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# 1. Session 1 - Acoustic characterization of marine organisms

## 1.1. Acoustic Backscattering from Gas and Liquid-Filled Prolate Spheroids Across a Wide Frequency Range and All Incident Angles: Applications in Fisheries Acoustics with Open-Source Software

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Prolate spheroid is an important scattering model in fisheries acoustics. Among the few geometries with analytical scattering solutions, prolate spheroid is perhaps the best representative models for fish body or its swimbladder, the dominant scattering organs. Despite the well-established mathematical formulation for exact solution of scattering from prolate spheroids, solving these equations are challenging, especially at high frequencies (small wavelength compared to scatterer dimensions). The initial challenge is the difficulty in calculating prolate spheroidal wave functions (PSWFs), special functions that arise in solving the Helmholtz equation in prolate spheroidal coordinates. Other challenges include handling numerical overflow and underflow, determining how to truncate the infinite series arising in the solution, and solving ill-conditioned systems of equations.
We have addressed these issues and provided a model in an open-source software package developed using Python and Fortran, offering stable and precise solutions for both gas- and liquid-filled prolate spheroids. The model is valid across all incident angles and for $h_s(=\pi f d/c_s)$ values up to at least 173 and 230 for gas- and liquid-filled prolate spheroids, respectively, where $d$ [m] is the focal length and $c_s$ [m/s] is the sound speed in the prolate spheroid. The calculated backscattering results for aspect ratios (i.e., the ratio of the semi-major to semi-minor axis of the prolate spheroid) up to 10 are benchmarked against those estimated using finite element methods (FEM). Additionally, we have optimized the script for improved performance.

**Keywords:** Target Strength modelling, Prolate spheroid, Fluid-filled, Wideband

## 1.2. Integrating Bottom-Mounted Echosounders and eDNA to optimise Sandeel Monitoring

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Sandeels (Ammodytidae) are considered key species in marine ecosystems serving as an important link between lower and higher trophic levels. However, their spatial distribution and the factors influencing their habitat use remain poorly understood. Their patchy distribution, coupled with their unique life style—spending part of their time buried in the sediment and part in the water column—makes accurate monitoring difficult. This study explores the combined use of splitbeam bottom-mounted echosounders and environmental DNA (eDNA) to improve sandeel detection and quantification.

Acoustic backscatter datasets from sandeel-rich regions in the Belgian part of the North Sea (BPNS) are analyzed using Echoview software to detect single targets and schools. These detections are examined for variability in target strength (TS) and volumetric backscattering strength (Sv) across a frequency range around 200 kHz, alongside morphometrics and spatiotemporal dynamics. Machine learning techniques will then be leveraged to automate classification and improve accuracy. While acoustics offer broad temporal coverage and real-time data, eDNA provides high taxonomic resolution and may help resolve acoustic ambiguities. With this interdisciplinary approach, we aim to establish an optimal sandeel monitoring strategy for the BPNS while deepening our understanding of their spatial and temporal habitat dynamics.

**Keywords**: Sandeel, bottom-mounted echosounders, echoview, target classification, eDNA, quantitative monitoring strategy

### 1.3. An envelope-based acoustic classification method for krill in the California Current

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Krill, encompassing a range of euphausiid species, play a crucial role in all marine ecosystems by linking primary production to higher trophic levels. Krill distribution and abundance can be monitored reliably and efficiently using active acoustic methods, provided that krill echoes are adequately detected. Most commonly used algorithms for detecting krill echoes involve empirical filters based on the volume backscattering strength ($S_V$) spectra of krill aggregations. In this study, we introduce a novel method of krill echo classification using polynomial relationships between multi-frequency $S_V$ differences. Unlike the traditional Sv-differencing, our method accounts for significant correlations between pairs of Sv-differences, which enables more accurate classification of krill echoes. The new filter conforms closely to the multidimensional space of Sv-difference observations, which also improves the rejection of non-krill echoes. We compare the specificity and sensitivity of this new filter to that of existing methods, and demonstrate its enhanced performance.

**Keywords:** Echo-classification, Fisheries Acoustics, Plankton

### 1.4. Acoustic Discrimination of Herring and Sprat Aggregations

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Reliable hydroacoustic classification and discrimination of marine organisms species is often a challenge, especially in case of their similar backscattering properties, such as for Baltic herring and sprat. The aim of this study was to create a tool for hydroacoustic classification of fish schools as monospecies (herring or sprat) or multispecies aggregations in the Southern Baltic Sea. To achieve this, an artificial neural network for semantic segmentation of an image was applied to the analysis of echograms with schools of herring and sprat obtained at two different frequencies: 38kHz and 120 kHz. The data were collected during the standard hydroacoustic

assessment of Baltic herring and sprat biomass in Baltic International Acoustic Surveys cruises. Only filtered signals coming from schools were used in the classification. The network was trained on hydroacoustic data collected just before trawling, with training labels based on biological data from hauls.. As a result, the trained network allows us to determine the probability of assigning each pixel of the echogram to one of the classes.

**Keywords**: backscattering, neural network, frequency response, Baltic herring and sprat

# 2. Session 2 - Acoustic methods to characterize populations, ecosystems, habitat, and behavior

## 2.1. Pacific warm pool ecosystem characterized with hull-mounted acoustics and environmental variables

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The western equatorial Pacific Ocean is characterized by a unique ecosystem, featuring warm and fresh sub-surface water masses known as the warm pool. On the eastern side, the warm pool meets cooler, saltier waters from the equatorial upwelling, and its position shifts with the large-scale ENSO climatic oscillation. This ecosystem is critical for tuna fisheries, with over 90% of skipjack catch located within the warm pool. Despite its importance, the structure of the warm pool ecosystem, particularly in relation to tuna prey and lower trophic levels, remains poorly understood. This study used hull-mounted acoustic data to describe micronekton distribution in the western and central tropical Pacific Ocean and to investigate the structure of mid-trophic levels within the warm pool and surrounding ecosystems. Over five surveys, ranging from the warm pool to the equatorial upwelling, we identified distinct micronekton ecosystems using clustering algorithms on hull-mounted acoustics. The depth of scattering layers within each ecosystem was extracted and examined in relation to environmental parameters (temperature, salinity, fluorescence, oxygen), as well as current measurements from ADCP. We then described the specific characteristics of the warm pool ecosystem and the coherence between the structure of mid-trophic levels and environmental variables.

