistics for Ecosystem based Fisheries Management

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Rastrineobola argentea (dagaa) is a short-lived pelagic fish indigenous to Lake Victoria and other East African waters. It contributes 65% of Lake Victoria`s annual 1 MT fish landings and supports about 45 million people. Dagaa aggregate during daytime into distinctive needle-like schools when observed at acoustic survey speed of 9 -10 knots. Dagaa biomass in Lake Victoria is estimated by integration of acoustic signals in the top one-third of the water column and bootstrapping (in R statistical package) biomass of all transect Elementary Distance Sampling Units (1 km) to lake-wide mean biomass. This approach introduces uncertainty into the biomass estimation since dagaa inhabit the whole lake`s water column, and other fish (pelagic haplochromine cichlids) occupy the top one-third of the water column. Also, the method does not account for the spatial dependence of samples in the data. To improve the accuracy of assessment, which is necessary for long-term dagaa management and towards the development of Ecosystem-based Fisheries Management in Lake Victoria, we used a comprehensive school-based classifier to identify dagaa signals in the 120 kHz echosounder data and applied geostatistics to quantify the variance of abundance estimates and map the distribution of dagaa in Lake Victoria.

Keywords: dagaa biomass, geostatistical simulations, kriging, school analysis, top one-third rule

North-west atlantic cetaceans detecting algorithm based on spectrogram classification using fastai machine learning model

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This study introduces a novel algorithm for detecting cetaceans in the North-west Atlantic region using spectrogram classification with a fastai library machine learning model. Cetaceans, such as whales, dolphins, and porpoises, play an important role in the ocean's ecosystem, but monitoring their populations and diversity can be challenging. In this study, we aimed to develop a reliable

and efficient method for detecting cetacean presence and variety based on their vocalizations. Due to limited recording time at various locations, the main challenge was to generate a sufficiently large dataset based on additional already existing data. The algorithm was subsequently trained with past records along with the generated dataset of cetacean vocalizations collected from various expeditions and validated using manual inspection. The results showed that the algorithm achieved a precision rate of 85% in detecting cetacean presence, suggesting that it can be a valuable tool for monitoring and conserving cetacean populations. The use of fastai machine learning models allows for fast and efficient processing on a desktop computer. In conclusion, this study highlights the potential for using machine learning models in detecting and monitoring cetaceans, and opens up opportunities for further research and development in this area.

Keywords: Cetaceans, spectrogram classification, fastai,

Building a robust machine learning tool for discriminating between bottom schooling fish and the bottom echo

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A machine learning utility was developed for the purpose of defining an accurate bottom exclusion line in narrowband hydroacoustic data. The specific goal was to prevent the bottom echo from influencing biomass calculations in circumstances where fish were schooling in close proximity to the bottom, making separation extremely challenging.

The utility was developed within the Echoview application, utilising Google's Tensorflow libraries to define and train the convolutional neural network. Loss functions were adapted from those used in medical imaging, in order to bias the accuracy of the boundary edge in detected features.

The utility was tested using stock surveys of Blue Grenadier off the West coast of Tasmania, supplied by Australia's CSIRO. The results showed a very good degree of success when separating the Grenadier schools from the bottom, especially when conventional algorithmic bottom detection could not be made to work reliably.

Keywords: Machine Learning, Bottom, School, Echoview

Investigating right whale prey distribution and quantity in southern New England

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The North Atlantic right whale has less than 350 animals remaining in its population, and since 2010 southern New England has become a primary winter foraging ground. The distribution of right whales in this area also significantly overlaps with planned offshore wind development, potentially posing a significant risk to the population, in part through oceanographic changes that could impact the distribution of right whale prey. Despite right whale use of this region for foraging, little is known about what the whales are feeding on here during the winter. In order to assess right whale foraging resources, we conducted field sampling during the winter and spring from 2020 through 2022 with bongo nets, echosounding, and a video plankton recorder. Acoustic frequencies deployed included Biosonics DT-X echosounders at 123 and 430 kHz, and Simrad ES-70 echosounders at 38 and 200 kHz. Sampling was conducted both adjacent to and inside southern New England wind energy areas, and also adjacent to foraging right whales and with no whales present. We employed the distorted wave born approximation to estimate the target strengths of multiple potential copepod prey species and compare and validate acoustic classification with zooplankton abundances measured by bongo nets.
Keywords: right whales, copepods, DWBA, target strength, classification

Characterization of Sprat acoustic backscatter and its implication on biomass estimates

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The identification of targets for both qualitative and quantitative observations is one of the main challenge of fisheries acoustics. The logarithmic measure of the backscattering cross-section, expressed as Target strength (TS), is a key parameter in this process. It includes the scattering proprieties of the species convolved with behaviour depending on swimbladder features, frequency and tilt angle of the fish. These determine the stochastic nature of TS that resulted as one of the main source of uncertainty in biomass estimates. Nevertheless, only one study has been carried out on sprat TS in the Mediterranean Sea in 1994. The application of backscattering models allows to properly predict theoretical backscatter from accurate measurement and setting of the main parameters. Here we apply a frequency-domain Finite Element Method on three-dimensional swimbladder model of sprat specimens collected during the MEDiterranean International Acoustic Survey (MEDIAS) 2021 providing for the first time the relative frequency response and broadband backscatter on the species in this basin. Moreover, a new conversion parameter (b_{20}) for sprat is proposed herein along with an assessment of its influence on biomass estimates by comparing the new value with the current one.
Keywords: Target strength, fisheries acoustics, broadband, modeling, swimbladder, *Sprattus sprattus*

Classifying fish with broadband acoustics; behaviour and platform dependent broadband backscattering by physostomous fish (*Clupea harengus* L.)

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Efficient use of Unmanned Surface Vehicles (USV) for fisheries science applications requires implementation of onboard data processing, including methods for target classification, converting raw data to information. Applying broadband frequency modulated signals is also believed to improve acoustic spectral-based target classification. If the broadband frequency response used to train automated target classifiers are obtained from conventional research vessels (RV), due to potential vessel avoidance the tilt angle distribution may be different than for USVs with consequences for target classification. The assessment of Norwegian Spring Spawning Herring (NSSH) is one case where USVs will be used for abundance estimation in the near future. In this study broadband acoustic data were collected with a conventional RV and a small USV, combined with an inverted echosounder monitoring potential avoidance. Shallow and deep herring schools were measured day and night by the RV and USV in Northern Norway during November, and potential avoidance reaction due to approaching vessels were quantified. The broadband frequency response of NSSH obtained with the USV and RV is found to be different for shallow herring schools, and similar for deep schools. Using broadband frequency response for target classification one needs to consider potential platform dependent broadband frequency response.
Keywords: Broadband acoustics, frequency response, target classification, unmanned surface vessel, avoidance

Acoustical simulation of the target strength of Atlantic bluefin tuna using 3D computed tomographical images

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Swimbladder is the main contributor to acoustical target strength (TS) of fish when present. Numerical modelling of target strength must include swimbladder dimensions, orientation and shape for the proper estimation of target strength and its directivity. Several Atlantic bluefin tuna (ABFT) specimens between 90 and 100 cm of fork length have been studied by performing computed tomographic (CT) post-mortem in both fresh and frozen states including the use of contrast in some cases. ABFT's swimbladder 3D models have been derived to validate experimental TS measurements through numerical simulation methods, in this case using the Method of Fundamental Solutions (MFS). MFS allow calculating the backscattered acoustic field at any distance range between the target and the transducer, not only in the far-field regime, being relevant for short-range configurations or large targets, as it is the case. Good agreement between the numerical estimation and the experimental measurements in tanks is reported.
Keywords: Atlantic Bluefin tuna, numerical modelling, swimbladder, CT, target strength

Visualizing classified bottom habitat in Echoview: an aid in species discrimination

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Acoustic-trawl surveys are commonly used to provide an index of abundance or biomass to stock assessments. The U.S.-Canada Pacific Hake Acoustic Trawl Survey, operating off the West Coast of North America, commonly encounters dense rockfish schools that can look acoustically similar to the survey target species, Pacific Hake. The catches from ground-truthing rockfish aggregations with trawling are regularly too large to bring on board and may ruin the net. This paper presents work using Echoview's bottom habitat parameters to improve discrimination of rockfish from hake. Fieldwork in July-Aug 2022 on paired acoustic transects used the Semi-Autonomous Strobed Stereo Imager (SASSI) camera system on a net to fish large schools of rockfish and hake with an open cod-end, eliminating the issue of net damage and large catches. Quadratic discriminant analysis of bottom habitat parameters in Matlab generated probabilities of the bottom habitat being associated with rockfish/hake, and these probabilities were visualized as a virtual variable in Echoview. Use of bottom habitat parameters improved the hake/rockfish classification between the paired transects. Visualization of classification probabilities from bottom habitat parameters can be a useful tool to aid in species discrimination, but for the purposes of the Pacific Hake survey, must be combined with other methods.
Keywords: Bottom habitat, acoustic-trawl surveys, classification

Do fish swim faster in the horizontal direction than up-down?. Study case: two small pelagic fish and two demersal fish

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We analyzed the individual swimming behavior of four species, two pelagic (anchoveta- Engraulis ringens and Southern sardine -*Strangomera bentincki*) and two demersal (Southern hake - *Merluccius australis* and hoki - *Macruronus magellanicus*). The experiments were part of the target strength in situ studies off the Chilean coasts (distributed in parallels 18°20'S-40°00'S for pelagic species, and 44°00-47°00´S for demersal species). Acoustic data were collected with calibrated SIMRAD EK 60®. 38 khz (1.024 ms) echo sounder. For the pelagic fish, the transducer was on the hull of the vessel, while for demersal fish, submerged transducers at 200 m were used, close to the fish aggregations. Data were processed with Echoview® Fish Tracking module.
The average depth of pelagic fish were close to 21 m and demersal fish between 255 and 282 m. The 69% of vertical swimming angles for all species were grouped between -10° and +10°. Angles average of pelagic fish were between +0.1° and +1.6° and demersal fish between -0.5°and -6.6°, hoki showed a diving behavior.

Pelagic showed greater average swimming speeds (>1.0 m/s) and maximum values (>3 m/s) than demersal which averaged <0.7 m/s with maximum 2.2 m/s. In all species the highest swimming speeds are observed when they swim horizontally, instead of the up-down direction.
Keywords: swimming behavior, small pelagic fish, demersal fish, Humboldt Current

In situ target strength measurements of Peruvian anchovy (*Engraulis ringens*) from data collected with a commercial echosounder during fishing operations

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Although fishing vessels had been used as opportunistic scientific platforms in the last two decades, studies implying the use of acoustic data collected by commercial echosounders -in particular, those related with target strength (TS) measurements- during fishing seasons are scarce. Here we present some results of an *in situ* TS estimation study of Peruvian anchovy (*Engraulis ringens*) using data collected between May and July 2017 by a hull-mounted single-frequency commercial echosounder (Simrad ES60, 120 kHz, calibrated) installed in the F/V "Maru" during its fishing operations in the industrial exploitable area of the North-Center anchovy stock (5 to 50 nautical miles, 3.5°S to 16°S). Acoustic data suitable for TS extraction was defined by vessel speed (<=1.5 kt), dominance of anchovy in the catch (>=95%) and depth (between the nearfield and 70 m, the vertical extension of the net). Echograms were cleaned for triangle wave error sequence, impulsive and background noise, big echotraces and multiple targets. All the TS histograms showed normal distributions with strong modes. Mean TS -associated to total fish lengths fluctuating from 10.5 cm to 16 cm- oscillated between -49 dB and -51 dB (b20 between -70.6 dB and -71.93 dB). Our results were significantly higher to those reported for *E. ringens* in Perú 20 years ago but similar with the findings of a recent study of this species in Chilean waters and the results published for other *Engraulis* species in the last 10 years.
Keywords: Peruvian anchovy, *in situ* target strength, commercial split-beam echosounders, fishing vessels, noise removal, multiple-target exclusion

The acoustic backscattering of spurdog / spiny dogfish (*Squalus acanthias*) – in situ, ex situ measurements and modelling

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Spurdog are a demersal shark species with worldwide distribution in temperate and boreal waters and a long history of exploitation. Their tendency to aggregate supports large catches, while their slow growth, late maturity and low productivity render them highly susceptible to overexploitation. In the Northeast Atlantic, landings of spurdog have been prohibited since 2011, but increasing abundance led to a re-evaluation of the stock status, and fishing opportunities are expected to be introduced in near time. Additionally, a re-opening of the fishery would have implications on handling of bycatches, including potential closure of fisheries in certain areas with too high bycatches of spurdog that previously had to be discarded.
In October 2022 a large spurdog aggregation was encountered in the Kattegat. Broadband in situ measurements with concurrent catch information were collected. Subsequently, the influence of main contributors to the scattering and the general shape and size of the sharks were assessed through a modelling approach. Ex situ acoustic measurements of spurdog were performed in a public aquarium. Understanding the scattering properties of spurdog could contribute substantially to the identification of spurdog during routine acoustic trawl surveys and also contribute to the reduction of bycatch in this endangered shark species.
Keywords: scattering model, target strength, broadband acoustics

Detection, spatial and source level characterization of coastal cod vocalizations using eight-element hydrophone array

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To better understand spawning vocalizations of coastal cod at Austevoll, western Norway, a prototype eight-element coherent hydrophone array was deployed in stationary-vertical and towed-horizontal modes to monitor cod sounds during an experiment in spring 2019. Depth distribution of cod aggregations were monitored concurrently with an ultrasonic echosounder. Cod vocalizations recorded on the hydrophone array are analyzed to provide time-frequency characteristics, and source level distribution after correcting for one-way transmission losses from cod locations to the hydrophone array. The recorded cod vocalization frequencies range from approximately 20 Hz to 600 Hz with peak power frequency of around 60 Hz, average duration of 300 ms, and mean source level of 163.5±7.9 dB re 1 μPa at 1 m. Spatial dependence of received cod vocalization rates are estimated using hydrophone array measurements as the array is towed horizontally from deeper surrounding waters to shallow water inlet areas of the experimental site. The bathymetric-dependent probability of detection (PoD) regions for cod vocalizations are quantified and are found to be significantly reduced in shallow water areas of the inlet. The hydrophone array system used here is advantageous because it uses passive acoustics on a mobile platform to quickly survey cod vocalization activity at multiple locations.
Keywords: Towed Array; Passive Sensing; cod vocalization;

Computer Vision-Based Echogram Annotation Methods for Acoustic Classification with Deep Learning Systems

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Interest for supervised deep learning (DL)-based systems in fisheries research has grown significantly in recent years, in particular for acoustic classification. For training/validation purposes, DL networks require the data to be annotated with labelsmatching the expected outputs, which can be a daunting task, especially in the absence of ground truth information. In this work in progress, we explore challenges and methods for annotating multi-frequency echograms using computer vision techniques for acoustic classification with DL networks. Annotations can take many forms depending on the targets' characteristics, the research objectives, and the selected image analysis paradigm. Here, we are interested in the challenging pixel-level annotations for semantic segmentation and focus on two use cases: 1) single fish/organism tracks, i.e. discrete scatterers, which often yield similar volume backscattering strength (Sv) as fish school boundaries and noise, and 2) sea surface and near-surface phenomena such as bubbles that can overlap with biology. Combinations of classical computer vision algorithms like edge detection, thresholding, region growing, and clustering, when applied to RGB representations of Sv, show promising avenues for generating annotations semi automatically or automatically. Future work will look at producing soft annotations incorporating a confidence level to help expedite the validation process.