**Key words**: Micronekton, Warm pool, Mesopelagic, Clustering, Mid-trophic level

## 2.2. Monitoring the effects of a storm on near-surface anchovy using a glider-mounted echosounder

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Juvenile anchovy in the Bay of Biscay perform a gradual migration from the shelf waters to the coast in autumn. This migration occurs gradually in periods of meteorological stability. However, it has been hypothesized that after

the autumn storms that mark the arrival of winter, the juvenile population abruptly accelerates its migration, causing juveniles to concentrate in coastal waters. In 2022, a conventional trawl-acoustic methodology of the JUVENA campaign was combined with an acoustic monitoring conducted from a glider. The glider, equipped with a CTD and an echosounder, traveled through a transect perpendicular to the coast. The experiment coincided with the arrival of an intense storm, allowing to obtain acoustic recordings of anchovy and hydrological conditions before and after the storm. The spatially extensive trawl-acoustic data combined with the temporally extensive data from the glider showed how the storm reinforced anchovy migration towards the coast. Moreover, a downwelling event was detected by the glider. The glider proved valid for sampling under rough climate conditions. However, bathymetries shallower than 80 m were not sampled for safety reasons, thus preventing us from locating the coastal end of the anchovy distribution and limiting the reliability of the study.

**Keywords**: *Engraulis encrasicolus*, glider, acoustics

### 2.3. Bottom-mounted echosounders shed light on pelagic fish in the Belgian part of the North Sea (BPNS)

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Five bottom-mounted split-beam echosounders (Simrad WBAT) with upward-facing transducers (70 and 200 kHz) have been deployed across the Belgian part of the North Sea (BPNS) since 2023. Within the context of the BAR (Brexit Adjustment Reserve) project, we aimed to detect and characterize schools of pelagic fish based on their size, depth, aggregation and presence throughout the 24-hour diel period. Echoview software was used to detect and characterize targets from both frequencies. The BPNS is characterized by strong tidal action, which often resulted in significant backscatter from entrained air bubbles, complicating the detection of fish schools. An entrained air boundary line was created through averaging and thresholding, effectively separating fish schools from entrained air bubbles. Analysis revealed a higher detection rate of schools during daylight hours (15-34% detection positive hours, DPH) compared to nighttime (6-17% DPH) across all stations. To infer possible species of detected schools, an acoustic pelagic trawl survey was conducted in December 2023. Herring, pilchard, whiting and mackerel constituted 95% of the total catch weight during the survey.

The semi-continuous data generated from bottom-mounted echosounders offer insights into the distribution of pelagic fish, providing high temporal coverage that will benefit stakeholders engaged in monitoring pelagic fish.

**Keywords**: echosounder, trawling, school detection, entrained air, bottom-mooring, school characterization

### 2.4. Decadal spatiotemporal distribution of anchoveta (Engraulis ringens) in the Peruvian marine ecosystem between 1985-2024

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Our analysis examined the decadal relationship between anchoveta and the Pacific Decadal Oscillation index in the Peruvian marine ecosystem. The acoustic data were obtained from Pelagic Resources Assessment Hydroacoustic Surveys conducted by the Instituto del Mar del Peru, while oceanographic data came from satellite images of sea surface thermal anomalies between 1985 and 2024. Results showed that during cold decadal periods, anchoveta were found a little far from the coast, concentrated mainly in the central-northern region. In warm decadal periods, they were closer to the coast and with greater abundance towards the central zone. An exception was the 1985-1988 warm period, when anchoveta distribution was wide and generally dispersed. The biomass trend was negative in warm decadal periods and positive in cold decadal periods, influenced by the El Niño events: 1997-98 and 2015-16, with a decrease in biomass recorded in 1998 and 2015. The last cold period (2017-2024) was influenced by the warm year of 2023. Between 2000 and 2024, anchoveta biomass averaged 8.26 million tons, with an average biomass of 7.46 million tons for the north-central region between 2004-2024.

**Keywords**: Decadal spatial distribution; Distribution and concentration; Oceanographic environmental dynamics; Biomass estimation

### 2.5. A review of multifrequency split-beam applications to aquatic ecosystem science

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Biplanar split-beam processing of echosounder data facilitates coherent-phase detections of scatterers and estimates of their three-dimensional positions within the acoustic beam. This processing is robust when the phase is coherent across a range of wavelengths. Target scatterers may be biotic or abiotic, entire individuals or aggregations of animals, or facets of animals or the seabed. The three-dimensional positions of coherent-echo samples are compensated for transducer location and motion, and located in geographic coordinates. The sample intensities are compensated for beam directivity and propagation loss. These data are used to estimate fish aggregation shapes, densities, abundances, and behaviours, and to simultaneously detect and classify echoes from animals and the seabed. These data are used to improve estimations of seabed depth; sub-beam slope, hardness, roughness and lithology; and the height of the unresolved boundary region, the so-called dead zone, for each transmission and beam. These approaches are also applied to data from a swath of split-beams spanning a range of frequencies, i.e., from the Simrad ME70, to provide more classification and measurement possibilities.

### 2.6. Herding of Antarctic krill (*Euphausia superba*) inside a trawl

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The catch efficiency of a fishing gear depends on the design of the gear and the species-specific behaviour, i.e., responses to stimuli from gear components and ability and inclination to escape. The Antarctic krill (*Euphausia superba*) fishery is the largest in the Southern Ocean. In a scientific macroplankton trawl, we placed a downward-facing 333 kHz and an upward-facing 70 kHz split-beam echosounder just behind the fishing circle during fishing off South Orkney Islands. In observations from six hauls, it was possible to track 264 and 237 individual krill from the 333 kHz and 70 kHz echosounder, respectively, in the 6 m high trawl mouth. Krill of 3-5 cm body length were actively moving away from the netting panels of the trawl. In the centre of the trawl body their movements were random. Their swimming speed was similar irrespective of their swimming direction. This pattern was consistent

for both the upper and lower half of the trawl. Thus, krill herding leads to lower krill densities close to the netting panels. The detailed behavioural description obtained, highlights the benefits of using split-beam acoustics to gain knowledge of fish responses to fishing gear in dark and turbid waters where camera observations are limited.

**Keywords:** narrowband split-beam, single target tracking, pelagic trawl, krill survey, crustacean behaviour, trawl mouth

### 2.7. Fine-Scale Variability in Prey Distribution and Its Influence on Goose-beaked Whale Presence in Southern California

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Goose-beaked whales (*Ziphius cavirostris*; Zc) use echolocation to forage on patchily distributed deep-sea squid. Zc exhibit a flight response to naval sonar, potentially displacing them from optimal foraging habitats. This displacement could result in significant energetic costs, as nearby habitats may have reduced prey availability. To assess the impact of naval sonar on Zc foraging behavior, we first examine the physical factors driving predator-prey dynamics. We hypothesize that deep-sea squid are attracted to warmer water advected into the deep sea by surface mesoscale oceanographic features. Warmer waters may stimulate cephalopod metabolic rates, providing an advantage given their semelparous life history strategy. Additionally, mesoscale features interacting with steep bathymetry may aggregate prey, increasing prey densities available to Zc during deep dives. We tested this by collecting both active and passive acoustic data at three Southern California submarine canyons from 2017 to 2022. Passive acoustic data revealed Zc presence across all years, with lower presence in late summer and early fall, varying by site. Each site had unique environmental conditions and prey fields, resulting in differing Zc foraging patterns. These findings suggest there are distinct prey communities in Southern California, and displacement from sonar could alter prey availability and Zc foraging success.

**Keywords**: Multi-site, multi-year acoustic ecological time series

### 2.8. Sensor fusion for rapid biomass estimates of *Calanus* sound scattering layer

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Rapid and automated estimates of zooplankton biomass within a sound scattering layer could validate satellite observations, optimize catch potential for *Calanus finmarchicus* harvesters and provide an indicator for ocean health. Instruments commonly used for non-lethal monitoring of zooplankton in the ocean, namely acoustics and optical sensors, each have inherent strengths and weaknesses. Utilizing both methods together leverages the advantages of each whilst minimizing each sensor's limitations. We developed a near real-time sound scattering layer (SSL) detector based on thresholding and mathematical morphology of echograms. A detected SSL triggers a submersible platform mounted with an optical sensor to investigate the SSL for a size and composition estimate of the particles. This data pipeline is

instrument- and platform agnostic. We will present two case studies: the first with a marine observatory buoy with a profiling frame, and the second with an uncrewed surface vehicle and an autonomous underwater vehicle. We present results for the data pipeline tested for sound scattering layers dominated by *Calanus finmarchicus* where a sound scattering model is used to estimate the target strength of the average copepod detected for a rapid biomass estimate. The solution is planned to be leveraged in a Digital Twins of the ocean demonstrator for plankton monitoring

**Keywords**: optical imaging, echosounder, sensor fusion, ocean monitoring, digital twins of the ocean

### 2.9. Follow the Fish

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West Coast Vancouver Island (WCVI) Chinook salmon are of conservation concern, with high mortality thought to occur during their early marine phase, spent largely in coastal areas. *Follow the Fish* is an integrated assessment and monitoring program to track juvenile fish throughout their first year at sea and to assess conditions that may affect their survival. The program includes a wide array of sampling efforts, such as purse seining, micro-trolling, e-DNA and fit-chips, zooplankton and oceanography, as well as biotoxin and contaminants. As part of this integrated monitoring, acoustic methods are used on several fronts, including the deployment of autonomous multi-frequency echosounders to obtain high-resolution temporal and vertical data on salmon and salmon prey. These acoustic data are also used to document and quantify near-surface predation events on juvenile salmon, particularly from diving birds. Locations of the instruments are carefully selected to complement and build on current and projected sampling efforts in the area. These projects also leverage a number of mobile surveys off WCVI that have (and continue) to collect acoustic data. These data are being used to build time-series of euphausiid and forage fish distribution, as well as adult Chinook salmon detections along the coast.

**Keywords:** Autonomous echosounder, juvenile salmon, predation, time-series

### 2.10. Omnidirectional sonar helps to understand anchovy behavior in the Northern Humboldt Current System

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Peruvian anchovy (*Engraulis ringens*) is a key species in the Northern Humboldt Current System, being a medullar component in food webs and playing a crucial role in the fishing industry. Its distribution and behaviour are influenced by environmental factors and fishing pressure. Understanding school dynamics could help to improve stock assessment strategies, optimize fishing operations, and minimize the environmental impact of extraction activities. In that sense, the goal of this study is to describe the behaviour of anchovy schools in the Peruvian marine ecosystem during the hydroacoustic survey of summer 2024. Real-time information of schools (such as swimming direction and speed) was obtained from data collected by an omnidirectional sonar SX-90 (tilt: 7°, Frequency: 24

kHz, range: 500 m). Our results reveal strong variability in swimming direction, but with a pattern in direction to the coast (80°). Average swimming speed of schools (~0.7 m $s^{-1}$) was coherent with that published for *E. ringens* in Peruvian Sea. These findings are essential for understanding the spatial dynamics of the anchovy in summer, providing key information for fisheries management and stock assessment

**Keywords:** Anchovy, omnidirectional sonar, Northern Humboldt Current System

### 2.11. EK80 transducers calibration within [4-20]°C temperature range and [1-400] bar pressure range

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IFREMER is led to deploy EK80 equipments in different deep waters conditions, recently down to 500m depth for New Caledonia seamounts observatories, or with 2500m Ariane and 6000m depth capable Victor ROVs in the framework of the national DeepSea'nnovation project. Echosounder calibration is necessary to perform quantitative analysis of collected data, and is not always convenient to achieve in-situ. To provide a general calibration gain behaviour in various conditions, ES70-7CD, ES70-7CDR 6k and ES200-7CDK 6k transducers and their electronics were immerged in the Ifremer hyperbaric chamber in Brest, with temperature control. Measurements of a calibration sphere were obtained over different pressure cycles ranging from 1 to 400 bars and temperature cycles ranging from 5 to 20° Celsius. Data analysis and resulting observation of transducers behaviour are presented.

### 2.12. Echoscape - Analysis of the multifrequency zooplankton backscattering seascape of the South Adriatic Sea

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Acoustic data were recorded in the South Adriatic Sea during the Mediterranean Acoustic Survey (MEDIAS) using an EK80 echosounder at four frequencies (38, 70, 120, and 200 kHz), alongside zooplankton sampling with a WP2 net and CTD casts. These data were analysed to describe the spatial variation of the sound scattering layer and the factors that might influence their distribution. MVBS and NASC were extracted in the water column, without a minimum Sv threshold. The NASC at 38 kHz showed the strongest correlation (Rho = 0.80) with zooplankton biomass. Therefore, this frequency was selected to assess the vertical variability of MVBS across all stations, linking it with the environmental variables. NASC and biomass correlated positively with chlorophyll, oxygen, and salinity, and negatively with temperature. PERMANOVA analysis revealed significant differences in relative frequency responses across depth strata, likely due to planktonic community variations. MVBS at 38 kHz was positively correlated with temperature and $N^2$ (buoyancy frequency), suggesting aggregation near the pycnocline. Chlorophyll correlations varied, indicating potential zooplankton predation effects at low chlorophyll levels and excess primary production at high levels.