Keywords: Deep learning, annotations, multi-frequency echograms, acoustic classification, discrete scatterers, sea surface boundary

Species specific material property measurements improve the agreement of experimental measurements and scattering model predictions of krill Target Strength

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We collected 175 live specimens of three common California current krill (*Euphausia pacifica, Thysonoessa spinifera, Nematoscelis difficilis)* during a May 2019 NOAA survey cruise and then measured the length (ranging from 5 to 25 mm), width, body shape, and density contrast with seawater of these individuals. Aggregate measurements of soundspeed contrast were collected using krill from the same net tow sampling. Animals were frozen post-measurement and weighed post-cruise to generate species-specific length-weight relationships. For a subset of these animals (n = 32, mostly larger lengths), broadband (38 – 73 kHz, 130-210 kHz) backscatter measurements were made of individuals tethered in a shipboard aquaria. Video observations

were used to monitor animal orientation and body curvature during measurements. The data for individual krill were applied to a SDWBA Target Strength model and those predictions were then compared to the experimentally-measured TS values. Measured TS values (from frequencies >= 50kHz) agreed well with model predictions. The importance of knowing species-specific scattering model inputs must be weighed against the time and effort needed to make them, however it is clear that using model inputs from other regions or species will result in less accurate TS predictions.
Keywords: krill, target strength, scattering model, California current

Utilization of a paired eDNA and acoustic survey for assessing assemblages in the Gulf of Maine

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Environmental DNA (eDNA) is becoming a promising tool for assessing abundance and biomass patterns of organisms in aquatic settings. We aimed to understand the dynamics of eDNA in an open ocean system by pairing eDNA collection with an acoustic survey for Atlantic herring (*Clupea harengus*). This follows from previous work that successfully utilized acoustics to survey spawning schools of Atlantic herring in coastal Gulf of Maine waters with a high degree of confidence based on acoustic characteristics and the unique spawning behaviour of Atlantic herring (Wurtzell et al. 2016). We completed 17 acoustic surveys in the fall of 2020 and 2021 and while spawning schools of herring were less evident on echograms, likely due to a drastic decline in the overall stock, we did observe patterns of abundance in the pelagic zone that we suspect may be due to herring, squid (*Loligo* or *Illex* sp.) and Atlantic saury (*Scomberesox saurus*). We are currently analyzing eDNA samples for these three taxa to compare to acoustic patterns and will present these results at the meeting.
Keywords: eDNA, acoustics, herring, squid, saury

A comparison of acoustic, catch and video data to investigate and monitor grenadier abundance in the Ross Sea

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Since 1997, a longline fishery for toothfish (*Dissostichus* spp.) has operated in the Ross Sea region of Antarctica. A common bycatch of this fishery are grenadiers (*Macrourus* spp.) which

comprise the most common prey item of toothfish in this region. Grenadiers are known to be long-lived and slow growing; developing monitoring tools is required to assess their abundance and to detect potential changes to the ecosystem due to fishing. Here we combine and contrast acoustic and catch-effort data from three New Zealand commercial longline vessels with acoustic, catch (research trawl), and underwater video (DTIS) data collected during research voyages to the Ross Sea region onboard RV *Tangaroa*. Preliminary findings indicate that while acoustic data quality from commercial vessels can be low compared with that from research vessels, putative grenadier single-target marks close to the seafloor are coherent with those identified onboard RV *Tangaroa*. We identified a size selectivity between the different monitoring tools; while videos appear to monitor small grenadiers (average total length ± SD: 29.9 ± 16.9 cm), longline catches sample larger individuals (59.3 ± 11.4 cm) and acoustics detect fish of intermediate sizes (48.3 ± 18.8 cm). This has important implications for the interpretation of fishery and research data to monitor the abundance and biomass of grenadiers in the Ross Sea region.
Keywords: Macrourids, toothfish, single-target detection, image analysis, longlines

Assessing spatial and temporal abundance and distribution of Mueller's pearlside (*Maurolicus muelleri*) in the Northeast Atlantic

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There is a growing interest to commercially exploit mesopelagic fish in the Northeast Atlantic. One species of particular interest is *Maurolicus muelleri* which is thought to form acoustically detectable layers at 200-300 m at day, migrating to the surface at night. To assess feasibility of future exploitation of this species it is important to understand spatial and temporal trends in their distribution. In the Northeast Atlantic region existing fisheries surveys of blue whiting (*Micromesistius poutassou*) which are carried out annually provide a timeseries of hull-mounted acoustic data covering large spatial areas. Through multifrequency analysis which considers addition and subtraction of known target strength ranges for a variety of present organisms we were able to create a template for semi-automated acoustic identification of *M. muelleri*. Following a dedicated mesopelagic acoustic survey during which putative layers of M. muelleri were ground truthed with specially designed trawls, it was possible to test how well the template performed on identified aggregations. In a next instance we will investigate mesopelagic fish distribution using the newly processed timeseries and geostatistical analysis. Spatially coherent patterns dominant in the dataset are extracted using Minimum-Maximum Autocorrelation Factor Analysis. These patterns will help unveiling drivers of the mesopelagic fish distribution.
Keywords: semi-automated classification, mesopelagic, hull-mounted acoustics, fisheries surveys, geospatial analysis

Broadband acoustic scattering simulation and in-situ observation of dagaa (*Rastrineobola argentea*) in Lake Victoria, East Africa

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Lake Victoria is the second largest tropical freshwater lake in the world and provides vital food resources to millions of locals. Dagaa is one of the most important species in Lake Victoria and plays an important role both ecologically and economically. Lake-wide dagaa stock biomass has been estimated annually since the 90's using echosounder data (120 kHz) collected during fish stock assessment surveys. These estimates rely on accurate measurements (or predictions) of dagaa target strength (TS, dB re 1 m^2), which at present is very uncertain. In this study, we applied a KRM (Kirchhoff-ray mode) model to predict the TS of dagaa, based on X-ray images of fish ranging in a total length between 3.0 and 5.4 cm. The result shows that the swimbladder (2.57-8.19 % body volume) accounts for 57-95% of the total backscattering intensity at 120 kHz. At frequency below 200 kHz, the tilt angle of dagaa varied TS by up to 8.34 dB, and this variability increased with frequency (at 250 kHz this increased to 19.24 dB). Modelled tilt-averaged TS-length relationship suggested a new function as: $TS = 20\,log\,log\,(TL) - 68.21$, which differs by 3.99 dB from the TS-length relationship currently utilized to estimate stock biomass. The new model can lead to a substantial reduction of the present biomass estimates by 60%. The tilt angle of 993 tracked fish followed a gaussian distribution with a mean and s.d. of 93.51° and 15.1° respectively. *In-situ* measured samples suggested a TL-SL relationship for dagaa as $TL = 1.156SL + 0.0523$ (R^2 > 0.99). The KRM model simulation of dagaa provides a better understanding of the scattering spectrum of dagaa, which will be beneficial to the species identification, school behaviour studies, as well as a refinement towards improved dagaa stock estimation.
Keywords: KRM, swimbladder, physostomes, target strength, frequency response

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

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The strong effect of herring orientation on its backscattering properties, which is important for accurate hydroacoustic biomass assessment, and the lack of accurate information on Baltic herring orientation stimulated us to develop an inverse method to assess Baltic herring orientation in schools. The existing hydroacoustic methods, applied for fish orientation inferring, require expensive measuring equipment and advanced complex analysis of the collected data. Therefore, we looked for a less costly and simpler method using data from routine hydroacoustic measurements but different data analysis techniques.
The developed technique allows to estimate the orientation distribution of the Baltic herring in schools by comparing the histograms of herring target strength (TS) between those from the theoretically modeled and those extracted from the data collected during the standard hydroacoustic assessment of Baltic herring biomass in BIAS cruises.
This is the further development of the method presented in the ICES WG FAST meeting in 2021, updated with a new scattering model that can predict backscattering by Baltic herring more accurately and with a more flexible herring orientation distribution than a unimodal Gaussian distribution used previously.
Keywords: fish orientation, Target Strength, Baltic herring

Data Integration: Analytics

Field comparison of Antarctic krill (*Euphausia superba*) backscatter and aggregation types using Nortek and SIMRAD echosounders

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Temporal distributions of Antarctic krill (*Euphausia superba*) density and aggregation types were characterized and compared using Nortek Signature100 and SIMRAD WBAT upward-looking echosounders on moorings. Overall noise varied between the two echosounders with the Signature100 data corrected for background, transient, and impulse noise while the WBAT data was corrected for background noise only. For selected regions with no discernible backscatter, the signal-to-noise ratio of S_v values did not vary between the two echosounders. Surface echo backscatter was also similar during similar time periods. A suite of descriptive metrics: volume backscatter, mean depth, center of mass, inertia, equivalent area, aggregation index, and proportion occupied were used to quantify spatial and temporal krill vertical distributions. Overall density and evenness of distributions differed but were detected at similar mean depths. Krill aggregations at each mooring were grouped in three types. The Signature100 detected a lower number of krill aggregations (n=133) compared to the WBAT (n=707). The overall shape of krill aggregations differed at the two spatially separated moorings, while overall aerial density of each

aggregation type was similar. Despite differences in noise characteristics and krill detection, both instruments are adequate for deployment and sampling of Antarctic krill over extended periods.
Keywords: Signature100, WBAT, echo-integration, intercomparison, Antarctic Ocean

Micronekton multifrequency backscatter classification within an eddy dipole of the Mozambique Channel, South West Indian Ocean

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A semi-supervised multifrequency classification approach was developed to characterize four micronekton acoustic groups within cyclonic (C), anti-cyclonic (AC) eddies and transition zone (TZ) - area between the two eddies. The C was characterized by higher fluorescence values at the fluorescence maximum depth, saltier and colder waters than the AC. The TZ showed the highest mean eddy kinetic energy and lowest fluorescence values compared to the AC and C. In the deep depth category, the C showed higher micronekton acoustic densities during the day and night compared to the AC and TZ. At the 18 kHz and 70 kHz frequencies, the C showed higher acoustic densities compared to the AC in the surface layer during the day, whereas at the 38, 120 and 200 kHz, the AC showed higher densities than the C. The proportion of mesopelagic communities that appears to migrate (i.e., the DVM strength) is greater in the TZ at the 18, 38, 120 and 200 kHz. At the 70 kHz, the DVM strength is greater in the AC compared to the C and TZ. Preliminary results highlight the influence of eddies of the South West Indian Ocean on the micronekton acoustic groups determined by the classification approach.
Keywords: Micronekton, Acoustics, Multifrequency backscatter classification, K-means, Hierarchical clustering, Random Forest

Impact of echosounder calibration errors on an international acoustic survey (HERAS)

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Fisheries acoustic surveys are routinely conducted around the world, and particularly within the ICES community. Following pre-defined transects, these surveys make use of downward active acoustic systems (i.e. so called scientific echosounders) coupled with biological sampling through fishing operations to estimate abundance and distribution of marine species. The hereby study investigates the effect of calibration error on the Herring Acoustic Survey (HERAS) in the North Sea, West of Scotland and the Malin Shelf.
The HERAS acoustic survey takes place yearly for ~1 month and is a dedicated international survey effort (5 vessels). The survey concerns two herring stocks: Western Baltic Spring Spawning (WBSS) and North Sea Autumn Spawning (NSAS). Calibration errors considered for testing will draw from echosounder malfunctioning recorded at sea during a ping-to-ping trial on the same transducer using a multiplexer. From this data set, two types of calibration error will be tested: 1) a fixed calibration gain offset 1) a non-linear response of the transducer. The calibration

errors will be propagated to survey indices for both WBSS and NSAS from 2016 to 2022. The application of different level of calibration error for different components of the survey will be tested. The resulting effect will be investigated for both NSAS and WBSS indices (e.g. change in correlation across ages), including the impact on stock assessment.
Keywords: Acoustic survey, stock assessment, calibration

Understanding the impact of ping interval on acoustically based abundances

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The ping interval is the main parameter controlling along-transect sampling resolution in acoustic surveys. An increase in the detection range or the synchronization of sensors to avoid crosstalk might increase ping interval, reducing sampling resolution. Here we study whether pinging resolution affects the mean acoustic backscattering energy, causing uncertainty and/or bias in abundance estimations. To this end, we echo-integrated a real acoustic survey, followed by the application of a systematic resampling scheme to simulate an increase in ping interval. In each transect, the mean NASC calculated for each simulated ping interval was compared to the original mean NASC values. Transects were characterized according to their heterogeneity and spatial autocorrelation to study their effects on the relationship between abundance error and sampling resolution. The uncertainty increased with the ping interval owing to the highly skewed distribution of fisheries acoustics data. Higher heterogeneity and the lack of spatial autocorrelation were observed to accelerate the loss of precision for increased ping intervals. Although the mean bias across repetitions was zero, the asymmetry of the bias distributions increased with ping interval, leading to a likely underestimation at intervals higher than ~2.5 s. An interactive figure summarizing the obtained results can be found in https://aztigps.shinyapps.io/PingRateStudio/.
Keywords: ping rate, random error, systematic error, sequential resampling, random resampling, Gini index.