**Keywords:** Sound scattering layers, Zooplankton, Acoustic Backscattering, Adriatic Sea, Ecosystem variables.

### 2.13. Automated detection and tracking of fish in Scottish rivers using ARIS sonar data

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Monitoring fish populations is critical for effective fisheries management, particularly for species such as Atlantic salmon that are classified as endangered by the IUCN and play an important ecological and economic role in Scotland's river systems. In this study, a framework was developed to detect and track moving objects in ARIS Explorer 1800 sonar data (collected at sites on the River Deveron and Laxford), classify tracks as either fish or non-fish and perform a movement analysis to evaluate upstream and downstream fish counts. A random forest model was trained to distinguish fish from non-fish across sites. Model performance was significantly better for upstream fish than downstream fish, likely due to differences in fish behaviour, movement speed and track integrity. Model-based fish counts of upstream and downstream movements differed on average from annotated fish counts by 2.32% and 2.53% respectively but percentage errors were much higher when evaluated at daily time intervals (11.6% and 31.9% for upstream and downstream fish respectively). The methods developed in this study provide a framework for automated fish monitoring in rivers using sonar data, reducing the need for manual data processing. Future refinements include improved downstream tracking and classification, shoal detection, and species classification.

**Keywords:** ARIS imaging sonar, fish tracking, river ecosystems, Atlantic salmon, fisheries management, machine learning

## 2.14. Bridging the gap in fish data time series in offshore wind farm wake areas using seabed multi-instrument platforms

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Understanding how offshore wind farms (OWFs) influence fish distributions is critical for assessing ecosystem impacts. This study presents findings from the PELAgIO project seabed-mounted active acoustic deployments at the Seagreen Offshore Wind Farm (Scotland) in the seasonally stratified region of North Sea, investigating measurements in the turbine wind and tide wakes across seasons.

Upward-facing WBAT EK80 echosounders (38, and 200 or 120 kHz) were deployed with ADCPs, CTDs, and fluorometers to capture high-resolution temporal patterns of fish behaviour and environmental drivers. A bi-frequency classification approach, based on Sv thresholding, distinguished three fish categories: (1) fish with swimbladders, (2) fish without swimbladders, and (3) single targets with strong backscatter at both frequencies.

Echometrics (NASC, centre of mass, index of aggregation) were calculated to quantify temporal patterns in the vertical distribution of classified fish echoes.

Wavelet analysis decomposed acoustic signals to detect dominant temporal patterns in these metrics. Results highlight strong diel vertical migration, tidal periodicities, and a temporal link between fish distributions and phytoplankton blooms.

This study demonstrates the effectiveness of stationary echosounders for understanding fish behaviour in OWF environments. The approach provides valuable insights into temporal dynamics, advancing acoustic monitoring techniques for assessing anthropogenic impacts on marine ecosystems.

.**Keywords** : Offshore wind, fish behaviour, wavelet analysis, bi-frequency classification, environmental drivers, echometrics

## 2.15. Charactering and monitoring, a large, unique and enigmatic fish spawning aggregation in the deep sea

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Marine protected areas are crucial for conserving marine biodiversity, yet less than 3% of the world's oceans are fully protected. Australia, with the third-largest Exclusive Economic Zone, plays a key role in deep-sea conservation, with 82.2% of its marine park area lying deeper than 1,000 metres. However, the country lacks long-term monitoring of deep-sea ecosystems, presenting an opportunity to enhance conservation efforts. Patience Seamount, located within the Huon Marine Park off Tasmania, was heavily impacted by fishing but is now a critical conservation site. It hosts the world's only known spawning aggregation of deep-sea basketwork eels (*Diastobranchus capensis*), a unique ecological phenomenon. Previous studies confirmed the aggregation but left unanswered questions regarding biomass, spawning duration, and population connectivity. This study uses multiple lines of evidence including acoustics and optics to characterise the temporal and spatial extent of the aggregation and provide the first comprehensive data on the spawning ecology of *D. capensis* at Patience Seamount, contributing to global conservation discussions..

**Keywords:** Acoustics, optics, basketwork eels, spawning ecology, conservation

## 2.16. Preliminary results on fish behaviour in the mouth of a deep-water shrimp (Pandalus borealis) trawl

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Knowing fish behaviour inside commercial trawls is crucial in both relation to efficient capture and selectivity. New, acoustic technology enable detailed observations of animals in deep, dark and turbid waters. Split beam echosounders are capable to provide three-dimensional target tracking data of individual fishes inside the trawl

We mounted a Wideband Autonomous Transceiver (WBAT), which is a subsea transceiver, behind the headline of two commercial deep-water shrimp (Pandalus borealis) trawls. It was connected to a 120 kHz transducer that with an 18-degree beam angle mounted dorsally in the trawl mouth towards the seabed area just ahead of the groundgear. Data was collected in March and September 2024 with both day and night hauls, with a pingrate of 2 Hz. Shrimp and fish catches were collected in different codends.
The fish catch consisted of both species groups with (mainly gadoids and herring) and without (flatfish, elasmobranchs) a swimbladder. Over 30.000 tracks of individual fish were extracted from 10 hauls. Tracks for analysis contained on average 7 pings (range: 4 – 200 pings). The mean verticle displacement of tracks was 0.59 m (range +8 to -8 m). Most individuals had an upward trajectory (89.2%). Preliminary results from explorative investigations will be presented.
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**Keywords**: Selectivity, target tracking, behaviour, catch technology, WBAT

### 2.17. Effects of diel behavior on the accuracy and efficiency of acoustic-trawl surveys of small pelagic fishes off Northwest Mexico

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Acoustic-trawl (AT) surveys of small pelagic fishes (SPF) are conducted annually off Northwest Mexico. Species proportions and fish-length distributions from trawl catches are used to convert echosounder data to SPF-biomass estimates. To evaluate any effects of SPF diel behaviour on the accuracy and efficiency of AT sampling, we analyse echosounder and catch data collected irrespective of the time-of-day during four surveys, 2019-2021. We compare SPF backscatter versus depth and time-of-day. We assume that lower swimbladder-fish bycatch indicates less bias in nearby “SPF-backscatter”. Also, higher SPF diversity and larger length ranges indicate less bias in trawl catches. We compare these metrics across diel periods. Generally: during daytime, SPF aggregate deeply enough to be sampled by the echosounders and, during nighttime, they ascend near the surface and disperse for efficient capture. At nighttime, more non-SPF contribute to the catch and presumably the near-surface backscatter. Therefore, daytime echosounder data attributed to SPF is biased less by non-SPF backscatter. Furthermore, nighttime SPF-catches are generally larger and better represent the SPF-species compositions and lengths in the area, compared to daytime catches. We conclude that, compared to daytime only sampling, survey accuracy and efficiency are improved by conducting echosounder transects during daytime and trawling at nighttime

**Keywords**: Small pelagic fishes, forage assemblage, DVM, survey accuracy and efficiency

### 2.18. A step forward quantifying micronekton within deep layers with a combination of acoustics and trawls

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As part of the ANR APERO project, which aims to improve quantification of carbon fluxes in the mesopelagic zone, in the North-East Atlantic, micronekton scattering layers were studied day and night during 40h fixed stations, using trawl sampling, hull-mounted acquisitions and a WBAT broadband profiler in 2 bandwidths 35-45 kHz and 90-150 kHz, positioned in the deep scattering layer at daytime and nighttime.