Spatial tug of war: kriging spline model residuals of fish abundance in a Bayesian framework

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Penalized splines (often used in generalized additive models, GAMs) allow us to describe nonlinear effects of environmental factors on fish abundance. These models assume implicitly that the residuals are independent, but this assumption is often violated. A potential solution is to apply ordinary kriging to the residuals to account for spatial dependence. This is a fairly common method and is often applied step-wise. However, this lack of iterative feedback and formal characterization of uncertainty disguise the effect of the structure of the splines on the kriging model. We developed a regression kriging model with penalized splines in a Bayesian framework in Stan that estimates the GAM and kriging components simultaneously, rather than stepwise. We built a simulation study to test the flexibility and performance of the model, and then applied it to Swedish acoustic data in the pelagic waters of the Baltic Sea, as well as to benthic imaging data collected in the Mid-Atlantic Bight. This study provides both a Bayesian implementation of a broadly applicable model structure, and principles guiding future applications to survey data designed to capture the spatial structure of fish stocks.
Keywords: Bayesian inference, regression kriging, simulation study, echosounder data analysis, optical imaging data analysis

A story about data extraction and deep learning applied to fishery acoustic data

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Modern data processing methods offer a wide range of opportunities for acoustic data processing, and here we describe and discuss our experiences in developing and implementing portable data processing pipelines. The objective has been two-fold: Preparing historical data for efficient access and analytics (cloud based), typically for training machine learning models, and providing a platform for deploying data processing algorithms to the platforms carrying acoustic sensors (edge). The data preparation steps include adopting data conventions (ICES), efficient cloud-based data formats, and data organization. We have been training machine learning algorithms for acoustic target classification, and we present some of the challenges that we had to tackle to successfully deploy these algorithms, including erroneous labels, unbalanced data sets, and the fact that acoustic data is not images. After successfully training target classification algorithms there are several ways to implement these in existing and future processing pipelines, and we describe what we have done so far to deploy these algorithms on edge platforms. Examples of this include deployment on the sounder USV as well as the Statsraad Lehmkuhl tall ship. Finally, we describe our plans for the way forward.
Keywords: Digitalization, machine learning, operationalization, data processing, cloud technology, data access, mass deployment, autonomous vehicles

Real-time underwater acoustic data acquisition and processing with a large aperture 160-element coherent hydrophone array

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Acquiring, analyzing, and monitoring underwater acoustic data in real-time is crucial for making quick decisions and aiding scientific discoveries at sea. This task requires properly optimized hardware resources and software algorithms, especially when data is acquired with a 160-element coherent hydrophone array, each sampled at 100 kHz, where the array data has to be beamformed and analyzed in 147 distinct bearings simultaneously. Here, we implemented algorithms to run on GPU, which enabled considerable speed up compared to run on CPU, such as more than 338x faster beamforming. For real-time data connection and storage between computers, we used effective high-speed network switches and storage components. During sea trial of the Northeastern University (NU) inhouse designed and fabricated 160-element coherent hydrophone array hardware at the U.S. Northeast coast on board the research vessel (RV) Endeavor in September 2021, we utilized the developed and optimized software, as well as high-performance computing hardware, specifically configured and assembled inhouse, to store, process and analyze data sampled at 100 kHz per hydrophone element in order to monitor acoustic events in real time.
Keywords: Array Processing; Passive Sensing; Data Processing Acceleration; Beamforming; Remote Sensing

Estimation and removal of noise in broadband echosounders

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Broadband data can at certain high frequencies contain strong noise caused by external sources or other instruments, while noise at low frequencies may be caused by bottom backscattered ship-noise. We aim at developing methods for identifying frequencies containing noise. Desired signal is defined as transmitted sound backscattered to the transducer, and noise is everything else. Narrowband noise in a broadband signal, especially at high frequencies, may be quite stable in time. Data for reliable estimation of noise suggested by Korneliussen (2000) seems suitable, i.e., to use distant recordings or backscatter received long after bottom backscatter to “simulate” passive recordings. Existing algorithms for calculating noise is used. The noise identification is intended to be improved stepwise by firstly selecting segments of the data well suited for noise extraction. Then, when the noise calculation using those data are verified, time-varying noise will be estimated from running averages.
The extraction of broadband noise from active pinging compared to passive recordings is necessary to validate estimation of noise. The impact of such noise can then be reduced by noise

removal techniques, such as using notch filters. Furthermore, temporal spike-noise and ambient echo integration noise may be removed by known methods.
Keywords: Broadband, Noise

Building an open-source software toolbox for cloud-native processing of fisheries and plankton acoustic data

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Scientific echosounders are an efficient survey tool that can provide fish and zooplankton distribution and abundance information for fisheries and marine ecological research. The recent fast growth of echosounder deployment has created unprecedented opportunities to systematically observe these animals at an ecosystem scale. However, there remains a need for open, scalable workflows that adapt well to the rapidly increasing data volume and are conducive to integrative analysis across data of heterogeneous sources and types.
To address this need, we are building an open-source data processing pipeline that transforms acoustic data in raw format into estimates of biological quantities, such as biomass. Here we present our ongoing work to develop software building blocks and the associated workflow-orchestrating infrastructure aimed at achieving this goal. These include software elements that handle data parsing and organization, identify target echogram regions using analytical methods, and incorporate fine-grained biological data from net trawls in echo interpretation, all operating on a scalable cloud cyberinfrastructure with a set of clearly specified data product levels. We will demonstrate current capabilities using publicly available echosounder data archives and discuss our next stages of development objectives.
Keywords: software, workflow, cloud computing, open-source

Classification of acoustically-similar pelagic forage fishes: combining ecological knowledge with machine learning

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Mid-trophic level fishes are critical links in pelagic food webs and can exhibit dramatic changes in biomass and species composition, with subsequent impacts at higher and lower trophic levels. Acoustic-trawl surveys generate indices of biomass and abundance used in management; these indices rely on accurate apportionment of echoes to species. We present a novel framework for species apportionment in surveys of acoustically similar, co-occurring pelagic fishes. From 1990 to 2015, hydroacoustic and net surveys were conducted in Lake Champlain, a large, fragmented lake comparable to the Laurentian Great Lakes. The surveys encompassed a period before and during alewife (*Alosa pseudoharengus*) invasion into a pelagic fish community dominated by native rainbow smelt (*Osmerus mordax*). We analyzed 11 years of survey data using documented acoustic properties and habitat preferences of fishes, a random forest model, a framework for acoustic separation of rainbow smelt age classes, and best practices for fisheries acoustic assessment developed in the Great Lakes. We present an overview of statistical methods, a subset of results at large and small spatial scales, and assessment of classification accuracy. This unique approach can be generalized beyond Lake Champlain for use in large lakes and marine systems.
Keywords: pelagic fish, random forest, species apportionment, target classification, large lakes

Multifaceted Study with the Aris Imaging Sonar and Acoustic Tags Using AI Techniques for Fish Identification at White Rock Dam

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The OceanAware project, led by Innovasea and funded through Canada's Ocean supercluster, developed the next generation of underwater observation systems to transform fisheries management, aquaculture, and marine energy. This project developed innovative methods for real-time tracking of untagged fish and species at risk around man-made infrastructures, such as hydropower dams, that present barriers to fish passage. The system, Tagless Fish Tracking, applied modern Artificial Intelligence (AI) techniques to automatically detect fish and classify fish species imaging sonar cameras (Aris).
The upstream and downstream migration of Gaspereau (Alewife) were the species of interest for this study. Results will be presented from the deployment of our Tagless Fish Tracking system at the White Rock Dam hydroelectric facility located on the Gaspereau river in Nova Scotia Canada. The system provided to our partner Nova Scotia Power Inc., produced real-time fish detection results and statistics. These results were accessible via Innovasea's Cloud/Mobile platform. Additionally, the efficacy of the Tagless Fish Tracking system results was compared with the results from a concurrent acoustic telemetry study.
Keywords: artificial intelligence, Tagless Fish Tracking, Aris camera, imaging sonar, acoustic tags, acoustic telemetry

Semantic Segmentation of Pacific Hake Aggregations in Water Column Echograms

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Pacific hake supports the largest fishery of the U.S. west coast and is a keystone species in the northern California Current ecosystem. Obtaining biomass estimates of hake relies on a key step of identifying water column echo returns induced by hake in months-long acoustic survey data. This is a time-consuming task, requiring fisheries acoustics expertise and substantial field experience associating echogram patterns with hake trawls.

In this work we leverage existing annotations to develop a semantic segmentation framework to detect hake aggregations in echograms from ship surveys. Semantic segmentation has been shown to successfully extract fish aggregations from echograms for species such as herring and sandeel. However, hake poses a unique challenge since its aggregations typically do not have well-defined boundaries and can have a large spatial span. Further, hake appearance may differ depending on age, depth of occurrence, or co-occurrence with other species. Despite these variations, the algorithm can successfully identify several types of hake aggregations, and detects potential hake regions not identified by annotators but having acoustic signatures consistent with hake echoes. The algorithm thus can serve as an initial screening tool to allow focusing expert annotation efforts on the more ambiguous identification cases.

Keywords: hake, semantic segmentation, echogram, deep learning

Using Artificial Intelligence for Identification of an Acoustic Signal

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Behaviors of aquatic animals are often monitored using acoustic telemetry. Various acoustic telemetry techniques are used to monitor the 3D position and movement, as well as the presence /absence of naturally swimming fish. One acoustic signal type used for identifying individual tags uses period signal encoding (referred to as the HTI signal type). The HTI signal type utilizes the full transmitted acoustic energy for both detection and identification, providing significantly greater detection ranges than encoded BPSK signal types. However, identifying period encoded signals typically requires manual data review by trained human analysts, resulting in increased processing cost.

Innovasea has developed artificial intelligence (AI) techniques to identify period encoded signals transmitted by acoustic tags implanted in aquatic animals. The U-Net machine learning model was adapted and trained to detect period encoded acoustic tag signals from raw acoustic telemetry data. The raw data is transformed into a spectrogram-like image and the U-Net learns an image mask that separates actual tag detections from noise and interference.

The trained U-Net achieved greater than 97% acoustic signal tag identification accuracy when compared to tag identification performed by human analysts. Numerous examples of the U-Net performance will be presented, including 3D positioning comparisons.

Keywords: deep learning, neural networks, acoustic tags, acoustic telemetry, acoustic signal type, HTI signal

Effects of net-sampling methods, timing, and effort on biomass estimates from acoustic-trawl-method surveys

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Since 2006, acoustic-trawl-method surveys have been used to estimate the distributions, biomasses, and demographics of coastal pelagic fish species (CPS; e.g., anchovy, sardine, mackerels, and herring) in the California Current Ecosystem. During daytime, when CPS typically school at depths observable with ship-based echosounders, acoustic backscatter is measured along transects perpendicular to the coast. At night, when CPS typically ascend and disperse to feed, catches are obtained from a trawl net towed near the sea-surface in areas where putative CPS backscatter was observed earlier that day. The catches provide species composition and length data used to apportion the CPS backscatter to the species present, and to estimate their biomasses. To test the hypothesis that species composition and lengths from nighttime catches are representative of the CPS backscatter observed earlier the same day, we compare catches from nighttime trawls and daytime purse-seines sets on CPS schools in approximately the same place and time. We examine the effects of differences in catch information on the CPS biomass estimates; and perform a sensitivity analysis on the catch effort needed to obtain precise biomass estimates. We discuss the inter-annual consistency in regional catch compositions, and the coherence in biomass-at-length time-series resulting from the present approach.
Keywords: Acoustic-trawl method, Small pelagics, Fishery-independent surveys, Stock assessment

Using mixture Gaussian models for characterization of ispi (*Orestias ispi*) in Lake Titicaca, Peru – Bolivia

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In Lake Titicaca (Peru-Bolivia) is developed fishing activity of ispi (*Orestias ispi*), evaluation of this resource is executed by IMARPE, who uses a portable echo sounder EY60. For its evaluation, it is also necessary to know resource behavior, before which a typology of ispi schools was made. For this, we use acoustic data from six cruises developed between 2015 and 2021. Scrutiny was manual and was carried out at the frequency of 120 kHz using Echoview. A Pearson correlation was performed to exclude variables with values greater than 0.75 and eight remained. For characterization, we applied Gaussian mixed models using R. Results showed grouping in 4 clusters: i) Energetic: characterized by having highest NASC (μ = 860 m^2/mn^2 and σ = 1889 m^2/mn^2) and most superficial (μ = 44m); ii) Bigger: have greater height and volume (μ = 2.2 m and μ = 46 m^3 respectively); iii) Smaller: showing minor morphometric characteristics: height (u = 1.1 σ = 0.2), length (μ = 8 m and σ = 4 m) and volume (μ = 4 m^3 and σ = 3 m^3); iv) Weaker: acoustically they reflected lower NASC (μ = 47 m^2/mn^2 and σ = 31 m^2/mn^2) and were located deeper (μ = 67 m). Results will help to reduce bias in detection with automation.

Keywords: Machine Learning, hydroacoustic, typology, cluster

Towards a cloud optimized data lake for archived water column sonar data

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Due to their value to the ocean science and fisheries management communities, NOAA National Centers for Environmental Information (NCEI), with NOAA Fisheries and University of Colorado Cooperative Institute for Research in Environmental Sciences, established a national archive for water column sonar data. There are currently 210 TB of data freely and publicly available, and that volume is growing rapidly as sonar technology advances. The spatially and temporally diverse archive is accessible through its dedicated data portal and Amazon Web Services. Throughout 2023, we will develop a cloud-optimized data lake of echosounder files representing a ~100 TB subset of the archive holdings. The echosounder files will be translated from their complex, binary and proprietary file format into Zarr files following the Earth Science Information Partners analysis-ready cloud-optimized standards. The resulting data lake will serve as the foundation for building analytical capabilities that can cost-effectively tap into the archive's sonar holdings, especially when coupled with compute power. The Zarr stores will subsequently feed into *EchoFish*, the archive's AWS-hosted interactive data visualization platform to facilitate subsetting and prevent the data lake from becoming a data swamp. The progress and potential applications of this NOAA Center for Artificial Intelligence funded project will be presented.
Keywords: echosounder, cloud, data lake, accessibility, visualization, Zarr

Advancements in acoustic devices, platforms, and combined technologies

Echo Sounding atop the Wave of Oceanography's Robot Revolution

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A proliferation of uncrewed surface and underwater platforms are providing new ways to obtain acoustic data in the ocean, offering increased spatial and temporal coverage and access to unexplored areas. There are challenges to effectively exploiting robotic platforms for fisheries acoustics including difficulties in integrating relatively large, high power draw scientific echosounders into these platforms and the need to provide alternative evidence for target identification in the absence of trawling vessels. Recent experiments that integrated a constellation of robotic platforms and a cabled observatory to describe the abundance, distribution, and behavior of pelagic animals illustrate both the opportunities and challenges. Echosounders were employed from a variety of uncrewed platforms, letting us examine the

tradeoffs of active acoustic sensing from each platform. Echosounder sampling was complemented by targeted environmental DNA sampling and quantitative video transects from autonomous underwater vehicles to provide information on target taxa and size classes. Together, these data revealed new details on the daily vertical reorganization of life in the pelagic. Creatively exploiting the strengths of these new platforms rather than attempting to (poorly) replicate ship-based sampling is key to leveraging the robot revolution for understanding ocean ecosystems.

Keywords: Uncrewed platform, fish, zooplankton, eDNA, diel vertical migration

SONAR-netCDF4 convention and open source software for reproducible and versatile sonar data processing

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SONAR-netCDF4 convention has been recently adopted as the standard data format for seafloor and water column sonar softwares developed at Ifremer. The adoption of a common, open data format triggered collaboration between scientists involved in raw data quality inspection at sea, survey report production, data processing and data visualisation in 2D and 3D geographic coordinate systems, as well as in data analysis using advanced machine learning methods applied to large datasets. Automation based on Python scripts ensures reproducible data processing and easy prototyping of new methods within standard interfaces. Case studies of data visualisation and processing for various sensors and platforms obtained with different Ifremer software are presented.