This presentation will detail how, following a permissive extraction of individual targets applied to WBAT data, a set of selection and automatic validation criteria have been developed to retain only reliable spectral signatures. Two objectives were then pursued: firstly, to cluster the spectra in order to determine the type of scatterers by day and by night ; secondly, to extract TS values at 38 kHz in order to estimate an organism density from the Sv data of the hull-mounted echosounder and the WBAT, with a day/night comparison. The proportions of biological samples from the trawl, combined with the density of organisms obtained by acoustics, is a first step towards quantifying the biomass of the different groups of micronekton making up the deep layer in the studied geographic area.

**Keywords**: Broadband acoustic backscattering, Simrad WBAT, Individual target discrimination, Micronekton

# 3. Session 3 - Emerging technologies, methodologies, and protocols

### 3.1. Towards remote acoustic monitoring of marine ecosystems

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Remote, unsupervised, acoustic data collection, has been tremendously increasing in the past decades, with the use of fixed observatories, and the more recent introduction of Uncrewed Surface Vehicles. New incentives for scientific fleets to reduce costs and environmental impact simultaneously stress out the need to allow for opportunist data collection whenever possible, during vessel operations apart from dedicated surveys with scientific teams onboard. This requires to provide remote tools to control data acquisition, and scientists to adapt to new forms of remote surveys. Integration of these alternate data sources into marine ecosystems studies is a key, and raises the difficulty to analyze them within a reasonable time frame. To enable benchmarking data processing, standard and open machine learning pipelines, as well as secured and shared scientific databases, require a common data format and preprocessing framework.. Recent progress made on those lines by Ifremer and partners are presented, as fuel for thought for the community.

### 3.2. Looks Easy, Sound's Hard: Challenges for Image Segmentation on Acoustic Data

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When Echoview decided to develop a machine-learning driven feature for detecting bottom exclusion lines in acoustic data, the assumption was that it shouldn't be too hard. A human viewing an echogram of acoustic data can easily spot the bottom – state-of-the-art image segmentation algorithms, after a decade of incredible progress, were surely up to the task. In reality, the acoustic data domain presents various difficult challenges to machine-learning driven image segmentation – including poor resemblance between echograms and the natural images on which foundation models are trained, highly variable conditions of data collection, the requirement to balance global context against fine-grained local detail, and the lack of reliable or consistent ground truth. This presentation will summarize some of the difficulties encountered, steps Echoview has taken to manage them, and suggestions for the future.

**Keywords**: Machine learning, image segmentation

### 3.3. Advancing *In Situ* Acoustic Measurements of Deep-Sea Squid: Bridging Data Gaps for Modeling Beaked Whale Prey Availability

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Environmental changes and anthropogenic disturbances may affect beaked whales and other deep-sea marine species. Beaked whale prey is surveyed using echosounders and the backscatter data informs models of deep-sea predator-prey relationships. However, to accurately interpret echosounder observations of beaked whale prey, it is essential to identify the deep-sea species and their sizes, and ultimately characterize their acoustic target strength (*TS*). This information is necessary to attribute acoustic backscatter to species and convert it to length-weighted biomass densities. In this study, we simultaneously image and measure *TS* of *in situ* squid and fish, the primary prey items of beaked whales, at depths exceeding 1 km in the Southern California Bight. To accomplish this, we developed the Visual & Acoustic Marine Mammal Prey Station (VAMMPS), which uses light to attract prey species into a volume concomitantly sampled by a video camera and a wideband echosounder. We present the evolution of VAMMPS, and the preliminary results of initial deployments. Examples include continuous-wave and frequency-modulated *TS*-tracks of video-imaged species. We also explore variations in filmed organisms and their relations to temperature, salinity, and dissolved oxygen.

**Keywords**: Mooring, target strength, squid, WBAT, camera

### 3.4. The Sonophore – an autonomous vertically-profiling multi-frequency echosounder system

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Deepwater micronekton communities are key functional groups in marine ecosystems that are difficult and costly to adequately observe and sample from vessels – nets and lowered echosounders are slow and spatially and temporally limited, and vessel-mounted acoustics have limited range at higher frequencies. To address these constraints, we have developed a prototype autonomous profiling echosounder by merging a multi-frequency Kongsberg WBAT and an Argo profiler, which we call the Sonophore. It has been designed to obtain high-quality single target detections and tracks from individual organisms via multiple vertical profiles from the surface to 1000 m over periods of several weeks. The aim is to use such data to remotely and relatively cheaply monitor micronekton

community composition as a function of depth, and thence to develop data products relevant to fisheries and ecosystem management. 38/120 kHz and 70/200 kHz versions of the system have been tested and calibrated to 800 m depth off Tasmania, with their first research use planned for mid-2025 in the Southern Ocean.

**Keywords**: Autonomous, echosounder, profiling, argo, zooplankton, microplankton

### 3.5. New lightweight, portable Pamela USV: Echosounder data quality assessment and fleet operation testing

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*In-situ* ocean observations are essential for improving the reliability of environmental monitoring, providing data for modelling, and informing decision-making processes that impact ocean policy and management. We tested a small, versatile and user-friendly uncrewed surface vehicle (Pamela USV, F & Z Solutions) equipped with diverse sensor payloads for real-time, *in-situ* ocean sensing. We conducted two field campaigns demonstrating the use of the Pamela USV platform for acoustic surveys of underwater environments with an active acoustic payload (WBT Mini echosounder and 333 kHz transducer, Kongsberg Discovery). The first field campaign assessed the data quality. The second field campaign tested fleet operations with follow-the-leader operation of multiple Pamela USVs configured with different payloads (active acoustics, underwater camera and plankton trawl) to provide a more comprehensive dataset. The data quality assessment indicated transient noise and electrical noise while driving at greater than 15% of the motor capacity and great data quality during loitering operations. The fleet test was successful, with minor improvements recommended to adjust to follow-the-closest-leader operation. These findings advance the goal of aligning scientific research with scalable USV operations, illustrating the value of collaborative and innovative approaches to ocean sensing.