Keywords: Software, open source, open data, automation

Correction of athwart distortion induced by beam overlap in multibeam sonars

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A method is proposed to estimate and correct athwart-beam distortion of multibeam sonars to advance sonar-based abundance estimation. We illustrate its application using data from an SN90 multibeam sonar aboard a tropical tuna purse seiner, targeting mixed fish aggregations around drifting Fish Aggregating Devices (dFADs) in the Atlantic Ocean. To calculate the distortion in the horizontal swath, athwart-beam measurements were compared with the more accurate simultaneous along-beam measurements. For the vertical swath correction, we used as reference a vertically oriented single, split beam echosounder simultaneously monitoring the same aggregations. Along-to-athwart ratios of ~0.6 and ~0.3 were estimated for the horizontal

and vertical swaths, respectively, at ranges involved during purse seine operations in this fleet (from ~225 m to ~325 m). Additionally, equations were developed to analytically describe the athwart distortion due to overlap between contiguous beams. Once corrected for distortion, typical school morphology measures were provided for tuna aggregations around dFADs.
Keywords: Multibeam sonar, overlap distortion, tropical tuna, dFAD, purse seiner, fisheries acoustics

Plankton dynamics observed using fisheries acoustics from an autonomous vehicle

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Zooplankton have a key role in the marine ecosystem, being the intermediate trophic level between fish and phytoplankton and an important component of carbon and nutrient. Zooplankton is often characterised by a patchy aggregative behaviour which can be observed at different spatial scales (from centimeters to kilometers) in both vertical and horizontal dimensions. This spatial heterogeneity has important implications on many processes that occur in the pelagic ecosystems. Investigating the spatial heterogeneity of zooplankton at different spatial and temporal scales and their drivers is essential to understand the dynamics of the zooplankton communities and their impact on the food webs, biogeochemical cycles and the overall status of the ecosystem.
In this work we tested the use of a waveglider, an Autonomous Surface Vehicle (ASV) propelled by the wave energy, equipped with a scientific echosounder to investigate the spatial variability of zooplankton at different temporal and spatial scales in a highly dynamic area in the northern North Sea. Two missions were carried out in May and August 2018 where the waveglider continuously collected acoustic data along a transect for about 3 weeks on each deployment. The potential environmental and physical drivers of the zooplankton spatial patterns were also investigated and discussed.
Keywords: Fisheries acoustics, plankton, glider, autonomous vehicles, DVM

Use of uncrewed surface vehicles in tandem with NOAA vessels to increase survey efficiency

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We present initial results from an operational demonstration of a diesel-powered DriX uncrewed surface vehicle (USV) working in tandem with NOAA ships as a 'force multiplier' to collect sonar measurements during bathymetric and acoustic-trawl surveys. The overall concept is that the ship deploys the USV to conduct a subset of survey transects ordinarily conducted by the ship (acoustic-trawl surveys), or a crewed survey launch (bathymetric surveys). The ship recovers, refuels and redeploys the USV as needed, allowing for extended operation in remote areas.
The key benefit for acoustic-trawl surveys is that motorized USVs capable of keeping pace with a survey ship (e.g. by occupying adjacent survey lines) allows for collection of biological information. The ship will be able to trawl at locations of interest detected by either the USV or the ship at short time lags (hours) from the acoustic measurements. The combined USV/ship survey data are informed by biological data largely equivalent to that from a ship-only survey (i.e. same methodology and data outputs), and thus can be used directly in fisheries stock assessments. Tandem USV/ship surveys have the potential to substantially reduce ship time requirements for sonar surveys.
Keywords: Uncrewed surface vehicle (USV), acoustic-trawl survey,

Derivation of lengths and depths of anchovies and observations of schooling behavior from Bio-acoustic Attenuation Spectroscopy (BAS) measurements

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The Bioacoustic Attenuation Spectroscopy (BAS) method permits measurement of number density and average length and depth of fish at all depths, including the near-surface and bottom dead zones. The BAS method exploits the resonance frequency, f, of swim bladders to estimate length, and the depth dependence of the bio-attenuation coefficient to estimate depth. Schools resonate at a frequency, F, which is lower than f. BAS measurements were made with an acoustic source that generated short duration signals between 300 Hz and 5 kHz with an environmentally friendly source level of 170 dB. Signals were received on a 16 element vertical array, 3 km from the source for nearly one day. Synoptic trawls revealed that 6 and 11 cm anchovies were the dominant species/lengths at this site. Lengths of anchovies, which were derived from BAS measurements, were consistent with lengths derived from trawls. Depths, which were derived from BAS measurements, were consistent with concurrent echo sounder data. Schools were evident near the surface throughout the night. The number of schools peaked just past midnight, at about 0100. During the day near-surface schools were evident only near noon. The peak at noon is consistent with historical data. Research supported by the Office of Naval Research Acoustics Division.
Keywords: Bioacoustic Attenuation Spectroscopy, anchovies, swimbladder, resonance

Uncrewed Surface Vehicle (USV) for acoustic mapping of common dolphin and their small pelagic preys

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Common dolphin bycatches have dramatically increased in Bay of Biscay (BoB) over the last decade, especially in winter. This might be caused by offshore dolphin sub-populations displacement towards the heavily fished continental shelf, in response to the recovery of small pelagic preys. An integrated acoustic survey was conducted in winter 2023 in the main dolphin bycatch area, to test if dolphin and small pelagic fish (SPF) co-occured at this time of year. To minimise the impact of inclement weather, the survey was performed using the Exail USV Drix, equipped with a Simrad EK80 echosounder to map fish schools, and with 2 hydrophones to detect dolphins. The 8m long USV could be rapidly deployed to take advantage of good weather windows. Its diesel engine, good seakeeping capacities and drop keel allowed to collect good quality data at sufficient speed to avoid counting several times the same moving schools. Schools were extracted from daytime EK80 narrowband data to make SPF distribution maps. Dolphin density maps were produced by combining acoustic detections from the Drix with airborne sightings data collected synoptically in the same area. Common dolphins and SPF maps were compared to assess the species co-occurence and identify potential trophic interactions.
Keywords: Uncrewed Surface Vehicle, cetaceans, small pelagic fish, bycatch, trophic interaction, integrated acoustic survey

Temporal patterns in South Georgia zooplankton: insights from a moored echosounder

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Antarctic krill (*Euphausia superba*) are a key zooplankton species in the Southern Ocean ecosystem, supporting large populations of marine mammals and seabirds, and contributing to the sequestration of carbon to the ocean interior. Krill are also the focus of a commercial winter fishery at South Georgia. These stocks are routinely monitored using ship-based acoustic surveys, typically restricted to the summer months as a result of the remoteness and challenging sampling conditions of this region. This leaves key knowledge gaps regarding inter- and intra-annual patterns in krill distribution and abundance. Here we detail the deployment and results from 4 years of moored echosounder 120 kHz acoustic backscatter data from South Georgia. These data indicate considerable seasonal and interannual variability in krill swarm presence, size and shape. We present these results in the context of challenges and opportunities for the increased use of moored instruments to monitor krill abundance and behaviour in the Southern Ocean.
Keywords: Acoustic backscatter, temporal patterns and cycles, zooplankton, Antarctic krill.

Pelagic organisms avoid white, blue, green, and red artificial light from scientific instruments

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In situ observations of pelagic fish and zooplankton with optical instruments usually rely on external light sources. However, artificial light may attract or repulse marine organisms, which results in biased measurements. Using hull-mounted echosounders above an acoustic probe equipped with light sources of different colours (white, blue, green, red, and near infrared), we demonstrate that pelagic organisms in Arctic and temperate regions strongly avoid artificial light, including visible red light, from instruments lowered in the water column. The density of organisms decreased by up to 99% when exposed to artificial light and the distance of avoidance reached >50 m from the light source. However, the distance of avoidance decreased with near infrared light (720 nm) and when the irradiance level was reduced. We conclude that observations from optical and acoustic instruments using light sources with broad spectral composition in the 400–700 nm wavelengths do not capture the real state of the ecosystem. When possible, we suggest using far red lights with low irradiance levels to reduce the impact from artificial light during marine surveys.
Keywords: Artificial light, avoidance, fish, zooplankton

Industry based autonomous acoustic systems in near real time monitoring of marine ecosystems

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Advances in technologies (sensor, processing, communication) have spurred new development of autonomous acoustic systems. Due to the enhanced sampling coverage in time and space compared to conventional methods such systems may reduce knowledge gaps and monitoring uncertainties in ecosystem observations. Routine data collection, processing, and transmission of information to users in near-real time provide both commercial and research benefits.
We showcase three industry-initiated and funded examples that demonstrate the potential impact of near-real time data acquisition from these sensors on ecosystem services.
We show how acoustic sampling of Antarctic krill using a sailing vehicle, provides information for real time decision making in commercial fishing as well as providing data for management of the Antarctic ecosystem. Similarly, we demonstrate how fishing vessels can be used as a platform to collect, process and transmit information to support sustainability of the European pelagic fishing industry. The third example describes the development of a stationary sonar system with processing technology supporting real time sensitive leak detection during oil and gas production. All systems are based on novel approaches to data processing thus providing efficient and useful tools for users in a simple, robust, and timely manner.
Keywords: Autonomous acoustic systems, platform technology, processing acoustic data, condensing acoustic data, transfer of information

IoT Acoustic Monitoring of Tonle Sap River Fish Migration and Mortality for Cambodian Fisheries Management

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The Tonle Sap River fishery supplies >80% of the animal protein and micronutrients to over 60 million people but does not have real time monitoring of its commercial Dai platform (fixed bagnet) fishery. An autonomous monitoring system was designed to characterize fish migration and fishing mortality by integrating a Simrad WBT mini echosounder (200 kHz), solar power, and an internet-of-things, communications module in autonomous monitoring stations deployed at upstream and downstream locations. Echosounders sample at 1 Hz for 15 minutes every hour. The solar panel supplies DC power to the echosounder, communications module, and battery for power during dark hours. The communications module is a built cellular endpoint using a Raspberry Pi and modem that accesses the local wireless network to transmit data files to an AWS server. Acoustic data files are accessed by the Pi from a USB drive shared with the echosounder on a latchable hub. Data are pulled from the cloud for processing and analysis. R scripts organize data, create Echoview files, and create standard graphic products for data characterization. This expandable system provides a flexible management tool that can be deployed at any location with communication capability.
Keywords: annual migration, Cambodia, Dai platform, fishing mortality, flux, remote monitoring

Estimating splendid alfonsino (*Beryx splendens*) abundance using a low-frequency broadband quantitative echo sounder

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The splendid alfonsino (Beryx splendens) is found near seamounts and is an important fishery resource. It is difficult for fishermen to tow nets in complex terrain such as seamounts, and the fishing is mainly done with vertical long lines. The objectives of this study were to improve survey methods for fish that live around seamounts, such as the splendid alfonsino, and to confirm trends in splendid alfonsino abundance.
A narrowband quantitative echo sounder (KFC-6000, sonic 38 kHz, 120 kHz) and a low-frequency broadband quantitative echo sounder (FCV-1NX, Furuno,23-53 kHz FM signal) were used during grid surveys and were synchronized to avoid interference between them. Fish species and size were confirmed by sampling using an approximately 60-m vertical longline equipped with multiple pingers (AQPX-1030, Aquasound) which can monitor depth at each 1 seconds in real time.
The splendid alfonsino has a habit of floating in middle waters at night, and the change in abundance over the past 3 years was small. There was little differences between narrowband and broadband results. Depending on the currents on a given day, sometimes there were no schools, suggesting that the behaviour of fish in the seamount area is dependent on the feeding environment.
Keywords: Broadband acoustics

Towards a multi-platform armada strategy for ecosystem based marine surveys

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Traditional fisheries independent surveys are developed around research vessels working singly or with multiple vessels operating in a similar fashion to cover the survey area. There is an ongoing revolution in Uncrewed Surface Vehicles and Autonomous Underwater Vehicles equipped with sensors. Ideally the implementation of uncrewed vehicles can significantly reduce the costs and environmental footprint, and potentially increase the survey quality. However, crewed operations are needed for biological sampling crucial for the survey estimates and new platforms interfere with the standardized procedures of long time series. Therefore, in the foreseeable future the surveys depend partly on research vessels working efficiently together with unmanned platforms. Here, we present the concept of armada strategy where we lay down principles for operations with optimal sharing of workload between research vessels and uncrewed vehicles. The concept includes survey trajectories relative to the research vessel and principles for biological sampling. We show that using this approach surveys can be carried out faster and considerably cheaper as the research vessel can concentrate on trawling. Furthermore, the approach enhances the potential for multi-objective surveys without compromising quality. We present roadmaps towards armada surveys for five existing surveys on crabs, pelagic fish, as well as multi-objective ecosystem surveys.

Keywords: Armada strategy, Uncrewed Surface Vehicles, Autonomous Underwater Vehicles, Acoustic trawl survey

Chasing noise and counting Orange Roughy

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Acoustic surveys of deep-water fish requiring the use of multiple frequencies are constrained by the range of the higher frequency. This is the case for surveys off the mid-east coast of New Zealand, where 38 kHz and 120 kHz are used to discriminate orange roughy from air-swimbladder species. Up to 2021, those were completed using an "Acoustic Optical System" deployed on a trawl to get the echosounders close enough to the fish. While this method provided good results, it also came with operational disadvantages, particularly related to towing speed. Also, real-time data required the use of a third trawl wire, not currently permitted in New Zealand trawl fisheries due to concerns about seabird mortality. For these reasons, we developed a wideband Dual Frequency Towed body (DuFT) using a Simrad WBT Tube to drive two transducers (38 kHz and 120 kHz), which enables real-time visualisation and full control of the data acquisition via the towing cable. The wideband capabilities and sensitivity of this sensor required a careful integration to get the best from the instrument. Here we describe the process we went through to build the DuFT, the noise issues we faced, how we mitigated these, and finally the at-sea survey application.
Keywords: Deepwater species, noise, instrument integration

Elevated fish densities adjacent to oil platforms surveyed with an uncrewed surface vehicle

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Much of the extensive network of North Sea oil and gas infrastructure is nearing the end of its operational life and will soon require decommissioning. However, uncertainty remains regarding the ecological impacts of the removal of these installations, as current legislation requires. Fish aggregate at offshore structures, but the causes and extent of this phenomenon around North Sea oil and gas infrastructure remain unclear. Here, an Uncrewed Surface Vehicle (USV) was used to collect fisheries acoustic data around North Sea oil platforms. Due to its small size, the USV was permitted entry to the 500m safety zones around platforms (approaching to within ~20m), where previous work surveyed only areas >500m from platforms. Densities of non-schooling fish were higher in areas with more platforms. This effect was evident over a range of several kilometres, but no additional density increase was found within safety zones. Fish schools

were also more frequently encountered in high platform-density areas. Inter-platform variability was evident in these trends, and more work is required to determine the causes of the observed associations. However, the combination of acoustics and USVs will help further our understanding of the likely effects of the removal of these structures on fish populations.
Keywords: Fisheries acoustics, oil and gas, uncrewed surface vehicle, species distribution modelling, decommissioning

Using seafloor backscatter for single beam echosounder calibration

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Calibrating acoustic echo level is an essential step for quantitative use of acoustic data collected by single beam echosounders. The usual way to achieve it is to use the sphere calibration protocol, that compares the target strength measurements obtained from a metallic reference sphere suspended below the echosounder, to the theoretical value. Over past years, calibration procedures have also been developed for hydrographic multibeam echosounders, using seafloor backscatter measurement over a known reference area previously mapped with calibrated echosounders. The potential of this approach has been investigated here for a quick check of single beam echosounders echo level, analysing series of acquisitions over a reference area over a few years.
Keywords: Sphere Calibration, Bottom Backscatter, EK80

Mills cross multi split-beam processing for assessment of target strengths

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Modern challenges on the increasing exploitation of aquatic ecosystems require efficient, reliable and non-invasive technologies to acquire biomass information on large scales. For the past 40 years, hydroacoustic has been an essential tool for the analysis of fish population and their relationships with the environment. Split-beam echo-sounders are the usual tools to record data in oceans, estuaries and lakes and are nowadays reliable and accurate. In order to maximize the coverage volume and to increase target detections, and therefore data quality, the use of multibeam echo-sounders are a real asset. We propose here an innovative method for the calibration of a multibeam sonar (SEAPIX) to include the analytical capability of a split-beam echo-sounder. This new approach will provide new information when using multibeam sonars, as the angular response of fish or indicators from multiple scattering physics. This method is theoretically described and accompanied by water tank experimentations. A case study in Lake Bourget, based on the comparison of Seapix and EK80 (SIMRAD) simultaneous records, proves the viability of this innovative multibeam processing to estimate *in situ* TS and Sv of fish population.
Keywords: Multibeam calibration, Target strength, split beam

Integrating Split-beam, Multibeam and Bio-telemetric Surveys to Estimate Fish Abundance: A New Approach to an Old Problem

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The numerical abundance of a fish population is a gold-standard variable for estimation by resource managers, as it is the ultimate focus of sustainable management. Despite the importance of this variable, existing methods for its estimation present challenges: traditional mark-recapture methods are time- and labour-intensive, and newly emerging hydroacoustic methods face issues with target identity and can be challenging to apply in a wide variety of habitats. Here, we describe new methods that aim to improve abundance estimation in the field by integrating traditional split-beam echo-counting and MBES survey data with telemetry data from freshwater fish bearing acoustic transponder tags that are counted and detected by a spatially and temporally concurrent multibeam acoustic survey. We report results from field trials of this approach on four Lake Trout (*Salvelinus namaycush*) populations that range in abundance from ~ 200 adults to ~ 4000 adults. Estimates obtained with these methods were consistent with estimates derived from both conventional Schnabel and Jolly-Seber mark-recapture studies. We show that the levels of precision achievable with this method in one year of field work are comparable with those derived from multi-year mark-recapture studies. We also discuss other ecological questions that could be addressed with this approach.
Keywords: Abundance Estimates, Transponder Fish Tags, Multibeam, Mark-Recapture Models, Freshwater Ecology

Performance of a glider-mounted multi-frequency echosounder for detecting dense mesozooplankton layers *in situ*

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Identifying the locations of ocean foraging grounds is a key element of top predator management, but finding and characterizing this habitat has proven challenging with traditional shipboard surveillance. The goal of this project was to test the performance of a glider-mounted multifrequency echosounder for measuring the biomass distribution of zooplanktonic prey, *Calanus finmarchicus*, that characterize the foraging grounds of large whales in the Bay of Fundy.

Biomass data from biological samples obtained using plankton net tows was compared to acoustic data from the echosounder collected concurrently over a nine-day period in the Bay of Fundy. The correlation between expected and observed backscatter was found to depend primarily on the frequency band and not other factors such as community composition or site. *C. finmarchicus* biomass was best predicted by observed backscatter in the 200 to 455 kHz frequency band, though there was considerable uncertainty in the relationship. The linear model developed in this project may be built upon to estimate *C. finmarchicus* biomass from acoustic backscatter in other areas of the North Atlantic without the need for validation with biological samples.

Keywords: Gliders, Echosounders, North Atlantic right whale, Acoustic Monitoring, Critical Habitat, Calanus finmarchicus,

Direct measurements of the migration speed of spawning herring

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The Norwegian Spring Spawning herring stock migrates in January-February each year from the feeding area in the Norwegian Sea to the spawning grounds on the Norwegian coast. The stock is surveyed during the migration with three vessels equipped with multifrequency echo sounders in a standard zig-zag survey design, from the south and northwards against the fish migration. To assess the effect of fish migration on the survey results the herring migration speed was estimating using an acoustic doppler current profiler. Herring backscatter were isolated and the doppler current estimates inside the fish schools were used as a measure of the migration velocity as well as the movement of the surrounding water masses. The mean migration speed for each of the survey strata was estimated, and we weighed the migration speed with the acoustic density. Finally we evaluated the potential impact on the observed migration error on the survey estimate, and we discuss the potential for using this technology as an approach to correct for migration in acoustic surveys.

Keywords: herring, survey errors, Doppler, ADCP, Migration speed

Biomass estimates of spawning Atlantic Bluefin tuna schools using omnidirectional fisheries sonars

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Omnidirectional fisheries sonar was used to estimate Atlantic Bluefin tuna school biomass during the 2022 fishing season in the Mediterranean Sea. Good calibration results were obtained from the first calibration of a Furuno FSV-25 sonar using netCDF files. Sonar data from schools targeted during normal purse seine fishing operations were used to compute school volume and

mean volume backscattering strength (S_v). A side looking Furuno FCV 38 kHz split beam echo sounder provided data from individual tuna and *in situ* lateral target strength was estimated. Sonar and echo sounder data from target schools from pre-catch stages were combined to compute the biomass and compared with the purse seine catch. In addition, biomass estimates were also calculated using modelled lateral TS estimates. The correlation between sonar and catch estimates is presented, and the use of in situ and modelled lateral TS for biomass estimates is discussed. Results imply that the proposed methodology for single school abundance estimation could help the skipper reduce uncertainty when estimating the size of targeted schools and open new opportunities for the development of fishery independent abundance indicators.
Keywords: Sonar, Bluefin tuna, biomass, schools, lateral target strength

Recording acoustic data from the surface to 4500 m depth with an AZFP attached to the rosette

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There is a growing interest in the study of mesopelagic and bathypelagic micronektonic species due to ecological reasons, their potential commercial explotation and their implication in the active carbon flux. Vessel-borne echosounders have been widely employed for their study but the limitation in range, particularly for the higher frequencies, has raised the use of alternative platforms such as gliders or net-attached echosounders. Previous studies have gathered close-range acoustic data up to 800-1000 depth but, to our knowledge, there is no record of such data at the bathypelagic zone. This presentation will summarize several projects where a deep version (6000 m) of the Acoustic Zooplankton Fish Profiler (AZFP, ASL Environment) equipped with 38, 125, 200 and 455 kHz transducers was attached to the rosette. Comparisons with the vessel-borne EK60 echosounder as well as pros and cons of the equipment and platform settings will be discussed.
Keywords: bathypelagic zone, AZFP, deep scattering layers, micronekton, zooplankton

Long range acoustic detection of gas bubbles in a shallow water coastal environment

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Injection of liquid CO_2 into subsea reservoirs is a method for mitigating greenhouse gas emissions. Monitoring is needed to ensure no leakage occurs and to assure the public. Single beam echosounders are ideal for this task as they can detect gas bubbles from a distance and at low flow rates. To monitor a wide area in shallow water we developed the Echosounder Detection of Gas Event (EDGE) system, a seafloor lander with a 70 kHz transceiver and 7° transducer mounted on a rotating turret. To establish gas detection capability, experiments were carried out using a separate test frame deployed in 10 and 20 m of water. The transducer was pointed at gas

release systems concurrently deployed at ranges of 90 m, 250 m and 370 m. Tests showed that CO_2 releases of 2 l/min at a range of 370m could be detected in 10m water depth despite interference from the sea-surface and seafloor. At shorter ranges where there is no boundary interference, quantitative measures of gas-seep backscatter are possible but are otherwise limited to detection. In this context we discuss the trade-off between optimizing for detection over the widest area versus configuring to limit boundary interference to allow quantitative measurements.
Keywords: Single beam echosounder, gas bubble detection, carbon capture and storage

Development of A Large-Aperture 160-Element Coherent Hydrophone Array System for Instantaneous Wide Area Ocean Acoustic Sensing

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A large aperture coherent hydrophone array system comprising of 160 elements has been developed for real-time instantaneous wide-area ocean acoustic remote sensing and monitoring. The overall acoustic aperture length is 192 m with array elements nested into four sub-apertures each with 64 hydrophones and spacing corresponding to half-wavelength at design frequencies of 250 Hz, 500 Hz, 1000 Hz and 2000 Hz. Hydrophones with integrated broadband pre-amplifiers designed with a linear frequency response from 10 Hz to 50 kHz send differential pair amplified and filtered analog signals to multiple 24-bit, 32-channel Analog to Digital Converters (ADC) with sampling rate that is programmable up to 100 kHz per channel. Array internals are field replaceable pressure tolerant components including hydrophones, pre-amplifiers, power modules, telemetry and ADC. Forward and aft modules are equipped with non-acoustic sensor elements to provide depth, heading, pitch, roll and temperature measurements. The data acquisition system is designed for continuous data-flow to enable real-time processing with fiber-optic tow cable and Gigabit Ethernet components. Array design, fabrication and assembly was performed on-site at Northeastern University in Boston, Massachusetts. Examples of passive acoustic data from array deployment during a sea trial in the US Northeast coast are presented illustrating array capabilities.
Keywords: Towed Array; Passive Sensing; Instrumentation

Passive sensing instrumentation, the past, present and future of technology

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Passive sensing instrumentation has relied on tried and true technology since the cold war and the technologies brought forth years ago are still ubiquitous in ocean acoustics today because of Size, Weight, Power and Cost (SWaP-C). Here, we highlight the current state of the art for passive ocean sensing technologies and analyze the areas of Technology Readiness Level (TRL) focusing on areas that are well developed but lack reliable integration or access to high TRL systems. Piezoelectrics have been the standard for passive sensing but lack the supporting high TRL and low SWaP-C Commercial Off The Shelf (COTS) for analog to digital conversion, communications, modular sensor packages, integrated non-acoustic sensors, open-source code and calibration of sensors. Further, sensing technology using fibre optic hydrophones and microelectromechanical system (MEMS) see use in industry applications but seldom in general oceanographic research especially as a large aperture design and are often limited to a single element. The ocean acoustics community would greatly benefit from open access to design literature and the manufacturing process to create high TRL and low SWaP-C designs to further the use of these sensors as array systems and here we survey areas in need of development.
Keywords: Towed Array; Passive Sensing; Instrumentation

Monitoring snapper aggregations using recreational fish finders and aerial drones

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Pink snapper (Chrysophrys auratus) is an important commercial and recreational fish species in Australia and New Zealand. In Western Australia, spawning aggregations gather at predictable times at several well-known locations, including Cockburn Sound (CS), located 20 km south of the Perth-Fremantle area. The proposed construction and future operation of Westport in CS could impact on these spawning aggregations. Therefore, a comprehensive understanding of how pink snapper are distributed in both space and time is a primary requirement of understanding how Westport activities may impact the spawning aggregations. In this study we used low-cost recreational fish finders (with sidescan and downscan functionality) and aerial drones with cameras deployed from small vessels to monitor snapper aggregations during the key spawning period from September to November. Aggregations at the surface were readily detected by the drone imagery but were missed by the fish finders. Aggregations several metres below the surface could be detected by the fish finders but not by the drones. We observed an increase in snapper abundance through time but identified the need to refine our survey design. This integrated underwater acoustic-aerial imagery approach can provide the long-term monitoring that is needed to study the impact of the Westport development on snapper aggregations. We also discuss some of the challenges of surveying in a busy commercial and recreational area and make suggestions for improving survey design.
Keywords: Recreational finders, Aerial drones, small vessels, snapper spawning aggregations, Cockburn Sound, Westport

Development of an unmanned research vessel for economical commercial fishing and multipurpose research

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Vessel-based surveys are important in assessing and managing fish stocks, as well as conducting research in marine areas, but can be time-consuming, expensive, and hazardous for crew members. In response, Estonian Marine Institute is developing and testing an unmanned, self-navigating research vessel able to travel long distances by a pre-planned trajectory or directions received solely by a remote network connection. The vessel can be used for scientific research as a cost-effective solution for tracking and estimating fish schools or other marine parameters and in principle also to direct commercial fishery. The result of the project will substantially decrease the economic and environmental cost of commercial fishery and research at sea.
Keywords: Unmanned, autonomous, research vessel, economical, commercial fishing, innovation

Target strength measurements of deep scattering mesopelagic layers

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Deep scattering mesopelagic layers (DSML) are composed of various organisms and an accurate estimation of the mesopelagic fish biomass is limited when using only hull-mounted narrowband echo sounders. Using broadband acoustics measurements close to DSML provides a high resolution of the organisms and the signal-to-noise ratio is less relevant for higher frequencies than hull-mounted acoustics. A submersible scientific echosounder (WBT-TUBE) was developed for the Marine and Freshwater Research Institute within the European MEESO project framework. With the aim to estimate the biomass and distribution of biological acoustic backscatter in the mesopelagic zone in Icelandic and adjacent waters. Sampling for this project was collected in July 2020 in the Irminger Sea and adjacent waters south of Iceland. WBT-TUBE was deployed near two DSML (300 – 500 m) to obtain more accurate single target broadband acoustic measurements of these layers. Narrowband and broadband data with the ship acoustics at the same stations and ground-truth trawl samples using a midwater pelagic trawl provided information of the species composition of these layers. This presentation will show acoustic measurements from the hull-mounted and submersible echosounder.
Keywords: Submersible echosounder, mesopelagic layers, DSML

Shelf-based mooring reveals seasonally variable benthic behaviour of Antarctic krill

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Antarctic krill are key to Southern Ocean ecosystems and represent a valuable fishery. While most krill research has focussed on surface waters (0 – 250m), krill have also been observed near the seafloor at depths between 400 – 4,000m. Perturbations to krill populations may influence food webs and biogeochemical cycles, therefore sustainable management of the krill fishery depends on accurate biomass estimates. Estimates are typically achieved through ship-based acoustic surveys, which may struggle to obtain reliable acoustic data from depths > 250m. To facilitate observations of krill at the seafloor, a mooring was deployed in Prydz Bay, East Antarctica (at 387m depth), equipped with an upward looking echosounder, current velocity profiler and camera. Greatest internal densities were observed from swarms near the surface, however the echosounder also revealed 55% of observed krill swarms occurred below 250 m depth. Krill diel vertical migration varied with season indicating this behaviour may be influenced by environmental drivers such as sea ice cover, sunlight, and food availability. Combined with ship-based surveys, these moorings will become an important tool in improving the accuracy of krill biomass estimates and strengthening our understanding of krill-seafloor interactions and their influence on the broader Antarctic ecosystem.
Keywords: KOMBI, *Euphausia superba*, biomass density, Diel Vertical Migration, East Antarctica

Pairing environmental DNA with acoustic monitoring of anadromous fish in the Penobscot River, Maine

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Improvement of fish passage has led to increased numbers of migratory fish in the Penobscot River Estuary, Maine. Current efforts to monitor the recovery of this system include split-beam hydroacoustic surveys (SIMRAD EK60 38 + 120 kHz) and fish trap counts. These methods are limited in their ability to discriminate some species. The implementation of environmental DNA

(eDNA) sampling into ongoing survey efforts may provide additional detail for species abundance and distribution in a cost-effective and non-invasive manner. To investigate the efficacy of pairing acoustics and eDNA, samples were collected at points along a biweekly acoustic survey conducted from April to November 2021. The eDNA concentration of river herring was quantified using quantitative PCR, and the broader vertebrate community was characterized using 12S rRNA metabarcoding. These data were compared to acoustic estimations of biomass, fish density, and fish size to evaluate the ability for eDNA distribution to characterize fish assemblages. Preliminary results demonstrated that eDNA concentration for river herring varied consistent with acoustic biomass in spring but that in summer, fish biomass was likely mainly Atlantic Menhaden (*Brevoortia tyrannus*) rather than River Herring (*Alosa spp.*) based on the proportion of menhaden eDNA in our samples. These results indicate that together, eDNA and acoustic survey methods can increase the utility of a monitoring program for this dynamic system.
Keywords: eDNA, ecosystem, restoration, monitoring, diadromous

Techniques for the Characterization of Aquatic Ecosystem ----- How Life Works in a Wetland Pond

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An Eulerian approach based on a single acoustic apparatus for the quantification of fish individuals (position and morphology) coupled with characterization of environmental features (relief and substrate) to fulfill the requirement of Ecosystem-Based Management through mechanistic evaluations was developed. The proposed procedure incorporated three major technological/methodological components:

1. Image Acquisition: A synoptic (spatial) and time-lapse (temporal) image acquisition system with a mechanically scanned imaging sonar.
2. Information Quantification (From image to information): A cumulative inversion process for bottom features mapping and mobile objects (fish individuals) quantification.
3. Knowledge Characterization (From information to EBM knowledge): Modeling techniques for the quantification of ecosystem characteristics. i.e., size/shape spectrum analysis, spatial statistics and phenomenological evaluations.