**Keywords:** uncrewed surface vehicle, noise, echosounder, sensors, ocean monitoring

### 3.6. LSSS in CRIMAC

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The Large Scale Survey System (LSSS) is a software system for interpreting acoustic survey data. It has been developed by IMR and NORCE since 2005 and used in production since 2007. Recently, LSSS has been used increasingly in the IMR-lead CRIMAC project, which aims to improve and automate interpretation of broadband acoustics data.

This presentation will highlight some of the ways LSSS is used in the CRIMAC project. Echosounder rawdata-files are converted to NetCDF for easier use by other tools. Historical interpretation work-files (annotation-files) are converted to data formats suitable for machine learning. LSSS is also used as an experimentation tool when developing new methods, such as for broadband noise detection, and for design of data quality indicators.

The future of LSSS will be discussed. LSSS, as of version 3.0.0 from January 2025, can be downloaded and used free of charge. Plans for publishing parts of LSSS as open source was presented at WGFAST in 2024. A new API for extending LSSS with custom windows and layers on the map and echogram will be introduced**Keywords**: Small pelagic fish, biomass assessment, lateral beaming echosounder, lateral target strength

**Keywords:** LSSS, CRIMAC, NetCDF, Open source, API

### 3.7. A compilation of test data sets for applications of broadband echosounders with accompanying data processing pipeline

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New algorithms for processing broadband echosounder data are being actively developed within the fisheries acoustics community. These algorithms have the potential to enhance the enumeration and classification of acoustic targets. Test datasets are invaluable for developing and demonstrating the efficacy of such algorithms. Currently, the community lacks open resources and datasets for testing and benchmarking. The Institute of Marine Research (IMR) has made a selection of datasets available for this purpose, covering a range of different marine organisms and echosounder platforms. These platforms include traditional platforms such as ships and towed bodies, as well as stationary observations from within net pens. The species covered include zooplankton and fish, both with and without swim bladders. The datasets include stored raw decimated data, like that from the instruments, along with calibration files, descriptions of each dataset, and metadata, such as relative transducer placement. This dataset can be updated when new suitable data becomes available. A pipeline that converts raw data from the test datasets to NetCDF and further into multidimensional arrays for parallelizable access (Zarr), suitable for applications in machine learning, complements the datasets. Here, we describe the datasets as well as the accompanying processing pipeline.

**Keywords**: Broadband echosounder data; acoustic target classification; test datasets; algorithms; data processing pipeline

### 3.8. Echofilter 2.0: The echogram event horizon

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Echograms are image-like representations of acoustic backscatter amenable to machine vision analysis. Hydroacoustic surveys of biological organism abundance and biomass seek to isolate the backscattering intensity above the lake or seabed and below any entrained air bubbles near the water surface. Locating these non-biological scattering sources is often a bottleneck in producing fish biomass estimates. Commercial algorithms exist to automate fitting these boundaries; however, their outputs may require considerable manual adjustment and review. Echofilter (Lowe et al. 2022) is a machine learning (ML) method that automatically fits entrained air and bottom exclusion lines directly from echograms. Echofilter was initially trained on upfacing echosounders moored in tidal energy streams in the Bay of Fundy, Nova Scotia, Canada, and it may perform poorly when applied to new datasets from different environments. Here, we discuss practical considerations in adapting Echofilter to define entrained air

and bottom exclusion lines for echograms collected by downfacing echosounders carried by surface vessels in the Great Lakes. We estimate that the updated Echofilter 2.0 algorithm reduced the time taken to preprocess a 90-day acoustic survey from 6-8 months to 2-3 weeks. Site-specific training data conferred the best performance, but requisite data volumes are much less than originally reported.

**Keywords**: Great Lakes; fisheries acoustics; echosounder; machine learning; computer vision; artificial intelligence

### 3.9. Automatic Detection of Fish Schools in Acoustic Data by Two Methods: Double thresholding and Deep learning

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Seabird breeding success has been shown to depend on prey biomass around the colony across several ecosystems. Yet, more than prey biomass, prey distribution should play an essential role in their capacity to return regularly to the colony to raise chicks. Unfortunately, detailed information on prey distribution is often lacking. To address this, three sailing drones equipped with a 200kHz modulated frequency EK80 echosounder were deployed across different ecosystems in Australia, Canada, and Sweden. We developed two methods to automatically detect and extract schools from pre-processed, standardized acoustic images. First, **double thresholding** reconstructs schools through dilation from school nucleus (threshold 1) towards a relaxed threshold (2), both thresholds being optimized automatically for each image. The second method uses **deep learning** with Meta's *Segment Anything Model* (SAM) to extract schools. The detection performance of both methods was compared against analyses by five experts (100 images per site). Both methods performed well, with accuracies (81% for double thresholding, 76% for SAM), similar to the average expert accuracy of 82% ± 3. Even if schools detected had different characteristics depending on the ecosystems (larger in Canada, smaller and numerous in Sweden) the models accuracy varied little between sites showing their robustness.

**Keywords**: Fish detection – deep learning – sailing drone

### 3.10. Implementing uncrewed surface vehicles in existing acoustic trawl surveys: data infrastructure, remote operating centre, edge computing, data compression and transfer, data quality monitoring, and automated target classification

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[2]Kongsberg Discovery, Horten, Norway.
[3]Norwegian Computing Center, Oslo, Norway Successful application of machine learning (ML) methodology

IMR plan to use USVs on two surveys in 2025: The coastal sprat survey series and the North Sea sandeel survey series. Here we present the status and plans for using the USV in the surveys.

The USVs are operated through IMRs remote operating centre (ROC), and we will use the Kongsberg Discovery Blue Insight platform to run algorithms on the platform (edge) and telemeter the data and results to the ROC.

Raw acoustic data are compressed on the USV and transferred to the ROC and unpacked for further analysis.

Data quality tests will be deployed on the platform and the results will be telemetered to the ROC allowing the operator to monitor the data collection.

Machine learning models for acoustic target classification have been developed for sandeel, and we are currently developing a model for sprat. These models will be run on the USV and the resulting predictions will be sent to the ROC.

The annotations will be adjusted at the ROC and sent back to the USV and combined with the backscatter data to provide the backscatter by acoustic category in a distance/depth grid. This will be telemetered back to the ROC for review.