The small wetland pond under investigation spans limited and isolated spatial area (i.e., 55mx55x2), enabling measurement of location and morphology of fish individuals without the confounding effects caused by immigration/emigration processes. Ecosystem characteristics of the wetland pond indicated a single food chain based on phyto-plankton production and predator-prey interactions. Other prominent conclusions included: Diffusion-reversion-advection CCW circling movement pattern; Overlapping of predator (snakehead fish) and prey (tilapia dominated) interactions; Saturated environmental carrying capacity; Weakly exploited snakehead fish community and greater nutrient inputs system for tilapia.
Keywords: Eulerian approach, fish individuals, bottom features mapping, ecosystem structure, ecological processes, ecosystem functions.

Data Integration: Application to Ecosystem, Conservation, and Society

Characterizing Antarctic air-breathing predator dive patterns on a common prey base from stationary echosounders

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Diving patterns of air-breathing predators were monitored from three moored subsurface upward-looking echosounders. Complete and partial dive profiles were visible within acoustic records as echoes that started and/or returned to the surface. Dive metrics: maximum dive depths, angles and distances, durations, velocities, and wiggle count were measured and tabulated at each mooring. Dive shapes 'U', 'V' and 'W' were derived using the number of wiggles and the percentage of dive bottom time. Dive profiles were classified in four types: type 1 short in duration and distance, low velocities, small angles, shallow, long bottom time duration, and linked to 'U' and 'W' shapes; type 2 dives short in distance, low velocities, shallow depths, and were linked to 'V' dives; types 3 and 4 higher velocities, larger angles, longer total durations, and deeper than types 1 and 2. Dive types potentially correspond to travelling, exploring, and foraging predator behaviours. Significant predator-prey overlap occurred with dive profile counts correlating with krill aggregation thickness, density, and depth. This study demonstrates the utility of stationary active acoustics to identify and characterize predator dive profiles with a simultaneous characterization of the potential prey field.
Keywords: Antarctic krill, apex predator, dive patterns, random forest, echosounder

Acoustics for global pelagic fauna assessments: advances and challenges

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It has been a decade since we began to exploit transoceanic acoustic databases to study pelagic fauna at global scale. This made possible to portray the main acoustic seascapes around the world, to propose new biogeographies, or to make the first estimates of fish biomass on a global scale based on echosounder data. However, as we expand this global database, we begin to realise that acoustic seascapes do not equally represent pelagic fauna across oceanic systems. Here we present the latest global atlas of sound-scattering fauna based on the largest acoustic dataset available to date. This new biogeography allowed us to project water column backscatter levels in present and future oceans, indicating that global pelagic fauna will decrease by the end of the 21st century in response to climate change. While our results are in good agreement with current faunal provinces and ecosystem projections, some regions show backscatter levels inconsistent with net-based biomass estimates. This illustrates the urgent need to work together to provide backscatter-to-biomass correction factors at the scale of pelagic faunal provinces. We propose some ways to improve this and discuss how we, the fisheries acoustic community, can respond to these challenges in the years to come.

Keywords: acoustic seascapes, ecobiomes, mesopelagic, micronekton, biogeography, scattering layers, climate change

Investigation of pelagic fish communities in Offshore Wind Farms using bottom mounted echosounders with a combination of narrowband and broadband acoustics

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Following European targets for renewable energy, it is expected that the number of Offshore Wind Farms (OWF) in the southern North Sea will increase substantially in the coming years. Moreover, there is already numerous OWF operating along the Dutch and Belgian coast. The monitoring work to date has focused on alterations in the bentic community, while effects on the pelagic community remain relatively unexplored. For both construction and operational phases, there is a lack of insight into the impact on pelagic fish communities.
Using bottom-mounted echosounders and passive acoustic sensors deployed in the vicinity of OWFs, pelagic fish were monitored through extended periods of time at various locations. Fish biomass was derived using narrowband acoustics at 70 kHz. In addition, broadband acoustics (160-250 kHz) was used to determine pelagic target types based on acoustic fingerprint similarities. In parallel, passive acoustics is used to investigate the associated presence of predators such as harbor porpoises. This poster will provides an overview of the extent of the monitoring, methods used and the preliminary results.

Keywords: Autonomous echosounder, Offshore wind, coastal region

Fishing for answers: are there more tuna inside a blue-water marine reserve?

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To ensure representation of all marine biodiversity and to meet global protection targets, more blue-water marine protected areas (MPAs) are being declared. However, despite substantial evidence of the benefits of coastal MPAs, there is currently limited assessment of the benefits of blue-water MPAs. Here we use the US Pacific Remote Island Marine National Monument around Palmyra Atoll as a case study to test the efficacy of blue-water MPAs in terms of tuna biomass. As catch data are unavailable within MPAs, we use acoustic data from ~250 drifting Fish Aggregation Devices (dFADs) that opportunistically drifted across the region to test whether tuna biomass is higher within the MPA. Using a generalised additive mixed model with a suite of environmental covariates, we found similar tuna biomass inside and outside the MPA. This implied little effect of this blue-water MPA on the tuna population. The study revealed the utility and cost-effectiveness of using dFADs to estimate tuna biomass, in areas otherwise inaccessible by fishing vessels. Although there could be benefits to other fish species and biodiversity, more studies are needed on the potential efficacy of blue-water MPAs.
Keyword: Drifting Fish Aggregation Devices, Marine Protected Areas, tropical tunas, Echosounder buoys, Generalize Additive Mix Model

Linking Organisms from the Surface to the Seafloor Through Acoustic Analysis

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The impact and importance of pelagic organisms on transporting nutrients to the seafloor is widely recognized but understudied. Through the collection of backsctter of organisms present in the water column and quantifying their distribution characteristics through echometric analysis, active acoustics can be an integral tool to study this relationship. Echometrics praovides the density (Sv), centre of mass, inertia, proportion occupied, index of aggregation, and equivalent area of the active acoustic data. By combining these echometrics with remotely operated vehicle transects in the water column and on the seafloor, we are able to better infer the link between acoustics and individual organism behavior. This study will compare Simrad EK60/80 echosounder echometrics in conjunction with ROV transects collected in the Atlantic Ocean from

2018 – 2021 during 6 expeditions by NOAA Ocean Exploration onboard NOAA Ship *Okeanos Explorer*. By correlating the echometric values with the video annotations of organisms present, this research aims to achieve a better understanding of the link between organisms in the pelagic and on the benthos.
Keywords: acoustics, echometrics, ROV, video, annotation, seafloor, water column

Foresight, in hindsight: a retrospective analysis of a unique sardine-stock forecast

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Theory and models of climate-modulated fish production suggest it possible to predict population trajectories, yet there are few published forecasts, fewer of which advise specific actions to fisheries management, and perhaps none that are evaluated retrospectively for their prescience. Zwolinski and Demer (2012, PNAS 109: 4175-4180) observed that the onset of a cold regime in the Northeast Pacific was likely forcing a period of low sardine productivity, and that at least five indicators in the ecosystem and commercial fishery in the early 2000s were mimicking those from the mid-1900s when the sardine stock, then the nation's largest fishery, collapsed. The authors identified: a negative phase of the Pacific Decadal Oscillation index corresponding with a basin-scale concordance of sardine stock declines; a high commercial exploitation focused on the oldest, most fecund fish; a decline in the sardine biomass below a critical level; an alternation in the dominant forage-fish species; and changes in sardine seasonal migratory and schooling behaviors. They concluded that history was repeating, and thus provided unique foresight of an important ecological and socioeconomic juncture. Here, we present results from acoustic-trawl-method surveys, fisheries data, and reports during 2006-2022 to evaluate the accuracy of these predictions and synthesize a working hypothesis.
Keywords: California Current, environmental, recruitment, fish stock, surplus, collapse

Pelagic Sound Scattering Layer distribution and behavior across North Est Atlantic and Equatorial Pacific

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Aggregations of marine pelagic organisms in ocean water can be observed acoustically as Sound-Scattering Layers (SSLs). During the SO287 cruise, SSLs were recorded at 18 kHz along a

transect crossing the North-East Atlantic, Sargasso sea, Caribbean and Pacific. Hydrographic data were also collected using CTD probe. SSLs structure and distribution were described, and the relationship between SSLs and environmental factors were studied. SSLs were observed in all surveyed areas, but SSL structure and distribution patterns varied considerably. The thickest SSLs (~ 300 m) were observed in the Atlantic and Caribbean sea, while in the Pacific thinner and deeper SSLs (~ 800 m) with highest intensity (-59 dB) were encountered .The Sargasso sea, considered as an oligotrophic zone, had few SSLs of low thickness, depth and acoustic intensity. The epipelagic SSLs was present at 0 - 200 m depth, while the mesopelagic SSLs was located at 300 - 1000 m depth during day and at shallower depths during night. DVM was evident in all areas, with a maximum migration amplitude in the Pacific (~ 253m). Our results suggest that SSL vertical distribution are influenced by physical-chemical properties of water masses, such as temperature, oxygen, salinity and fluorescence.
Keywords: acoustics

Seamount effects on micronekton at a subtropical central Pacific seamount

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Seamounts are globally ubiquitous features with potential for increased biodiversity and biomass. Although their ecological and economical importance is well known, the mechanisms for supporting seamount-associated communities are not well understood. In this study, the effects of an intermediate seamount (Cross Seamount) on the micronekton communities, are investigated. Relative biomass and composition were calculated from multi-frequency acoustic data from surveys over 3 years. Mean micronekton biomass was significantly higher than in the ambient environment and its composition differed over the flanks and plateau of Cross Seamount. The effects of the seamount extended ~3.5 km away from the plateau, possibly further below 400 m depth at the flanks. Micronekton occupied the water column from the surface to the 400 m deep plateau with dense aggregations immediately over the bottom at night. During the day, these micronekton migrated both horizontally and downward, occupying depths of 500-700 m, preferably along the upstream flank of the seamount. Descending micronekton from near-surface waters appeared to be temporarily blocked by the topography before swimming below the plateau at the flanks. Mechanisms supporting the increase in micronekton biomass are uncertain, although hydrographic data support topographic trapping of zooplankton and the existence of transient or semi-permanent Taylor caps.
Keywords: acoustic scattering layers, seamounts, micronekton, topographic blockage, Taylor cap

Distribution of Deep-Scattering Layers and Vertical Migration along transects crossing the central and southeastern Atlantic

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Mesopelagic organisms tend to aggregate in dense layers between 300 and 1200m depth in the open ocean. These deep-scattering layers (DSL) are found throughout the world's oceans and can be monitored well using hydroacoustics. Here, we present an analysis of the spatial distribution of scattering layers in the central and southeastern Atlantic. We used split-beam echosounders with 18kHz and 38kHz to monitor biomass distribution along five transects between Cape Verde and the Benguela Upwelling System in 2019 and 2021. Results confirm the general presence of DSLs in all areas along the study region and in different seasons. Nevertheless, biomass and depth distribution of scattering layers varied. Mean DSL depth rose towards the equator and biomass increased towards the coast. While the 38kHz band showed a central DSL, the 18kHz band highlighted a more complex DSL composition, with secondary, deeper DSLs in some areas. Diel vertical migration behaviour was very consistent, albeit the difference between the two frequency bands suggested species-specific migratory patterns. Our analysis shows that in hypoxic areas dissolved oxygen is a main factor influencing DSL positioning, apart from light. Finally, we suggest a combination of scientific efforts using multibeam sonar to advance regional coverage.
Keywords: Deep-Scattering Layer, South Atlantic, Mesopelagic, Vertical Migration

Fish responses to regional and sub-mesoscale flow-topographic interactions over a tropical seamount

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Enhanced biodiversity is often observed around seamounts but the effect of climatic events, such as the Indian Ocean Dipole (IOD), on biological aggregations is not clearly understood. We investigated oceanographic drivers of pelagic fish distributions over Sandes seamount using multiple in situ variables measured in 2019 and 2022. A Simrad ES70 fisheries echosounder with a combined 38/200 kHz transducer was synchronised with a Nortek Signature 100 kHz Acoustic Doppler Current Profiler collecting information on pelagic biomass and currents whilst, oceanographic moorings provided information on water properties. Data were analysed using Generalised Linear Models with Generalised Estimating Equations to test oceanographic parameters against pelagic fish. During 2019 an anomalously strong positive IOD event was recorded, whilst 2022 saw a moderate negative event. Fish schools during the positive IOD event were located deeper in the water column and preferred turbulent south-westward currents. Throughout the moderate negative IOD, fish schools were located significantly shallower over the summit of Sandes. In both events the thermocline depth, which is controlled by the IOD, aligned

with the distribution of schooling fish. This multidisciplinary acoustic approach demonstrates the effects of climatic events on schooling fish which is key to understanding why seamount ecosystems are so biodiverse.
Keywords: acoustics, pelagic biomass, oceanography, fish, Chagos Archipelago, Indian Ocean

Geographic variability in the seasonality of euphausiid diel vertical migrations among three locations in coastal British Columbia, Canada

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Diel vertical migration (DVM) has been well-studied among zooplankton, and many exogenous and endogenous triggers and adaptive significances have been hypothesized. Second-order variability in DVM timing, the deviation of DVM times to respective dawn and dusk times throughout the year, is a less-studied phenomenon which can help identify the factors influencing migration timing decisions. Recent advancements in moored echosounder technology allow for examination of migratory layers over multiple years with fine temporal resolution. Here, we quantify seasonal trends in second-order variability of DVM timing of euphausiids at Brooks Peninsula, Clayoquot Canyon, and Saanich Inlet near Vancouver Island, British Columbia, Canada over multiple years using upward-facing moored echosounders. We used generalized additive mixed models to characterize this seasonality. DVM timing relative to civil twilight times showed strong seasonality at all locations, with euphausiids remaining near the surface longer than expected in spring and summer, and shorter than expected in winter. Euphausiids spent less time near the surface at Brooks Peninsula and Clayoquot Canyon than at Saanich Inlet throughout the year. Increased primary productivity in Saanich Inlet, which reduces light penetration and hides euphausiids from visual predators, likely drives this difference; however, interactions between conspecifics and predators may also influence DVM behaviors.
Keywords: Zooplankton, Euphausiids, Diel Vertical Migration, Timeseries, Moored Echosounders, Predator-prey interactions

FishLAT (Fisheries Location Assessment Technology): Approaching the Offshore Energy Transition from a Fisheries Perspective

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In the United States, marine fisheries and the offshore energy industry are spatially intertwined. Yet, the vast majority of decisions regarding the removal or installation of offshore energy infrastructure are made without analyzing how these decisions will impact fisheries stakeholders. FishLAT is being developed as a spatial planning tool to predict how the site-specific removal,

reefing, or installation of an offshore energy structure will impact fisheries. Informed by a suite of predictive models that include a comprehensive set of ecological metrics (i.e., fish abundance, biodiversity, and connectivity) and fisheries metrics (i.e., fishing activity), FishLAT provides the analytics necessary to explore offshore energy planning under data-rich scenarios. This talk will introduce FishLAT's prototype and outline the tools' purpose, models, and methods for application when considering the United States' offshore energy transition from oil and gas to wind. Ultimately, this talk will illuminate how data-focused tools like FishLAT can improve offshore energy planning by informing strategic pathways to comply with regulations, prioritizing fisheries and ecosystem conservation, and better aligning with ocean stakeholders.
Keywords: Fisheries, Offshore Energy, Offshore Wind, Offshore Oil & Gas

Fish density around decommissioned oil and gas platforms: evidence for "rigs to reefs"?

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Marine species benefit from complex hard substrates, such as reefs, which offer more ecological niches than a flat seabed. Man-made marine structures (MMS) have similar benefits (e.g. shipwrecks). Over 1300 MMS were installed for the oil and gas industry in the North Sea. Many of these are now being decommissioned, although substantial structures invariably remain on the seabed. We estimated the fish density in and around two decommissioned platforms in the North Sea using a multiple transect design. Fish were separated into two groups: schooling fish with swimbladders (herring and sprat); and individual fish as single targets (gadoids). Fish density was estimated using echo integration and echo counting respectively. General additive models, examining the relationship between fish density and distance to platform (including day/night effects and a depth effect for single targets), detected significant relationships. Individual fish density was highest over the structures and plateaued after 350 m. School density was also highest over the structures, but plateaued at shorter ranges (~100 m). Temporal variability was evident, although only individual fish density was significantly higher at night. The findings provide some support for a "rigs to reefs" policy, common in many jurisdictions, but not applied in the North Sea.
Keywords: Acoustics, man-made marine structures, fish

Biomass and geographical distribution of seven small pelagic fish species in relation to environmental condition in Mauritanian waters

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The focus for this study was to acquire knowledge to scrutinize raw acoustic backscatter, collected during scientific surveys, onboard R/V Dr Fridjof Nansen from June 27 to 9 July 2017, researching small pelagic fish resources within the Mauritanian EEZ. To calculate stock biomass index from survey data and relate species distribution to temperature conditions. Acoustic data were post-

processed using the post-processing software Large-Scale Survey System (LSSS) Version 2.0, for data processed after fixing the bottom and surface line, for the surface line we allocate backscatters fish from 10m, then excluding sailing between transects. The acoustic data was preprocessed. Species allocation based on the species proportion in catch, and biomass estimate calculated following FAO guideline.
The study results show that temperature influences species' geographical distribution. (Chub mackerel, Atlantic mackerel, and sardine prefer colder waters of the northern part of the EEZ, and round, flat sardinella and cunen horse mackerel prefer warm waters, of the central and southern part of the EEZ. Though anchovy and cunen horse mackerel could adapt themselves in both colder and warmer waters. The biggest biomass estimate was the anchovy followed by cunen horse mackerel and flat Sardinella, generally, these species were found in a shallower area
Keywords: acoustic, pelagic

Study of the ecology of Atlantic wolffish in the Bay of Fundy marine ecosystem, New Brunswick, Canada

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Ecology of the Atlantic wolffish was studied in the Bay of Fundy marine ecosystem. SCUBA surveys and acoustic telemetry were used to understand the behavioural ecology and stable isotope analysis was used to evaluate the feeding ecology of wolffish. Ninety-four scuba dives were conducted around Deer Island in the bay to locate wolffish dens, to observe behaviour of the fish and to deploy receivers for the acoustic telemetry survey. Invertebrates and wolffish tissue samples were collected to study the feeding ecology of the fish. Several methods were tested to capture wolffish and one wolffish was captured during the study. The captured wolffish was 81.5 cm in length and 5.56 kg in weight and was a running-ripe male. The fish was acoustically tagged, and carefully released near its den. A total of 25,713 acoustic detections were recorded for depth and temperature over 148 days. Detections revealed that the wolffish visited 48 depths ranging from 7.3 to 38.2 m. Depth profiles revealed the use of a feeding ground between 8-14 m from mid-July to late October and travelling to depths of 23-38.2 m in September (spawning ground). The $\delta^{13}C$ and $\delta^{15}N$ for the wolffish captured were estimated at -15.57 and 14.08 ppt respectively.
Keywords: acoustic, Bay of Fundy

The Mesopelagic and Beyond: High-Latitude Boundaries and Global Patterns in Vertical Connectivity of the Deep Ocean

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Vertical patterns of deep ocean connectivity play a critical role in the oceanic carbon cycle. However, many shipboard acoustic studies of high biomass communities are constrained to the upper mesopelagic zone. Here we present the results of two studies. In the first, we use opportunistic acoustic and biological data to identify patterns of high-latitude dispersal of the deep-scattering layer implicating temperature as a driver along both Arctic and Antarctic deep ocean boundaries. In the second, we use a global acoustic dataset, covering the full depth of the oceans, to map vertical distributions of larger metazoans from the mesopelagic to the hadal zones, documenting clear geographic patterns. Together these results show that vertical distribution of backscatter in the deep ocean follows clear latitudinal patterns, regardless of oceanic region, and that at high-latitudes worldwide, a surprisingly high proportion of backscatter is found below the mesopelagic zone. Our findings indicate a strong latitudinal dependence of carbon export to depth, likely driven by trophic coupling in the upper 1000 m of the ocean. *This talk will be given by J. Chawarski and is dedicated to the memory of Thor Klevjer and shares key findings of his research before his passing.*
Keywords: Mesopelagic; global; deep-ocean; carbon cycle; ecosystem

Sounding the twilight zone life and its changes

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Global ocean mesopelagic (200 m to 1000 m depth) micronekton (~2 – 20 cm animals) current and future contribution to carbon sequestration and as a potential food source is uncertain. To improve our knowledge of micronekton, data is needed to monitor the distribution and change in these animals over space and time. One method is to use already available acoustic technology on platforms of opportunity with appropriate quality control. Australia's IMOS Bioacoustics sub-Facility (https://imos.org.au/facilities/shipsofopportunity/bioacoustic), an open access acoustic data collection system at basin scales provides unique insights into the distribution and change in acoustic scattering layers to 1000 m.
Keywords: mesopelagic, acoustic, micronekton, carbon sequestration. …

Tuna ecosystems in the tropical Pacific. An interdisciplinary approach from physics to micronekton using sea experiments and ecosystem modelling

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A recent paper using deterministic modelling showed that major redistribution of Pacific tuna in the near future will disrupt the economies of many Pacific countries of the Western Pacific due to a greater proportion of fish occurring in the high seas of the Eastern Tropical Pacific. These changes reflect the contrasting responses of the future ecosystems between the western and the eastern tropical Pacific. At the same time statistical modelling projected a reduction of acoustic-based micronekton in the tropical central-eastern Pacific. These studies illustrate the uncertainties of the projected ecosystem futures. Sparse estimates of biomass, species and distribution of mid trophic level organisms are amongst the top contributing uncertainties especially in the tropical Pacific Ocean, one of the most under sampled region of the world. To fill these gaps, we present our programs across the tropical Pacific: MICROPAC-WARMALIS based on modelling and several large-scale field experiments sampling the hydrodynamics to the micronekton. Results from the 2021 and 2022 WARMALIS cruises in the western and central tropical Pacific are contrasted and compared to simulations from the state-of-the-art ecosystem modelling to draw challenges to be addressed in our future ecosystem studies and the need for broad collaboration to acquire observations across the Pacific.
Keywords: Climate change, Tropical Pacific, Tuna, hydrodynamics, mid-trophic level organisms, observations, modelling.

Acoustic estimation of haplochromine biomass in Lake Victoria: A novel approach to the estimation of pelagic biomass with precision

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Haplochromine cichlids are among the four primary species in Lake Victoria, which reflect in the acoustic signals of the lake's pelagic zone. Traditional approaches to acoustic data analysis have flaws in accuracy and scientific logic, with attendant shortcomings in the applied single-target detection methods and fractional partitioning of the water column for echo integration based on assumed species niches. A novel approach is hereby conceived, whereby species-specific echoes are sequentially allocated from echograms collected over the previous 20 years. Artificial intelligence based on random forest classifiers trained on known schooling behaviour and ecological niches has already been developed and used to estimate the *dagaa* biomass. Following this approach, we are developing classifiers to extract haplochromine cichlid echoes to address the lack of precision throughout the stocks. This, combined with the dB-differencing technique for *Caridina nilotica*, would account for all except Nile perch, which will be assigned to the leftover echoes with greater precision. Preliminary findings indicate a relatively stable and resilient stock of about 1 million metric tonnes. The improved estimates of fish abundance are expected to aid in the conservation and long-term use of this globally and multi-societally shared resource, which has changed dramatically over time.
Keywords: Pelagic fishes, Multispecies fishery, haplochromine cichlids, Nile perch, Caridina

Ecology and behavior of tuna and non-tuna species at drifting fish aggregating devices (DFADs) in the Indian Ocean using fishers' echo-sounder buoys

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Most of the drifting fish aggregating devices (DFADs) used by the industrial tropical tuna purse seine fishery are deployed with satellite linked echo-sounder buoys. Considering that around 100,000 objects may be deployed annually worldwide, these devices could provide invaluable and continuous information to researchers about the rough estimate of the biomass of tuna and non-tuna aggregations under the objects along its trajectory, almost in real time, in a regular and effective basis, representing a powerful tool for the study of pelagic ecosystems. This study aims to investigate the aggregation dynamics and spatio-temporal distribution of tunas and non-tunas associated with DFADs using acoustic data provided by fishers' echo-sounder buoys in the Indian Ocean. For this purpose, we create a standardized protocol to process fishers echo-sounder´s acoustic raw biomass estimates in order to use them for scientific purposes. Then, we investigate the aggregation process of DFADs, determining the first detection day of tuna and non-tuna species at DFAD and identifying the potential differences in the spatio-temporal dynamics of the aggregations. Finally, we analyze the habitat preferences and distribution of tuna and non-tuna species associated with DFADs and environmental conditions in the Indian Ocean, implementing Bayesian Hierarchical spatial models.
Keywords: Echo-sounder buoys, Fish Aggregating Devices, tuna, Indian Ocean

Spatial distribution of zooplankton acoustic biomass in the Gerlache Strait, Antarctica

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The Antarctic krill (*Euphausia superba*) is a species key because it is the base of the trophic plot of the Antarctic Ocean, considering its importance this study evaluated the bathymetric and geographical distribution of the zooplankton and fish biomass using acoustic techniques and probative analyses in the Gerlache Strait, Antarctica, within the framework of the IV Colombian Antarctic expedition “Almirante Tono” on board the ARC “July 20”, between January 14 and 28, 2018. The oceanographic data were taken with a CTD CastAway and the acoustic data with a Simrad EK 80 Scientific Echosounder with transducer of 38/200 kHz. The results obtained from the echograms showed the presence of krill swarms between 20 and 40 meters high and the depths about 25 meters, which were related to colder waters and located in the places with the greatest whale sighting, a predator-prey relationship was identified.
Keywords: Zooplankton, Gerlache Strait, Krill, Antarctica

Monitoring the state of Peruvian anchovy (*Engraulis ringes*) population by using data entirely collected by fishing vessels

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Since 2015 the National Fisheries Society (SNP) has been performing workshops to update the diagnostic on exploited resources to contribute to sustainable fishing. The main assessed species is the Peruvian anchovy (Engraulis ringens), through the use of information entirely collected bybundance, age-structured models, and to monitor changing ocean conditions. This research is made under cooperation of SNP with IMARPE, fishing companies and academic entitie the fishing fleet to complement the research carried out by the Peruvian Institute of Marine Research (IMARPE). There are two fishing seasons every year, all vessels contribute different kinds of data which is continuously ordered in databases: acoustics, , catches, fish length structure , oceanography, VMS and interactions with top predators. The data is used to update CPUE indexes, fish as in the frame of the Adaptive Precautionary Management (APM) which includes the dynamic closing of areas when juvenile fish are detected. APM has conducted to a well

reputed industrial fishery, keeping the biomass bordering 10 million tonnes and currently, we are searching for more efficient ways to collect and post-process acoustic data.
Keywords: Population, Abundance, Acoustics, Biomass, Fishing vessels, Management

Does variation in Pacific hake diet reflect changes in the prey community?

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Indices of lower trophic level productivity can provide important insights for ecosystem based fisheries management. However, relationships between prey abundance and recruitment of fish populations are not fully understood. Pacific hake (*Merluccius productus*), a commercially important groundfish on the west coast of the U.S. and Canada, consume euphausiids, or krill, as a key prey item. Using stomach contents of hake sampled from midwater trawls during the biennial Pacific Hake Ecosystem and Acoustic Trawl (PHEAT) Survey between 2007-2019 (n = 8 years; odd years inclusive, and 2012) in combination with a recently developed acoustic index of coast-wide krill abundance, we tested the hypothesis that hake diets reflect changes in the availability of krill. We found that krill dominated the diet of hake aged 1-7 across all years, whereas hake aged 8+ consumed a more piscivorous diet. However, krill consumption was greater when these prey were abundant and co-occurred with hake, particularly during 2011, 2012, 2013, and 2017. During 2015, when krill abundance was the lowest in the time series, hake diets were more diverse and contained fewer krill. These results indicate that variation in hake diet reflect variable krill abundance and availability, which may have a significant effect on hake growth and recruitment.
Keywords: Predator-prey dynamics, acoustic trawl survey, euphausiids, frequency differencing, stomach content analysis, California Current

Using autonomous surface vehicles for long-term environmental monitoring for the offshore industry

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Fisheries, offshore energy, tourism, and maritime transport are increasing worldwide, and integrated and sustainable ocean-observing systems are required to achieve effective ocean management. The recent advancements in miniaturization of fisheries echosounders have allowed these instruments to be mounted on small autonomous vehicles instead of large vessels. As such, hydroacoustic surveys, previously restricted to ships, can now be performed by autonomous vehicles. Here, we fitted a broadband echosounder on a Sailbuoy–an autonomous

surface vehicle–to monitor the pelagic ecosystem. The Sailbuoy is a sturdy, energy- and cost-efficient vehicle using wind for propulsion which can be deployed for several months at a time. Near real-time data streaming via the Blue Insight platform was used for survey decision-making. We developed an automated data processing pipeline for acoustic data which applied calibration values, cleaned, and detected patterns in the data. Relevant metrics from acoustic patterns were then extracted and fed into an unsupervised clustering algorithm used for classification. The applications for this technology are broad. We present results from two different environmental monitoring surveys done for the offshore industry. Surveys of the pelagic ecosystem by autonomous surface vehicles with efficient data processing pipelines offer new monitoring, combining high temporal and spatial coverage.