**Keywords**: uncrewed surface vehicles (USV), acoustic target classification, machine learning, remote operating centre (ROC), data quality, data infrastructure

### 3.11. NOAA Fisheries Active Acoustics Strategic Initiative on AI and model-based echo classification

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A NOAA Fisheries Active Acoustic Strategic Initiative (AA-SI) was established in July 2023 to "Revolutionize and expand opportunities for active acoustic data in ecosystem-based fisheries science and management through a NOAA-wide program that advances analytical methods for multi-disciplinary data collected from innovative platforms." This national venture among Fisheries Science Centers, Office of Marine and Aviation Operations (OMAO), and National Centers for Environmental Information (NCEI) aims to promote collaboration and facilitate development of open-source software for expanding our capabilities to collect, process, analyze, disseminate, and interpret active acoustic data. This initiative leverages numerous technological advancements to transition from local, on-premise computing and storage to cloud-based "big data" analytical methods. Highlighted are recent accomplishments and future plans to improve the objectivity, accuracy and efficiency of echo classification using AI/ML, Bayesian, and/or low-frequency approaches. We will also examine incorporating ancillary data into echo classification models, and expanding the use of active acoustic data in fisheries and ecosystem sciences through cloud implementation of shared data and processing tools.

**Keywords**: Big Data, echo classification, machine learning

### 3.12. Noise in the EK80/333-kHz channel can be greatly reduced.

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Frequency dependent acoustic backscatter depends on species, size of and behaviour, so a wide and continuous frequency-band is needed to characterize different ecosystem components. Small gas-inclusions have strong backscatter at low frequencies while other targets have varying characteristics at increasing frequencies. A broadband 18-kHz system could find resonance frequency of targets with small gas-inclusions. Although limited by range for high frequencies, hull-mounted acoustic systems are preferrable to towed vehicles due to the need for biological samples.

A EK60/333-kHz system introduced onboard RV "G.O.Sars" in 2008 was prone to noise, but IMR was eventually able remove noise-sources and correct for the remaining noise in CW-mode to achieve the sufficient range of 125m that IMR considers to be minimum for hull-mounted systems. When connected EK80 in broadband-mode, the 333-kHz transducer suffered from unacceptably much noise again. Thus, the EK80/333-kHz system has not been used much even by those institutions that have one.

A new system of grounding the 333-kHz transducer tested onboard "G.O.Sars" in 2023 reduced noise and improved the useful range in CW-mode greatly and doubled it in FM-mode. An 18-kHz broadband transducer tested in 2023 failed due to noise, but an improved 18-kHz transducer tested in 2024 reduced noise greatly.

**Keywords**: Fisheries, acoustics, echosounder, noise, grounding

### 3.13. Investigating the use of fisheries multibeam echosounders for survey-optimisation, decision making, and species characterisation.

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Fisheries multibeam echosounders have been available for nearly a decade, differentiating themselves from standard bathymetric multibeams by their increased dynamic range, fewer beams with reduced sidelobes, wideband signals, bi-planar split-beam processing, and shorter aperture lengths, providing high-quality calibrated water column data. However, their use as a standard tool in fisheries surveys remains limited to a few institutions across the globe. Here, we review the potential use of such systems and their limitations using a subset of data from the 2023 and 2024 California Current Ecosystem Surveys. We first study how using Kongsberg Discovery's ME70 can reduce the variability in backscatter measurements from acoustic transects, potentially increasing survey accuracy and precision. We then focus on its capacity to extract morphometric characteristics of fish schools and layers, their frequency and angular dependencies, and how to use that information to inform species composition and partitioning of acoustic backscatter. Finally, we explore bi-planar split-beam processing to produce high-resolution bathymetry and calibrated seafloor backscatter and assess how this can be relevant in fisheries and habitat mapping applications.

**Keywords:** Multibeam, data processing, school characterisation, habitat mapping, bathymetry

### 3.14. Impact of USV movements on acoustic data: attenuation and bubbling

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USV platforms mainly present reduced length compared to usual research vessels. Their behaviour at sea can be impacted in moderate weather conditions, and consequently affect acoustic data quality in terms of level attenuation and potential increase of surface bubbling. To situate the range of operational conditions suitable for acoustic survey, these effects are evaluated and compared between a 8m-long DriX USV and a simultaneous survey performed with a 30m-long research vessel. USV experienced a far stronger range of attitude amplitude, that reduces seafloor mean Sv level observed with unstabilized EK80. Attitude rate were not expected to impact received level up to 250m range, but would have to be considered for deeper acquisitions. Surface bubbling was observed up to 15m depth, identically for both platforms, corresponding to sea state origin. But data loss associated with blank pings provoked by bubbles in acoustic blind zone was only present with the research vessel, the longer length of the ship allowing the bubbles created at the bow to dive under the transducers.

### 3.15. Transforming raw acoustic and trawl data into biological information using an end-to-end, cross-platform data processing pipeline

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Integrating biological interpretation of echosounder data with biometric parameters derived from trawls is crucial in estimating biological distributions in fisheries acoustic-trawl surveys. Building on our previous ship-to-cloud pipeline, which focused solely on acoustic data, here we develop a truly end-to-end system that incorporates raw acoustic and trawl biological data and delivers biological estimates at output. The pipeline employs a deep learning echogram segmentation model that automatically detects the occurrence of Pacific hake. These detections are combined with volume backscatter measurements to generate nautical area scattering coefficients (NASC), which are then integrated with stratified trawl data to estimate hake abundance and biomass. In the pipeline, the acoustic data processing runs on the "edge" (ship), while biological data integration occurs on the cloud, ensuring full compatibility with a future scenario in which trawl-capable ships collaborate with acoustics-only drones to conduct large-scale, agile ecosystem surveys. Our pipeline is built on the open-source Echostack software suite, and includes near real-time visualization of all workflow elements, echograms with machine learning predictions, ship tracks, and geospatial distributions of hake abundance and biomass—all accessible via a cloud portal. We plan to modularize and generalize this pipeline in the next development stage for broader community usage.

**Keywords**: end-to-end data processing pipeline, cloud computing, edge computing, open-source software

### 3.16. Variability and influence of fisheries acoustic echogram annotations on machine learning applications

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High-frequency echosounders are the workhorse in fisheries and marine ecological surveys. Due to the inherent complexity of biological aggregations and ambiguity in interpreting echoes from species of similar size and anatomical composition, echogram annotations typically rely on a combination of spectral information referencing scattering physics, biological ground-truth from nearby trawls, and empirical school morphology of the target species. In this work, we investigate the variability of echogram annotations and its impact on machine learning performance using data from the biennial Pacific hake acoustic-trawl survey. Unlike many other fish species, hake

often form schools with loosely defined boundaries and occur in mixed-species aggregations in the mesopelagic. Using nonnegative matrix factorization and hierarchical clustering of volume backscattering strength distributions across the 18, 38, and 120 kHz channels, we discovered a spectrum of annotated region types with different morphological and acoustic features. These differences, along with the uneven sample sizes, influenced the performance of deep learning echogram segmentation models trained on this dataset. Our findings highlight the importance of understanding echogram annotation variability, its connection to scattering physics and the underlying aggregation composition, and the incorporation of such information in developing machine learning models.