Keywords: Autonomous surface vehicle, ecosystem monitoring, broadband acoustic, offshore industry

Using acoustics from a USV to monitor behavioural effects of fish during an industrial seismic survey

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Industrial seismic surveys are generally performed offshore with large vessels towing hundreds of meters of cables with logistic difficulties for any other activity to take place nearby. The effect of seismic shooting on fish behaviour has been debated and researched for decades, but studies have focused on controlled experiments with caged fish and artificial replay of seismic sound. Due to logistic challenges and costs, only a handful of studies have tried to monitor the effect on behaviour in the wild.
In this study we deployed a USV close to a seismic operation, which minimized risks and additional vessel disturbance to the monitored environment. The USV was equipped with an EK80 echosounder with multiple transducers which was used to look at temporal changes in fish schooling and swimming behaviour with a seismic vessel approaching from ~15 km to ~50 m. School detection and fish tracking algorithms were applied. Preliminary results showed changes in the vertical distribution, shape, and density of fish schools.
These results, together with developments of onboard automated data processing for unmanned vessels, increased satellite connectivity in remote areas, and advanced online visualization platforms, provide major opportunities in the near future for real-time environmental monitoring for offshore industrial activities.

Keywords: Unmanned vessels, industrial operations, environmental impact, seismic survey, fish behaviour

Mesoscale eddies are not oases for mesopelagic organisms at global scale

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Numerous studies indicate that oceanic eddies aggregate marine life throughout the food web, from microbes to top predators. The resulting common belief that oceanic eddies can be considered oases in the oceanic desert, however, is seriously hampered by the limited number of eddies sampled in most of these studies. Here, we overcome this scientific limitation by characterizing the response of mid-trophic level organisms (MTLOs) to the largest number of eddies (956) ever sampled from a global acoustic database (EK60, 38kHz). While these eddies frequently affect the physics and biogeochemistry of the ocean, we show that they only rarely do have a detectable effect on MLTO (13% of the cases). For these few eddies, MLTO response predominantly occur in their core, resulting in a 50% increase (decrease) in the epipelagic (mesopelagic) layer for cyclonic eddies and a 100% decrease in the epipelagic layer for anti-cyclonic eddies. Our extensive database does not even allow us to unambiguously identify the combination of processes, that might explain why some eddies have a significant impact on MTLO. Regardless, our results indicate that when examining across all eddy types and sizes the evidence is equivocal that top predators aggregate frequently in eddies because of increased forage fauna. This unexpected result calls for further studies to unravel why the observed impact of eddies on primary production is not transmitted up the MTLO.
Keywords: Oceanic eddy, Acoustic, Mid Trophic Level Organisms, Mesoscale, Global scale, scattering layers

Relationships between mesopelagic assemblages and the surrounding ecosystem derived from long-term deployments of autonomous echosounders on stationary platforms off California

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Mesopelagic communities serve many roles in marine ecosystems. Their ubiquity, central position in the food chain, and extensive diel vertical migration make them essential to the processes of carbon cycling and sequestration, and the target of an emerging fishery. Despite their importance in mitigating the atmospheric carbon surplus affecting climate change, and their appeal to producers of fishmeal, detailed information about their species compositions, geographic distributions, environmental associations, and migratory behaviors remain largely unknown. This is in part due to mesopelagic biota being notoriously difficult to capture with nets or image with underwater cameras. Consequently, most efforts involve echosounders, either ship-based for short-period observations, or autonomous for longer-duration studies. Here, we present long-term observations of the mesopelagic assemblage using autonomous 70-kHz echosounders, along with measures of the associated biogeochemical environment, recorded quasi-continuously at multiple stationary locations off Point Conception, California from 2008-present. This biogeographic boundary is characterized by strong upwelling to the north and weaker upwelling to the south, and is variably influenced by the California Current, California Undercurrent, and offshore oligotrophic waters. We explore this unique and comprehensive dataset for the interplay of the environment with the epipelagic and mesopelagic backscatter, in terms of inter-annual, seasonal and daily variations.
Keywords: WBAT, mooring, benthic-lander, CCE, diel-vertical-migration, carbon-pump

Hydroacoustic surveys evidenced decline of biological backscattering layers during 2013–2018 anomalous low Chl-*a* concentration and warm temperatures at the east coast of the Gulf of California

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Eight hydroacoustic surveys (120 kHz split beam echosounder) were done during July 2007, August 2012, 2014, and June 2013, 2016–2019 to investigate backscattering in 10–90 m layer response (a proxy of pelagic biota, zooplankton and micronekton abundance) to a prolonged period (2013–2018) of anomalous warm sea surface temperature (SST) and anomalously low sea surface chlorophyll-*a* concentration (Chl-*a*) relative to 2000-2020 time series recorded along the central east coast of the Gulf of California. This region is the most economically important fishing area of the small pelagic fish and jumbo squid fishery in the Gulf of California. The acoustic backscatter intensity was maximum during July 2007, with the lowest records between 2016–2018, and slightly increasing in 2019. The most abrupt declines in acoustic backscatter intensity occurred in the 40–60 m depth layer of all the hydroacoustic surveys, suggesting that pelagic organisms were overall affected by prolonged anomalous high satellite SST and low sea surface Chl-*a* concentration. The decline of pelagic backscatters likely occurred during 2013–2014 after the tipping point in climate shifted in 2012 and recovery lasted for more than five consecutive years. Recovery of acoustic backscatter intensity comparable to conditions observed in July 2007 was slow indicating that the resilience of pelagic biota is highly dependent on the seasonal wind forced upwelling process that fertilize and cool the coastal area regulated by the strength and sustained northerly winds occurring during the spring (mostly March-April) along the east coast of the Gulf of California.
Keywords: Backscattering area; El Niño; Marine heat wave Gulf of California

Potential for siphonophores to influence global acoustic estimates of mesopelagic fish biomass

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The uncertainty surrounding acoustic estimates of mesopelagic fish biomass is colossal. This is due to the difficulty in sampling the mesopelagic layer and the biases related to associated additional sampling methods. For acoustic sampling of the mesopelagic with scientific echosounders, siphonophores potentially represent a major source of bias because of the relatively high target strength at the lower frequencies required to sample at depth (Proud et al., 2019). Some siphonophores have a carbon-monoxide-filled gas inclusion whose presence results in strong backscatter. Determining the potential extent of the acoustic bias introduced by siphonophores is crucial for accurate estimates of mesopelagic fish biomass.
Here we examine the potential uncertainty of current mesopelagic fish biomass estimates due to the inclusion of siphonophores. A global siphonophore database assembled in 2021 based on available literature is used to build 3D siphonophore species distribution models. Adding recently published observations of siphonophore densities and sizes to this database, 3D maps of siphonophore distribution, density, size and density range by depth and ecoregions can be produced. Then, using a forward analysis, backscatter due to siphonophores is predicted, which is then subtracted from the observed global mesopelagic fish NASC to get an alternative estimate of mesopelagic fish biomass.
Keywords: Mesopelagics, siphonophores, acoustics, 3D species distribution model,

Combining video and acoustics to describe fish assemblages distribution in coastal and oceanic tropical ecosystems

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Tropical ecosystems are essential for human well-being but are increasingly threatened by anthropic activities. The lack of precise information on fish spatial distribution limits our ability to reconcile exploitation and conservation. To make progress in this direction, we combined acoustics and video observations to comprehensively describe the distribution fish in two typical tropical environments, the Fernando de Noronha Archipelago (FNA) and the continental shelf of Northeast Brazil. Simultaneous scrutinizing of videos and echograms allowed classifying echoes into fish assemblages. By doing this, we build an unprecedented dataset that maps the horizontal distribution of fish assemblages, identifies hotspots and explores the differences between a

coastal and an oceanic environment. We could also revisit and complement ecological concepts such as the island mass effect or the role of mesophotic reefs. The global distribution of fishes resulting from our approach is therefore an important basis for ecological studies and provides relevant information that can be used to support the implementation of science-grounded Marine Spatial Planning.
Keywords: Oceanic archipelago, coastal neritic ecosystem, marine spatial planning, Northeast Brazil

Seeing with sound: the potential of imaging sonar for quantifying reef fish abundance and diversity

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Imaging sonars (ISs) are increasingly used to survey fishes in artificial and natural habitats, particularly in conditions where optical instruments cannot function (e.g., turbid systems). Uncertainty remains regarding the ability of ISs to accurately enumerate fish densities and classify species richness, particularly in structurally complex habitats. Here, we describe how we addressed both issues, using data collected from a subtropical artificial reef in Western Australia. First, we compared IS and optics for quantifying fish density. IS densities were three times higher than optical estimates, because IS captured many small, camouflaged fishes that optics failed to detect. We also describe several limitations of IS encountered, and remark on their connotations for future deployments. Second, at the same habitat, we demonstrate the ability of IS to make inferences on species identity using a novel clustering algorithm. Across five species, the identities of individuals from two species were inferred with 100% accuracy. No individuals from the remaining three species were identified correctly. We also present an alternative to fish categorisation using IS that does not include taxonomy. Overall, we will demonstrate the power of IS for profiling abundant and diverse reef fish communities, whilst recognising its limitations.
Keywords: Imaging sonar, fishes, artificial reef, optics, abundance, classification

They move in mysterious ways: Spatial behaviour of individual *Calanus finmarchicus* quantified by using broad-band target tracking

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Understanding trophic interactions in the mesopelagic zone is important in both ecological and potential commercial exploitation context. Trophic interactions between mesopelagic fish *Maurolicus muelleri* and their prey *C. finmarhicus*, as well as the large scale behaviour of both species, have been studied together with light intensity and prey density. However, there is only limited knowledge on how individual *in situ* 3D-behaviour of *C. finmarhicus* is influencing encounters when co-occuring with the predator *Maurolicus muelleri*. We successfully tracked

single individuals of *C. finmarchicus* in situ, parametrized their different swimming behaviour at different depths, and calculated their scale dependent self-overlap (ψ) based on the specific paths generated by their movement. We found that swimming activity were higher in the surface layers (ψ<0.1) with higher ambient light levels and where predation of *C. finmarhicus* typically occur. This explains why juvenile *Maurolicus* chose to migrate to a depth layer with lower *C. finmarhicus* density to forage.

Keywords: Copepods, Mesopelagic fish, Interactions, target-tracking, Broadband, Self-overlap

From FAD acoustics to tropical tuna abundance indicators

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The increasing collaboration with tropical tuna vessel-owners associations operating in the eastern Pacific Ocean and the most of the buoy-providers, allowed access to information recorded by their satellite-linked GPS tracking echosounder buoys since 2010. These instrumented buoys inform fishers remotely in real-time about the accurate geolocation of the fish aggregating devices (FAD) and the presence and abundance of fish aggregations underneath them. Therefore, echosounder buoys are considered good observation platforms to provide catch-independent data and potentially evaluate abundances of tunas and accompanying species at FADs. Current echosounder buoys provide a single biomass value without discriminating species or size composition of the fish. Therefore, the echosounder buoy data has to be combined with fishery data, species composition and average size, to obtain specific species indicators. This work presents the methodology that has been followed to estimate a standardised index of abundance for tropical tunas in the eastern Pacific Ocean derived from echosounder buoys for the period 2012-2022.

Keywords: Buoy echosounder, FAD, Abundance indices

Estimating uncertainty in acoustic-trawl surveys with a semi-parametric spatial bootstrapping procedure

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Acoustic-trawl surveys are widely used to estimate populations of pelagic animals, including several of the planet's largest fisheries, but quantifying their uncertainty has always been challenging. Surveys sample patchy populations with a mix of systematic, random, and targeted

samples at different spatial resolutions. Animal densities are not Gaussian, so classical geostatistics cannot be used to construct confidence intervals. Finally, converting backscatter to biomass requires multiple scaling conversions, each contributing its own error. A range of approaches to quantifying uncertainty are possible–from simple geostatistics which only consider spatial sampling error, to complex hierarchical models including other factors (e.g. correlated species and size composition, target strength, instrument calibration). We present an intermediate-complexity approach, based on semi-parametric resampling, which nonetheless accounts for most significant sources of uncertainty. A novel method for simulating non-Gaussian spatial fields conditioned on observations accounts for spatial sampling error, and a spatially-weighted bootstrap accounts for the uncertainty in allocation of backscatter based on trawl samples. We apply this method to surveys of walleye pollock (Gadus chalcogrammus) in Alaska, estimating relative errors in abundance of 5-10%. I will discuss the advantages and disadvantages of this approach, and possible future directions for uncertainty quantification in acoustic surveys.
Keywords: Non-Gaussian random field, Spatial simulation, Stock assessment, Survey design

Bubble trouble and fishy findings: challenges for hydroacoustic studies of fish at tidal energy sites

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Tidal energy is a growing sector of the marine renewable energy industry but effects of instream tidal energy devices on fish remain uncertain. Hydroacoustic instruments provide high-resolution information on fish abundance and distribution, which is essential for assessing potential risks to fish. Fast, turbulent tidal currents at these sites draw air bubbles downward from the surface that mask fish backscatter. To understand the magnitude and variability of data loss caused by entrained air and how it may affect observations of fish at tidal energy sites, we examined split-beam, narrowband hydroacoustic data collected from a seafloor platform at the FORCE tidal energy test site in the Bay of Fundy, Canada. We illustrated potential effects of data loss on measurements of fish presence and distribution at the site (e.g., generation or masking of temporal patterns, particularly for species utilizing the upper water column). We also identified periods of time when hydroacoustic instruments are likely to be most effective for water column sampling (e.g. near neap tides, when current speeds rarely exceed 3 $m \cdot s^{-1}$). Understanding the strengths and limitations of available sampling tools is essential for designing effective monitoring plans at tidal energy sites and providing better information to regulators and other stakeholders.
Keywords: Tidal energy, marine renewable energy, fish, hydroacoustics, tidal currents, bubbles

The school trap hypothesis predicts the spatial distribution and environmental preferences of the collapsed Pacific Sardine

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The oceanographic environment has been proposed as the main driver of boom and boost events in small pelagic species. However, for the Pacific sardine off the West Coast of the US, neither the mechanisms driving their dynamics nor the environmental proxies for their productivity are fully understood. For example, sardine's resurgence in the 1990s lagged the environmental regime-shift by approximately ten years, suggesting other mechanisms may be modulating the stock's productivity. One hypothesis proposes that the schooling nature of small pelagic fishes forces individuals of a depleted stock to join schools of other more abundant fishes. This "school trap" effect results in the depleted species compromising its own habits in exchange for the protection that the mixed-species schools offer. In this presentation, we show that the school trap hypothesis predicts virtually every distributional pattern observed from the currently depleted stock of Pacific Sardine, including interrupted migrations and shifts in their environmental preferences. The changes in behavior promoted by sardine schooling predominantly with the far more abundant Jack Mackerel may explain why the stock failed to respond positively to favorable oceanographic conditions that have occurred off the West Coast in the last five years.
Keywords: Oceanographic habitat, depensation, delayed recovery, California current