**Keywords**: machine learning, image segmentation, annotation variability

### *3.17. Echopop: An open-source software package for acoustics-based population estimates and biological inversion*

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Acoustic-trawl surveys provide estimates of biological distributions that can inform stock assessments and other ecosystem-based management strategies. These measurements can also derive other biometrics (e.g. average body length) and behavioral information (e.g. tilt distributions) via inversion that can supplement sparse biological datasets. Acoustic and biological data processing methods often differ significantly across research groups and require bespoke code that could hinder collaborative efforts. As part of the effort to enhance the data processing workflow for the Pacific hake survey, we have developed *Echopop* (https://github.com/OSOceanAcoustics/echopop), a Python software package for integrating acoustic and biological trawl data to estimate biomass and other biological quantities. *Echopop* allows configuration through text-based "recipes" and is accompanied by detailed documentation and interactive Juptyer notebook usage examples. At present, it supports reproducing historical biomass estimates of Pacific hake, inverting for abundance of euphausiids, and ingesting biological trawl data during surveys in near real-time. In the next stage of development, we will expand the package to support a broader range of input data formats, scattering models, and inversion methods, along with enhanced interoperability across other packages within the *Echostack* software suite.

**Keywords**: acoustic-trawl survey processing, open-source software, population estimation, biological inversion, live data ingestion, uncertainty estimation

### 3.18. EchoSMs - open-source fisheries acoustics scattering models

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To facilitate access and use of scattering models (SMs) by the fisheries acoustics community and to promote the appropriate use and comparison of different models, the echoSMs initiative is developing an open-source Python package that includes most of the models used to simulate backscatter by fish and plankton (Jech et al., 2015, Comparisons among ten models of acoustic backscattering used in aquatic ecosystem research. JASA). The echoSMs code is written to be straightforward to use and to closely follow the symbology and equations in the original publications. Common conventions for calling, units, and coordinates are used for all models and the model outputs are validated against the results in Jech et al. (2015). EchoSMs is available at https://github.com/ices-tools-dev/echoSMs.

The next steps in the initiative are to develop consensus on 1) anatomical/morphological data requirements and formats for numerical models (e.g., finite element and boundary element), 2) an online interface for running echoSMs models, and 3) mechanisms for incorporating existing scattering model codes into the echoSMs initiative. Discussions on items 1 and 3 are scheduled to take place in the echoSMs workshop immediately prior to WGFAST 2025, with a summary to be provided here.

**Keyword**: Backscattering models, open-source, echoSMs

### 3.19. Data-Driven AUV Path Planning for Hybrid Acoustic-Magnetic Induction Underwater Communication

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Underwater autonomous systems are vital for marine exploration, environmental monitoring, and resource management. However, they face daunting challenges including complex ocean dynamics, limited energy, and unreliable communication links. In response, we introduce Hybrid COMM-Planner, a data-driven path planning framework that seamlessly integrates dual communication modalities—acoustic for long-range and magnetic induction (MI) for short-range, high-bandwidth connectivity. This innovative approach leverages comprehensive analysis of oceanographic conditions (depth, salinity, and temperature) to predict communication quality along potential routes. By incorporating a hybrid communication-aware cost function within the navigation algorithm, our method enables AUVs to dynamically select paths that balance efficient navigation with robust connectivity. Extensive simulations in realistic coastal monitoring scenarios demonstrate that Hybrid COMM-Planner significantly enhances communication reliability, reduces mission time, and adapts well under uncertain environmental conditions. Our results underscore the transformative impact of combining acoustic and MI communication, guided by data-driven insights, to overcome limitations of conventional strategies. This work lays a solid foundation for next-generation underwater networks and marks a forward-thinking leap in autonomous marine systems, promising improved mission performance and paving the way for resilient, high-performance underwater operations.

**Keyword**: Underwater Autonomous Vehicles (AUVs), Hybrid Acoustic-Magnetic Communication, Data-Driven Path Planning, Multi-AUV Cooperation, Energy-Efficient Navigation

### 3.20. Individual targets peculiarities and scattering layers variations observed in Lake Guerlédan using USV equipped with Simrad EK60 120kHz

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Lake Guerlédan is a 40m deep artificial lake created in the center of Brittany in 1930. After the last drain in 2015, fish were reintroduced. According to the French fishery association, species such as European perch, common carp, pike-perch and bleak are now present in the lake.

With the aim to analyse the behaviour of these species according to depth, position in the lake (east/north, on axis/sides) and seasons, we developed an unmanned surface vehicle (USV) capable of following autonomously pre-recorded survey lines. Control functions of the robot and integration of the echosounder EK60 120kHz were designed to handle water column acquisitions constraints.

Our poster presents the USV setup and the survey methodology conducted so far. Since january 2025, monthly measurements were made following the exact same survey lines. First results show multiple individual targets identified as individual fish and very few fish schools. Variations in scattering layers are also observed, mainly correlated to temperature profiles and lake morphology. Details on specific unidentified acoustic signatures are discussed.

**Keyword**: USV, individual fish response, fresh water, seasonal variations

### 3.21. An edge-to-cloud pipeline for echogram semantic segmentation using deep learning

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We demonstrate an edge-to-cloud framework for applying semantic segmentation of acoustic data to predict fish aggregations in real-time. A deep learning model was trained using a manually annotated Atlantic herring dataset (362 images, 10% reserved for testing). A U-Net with a ResNet34 encoder pretrained on ImageNet was selected following evaluations of multiple architectures and hyperparameters. The methodology uses Python-based tools (PyTorch and CUDA toolkit) and the processing pipeline is part of OceanStream – a platform designed to facilitate systematic acoustic data analytics.

Validation was performed with a simulated real-time inference pipeline, replicating EK60 data acquisition from a 2019 NOAA NEFSC survey aboard the Henry B. Bigelow. The trained model was deployed on a edge device for localised inference. The system achieved an 89% recall and 49% precision at a probability threshold of 0.5, indicating moderate efficacy in segmenting backscatter regions despite limited annotation coverage. The containerised solution utilises the IoT Edge runtime alongside Azure Data Lake for local/cloud synchronised storage, demonstrating the feasibility of on-device analytics for reduced latency and bandwidth consumption.

Future improvements will investigate improving prediction by adding secondary classification of predicted regions in original resolution and strategies to overcome limitation of annotation availability.

**Keywords:** IoT Edge; Computer Vision; PyTorch; Deep Learning; Cloud; Docker

### 3.22. Benthopelagic-mesopelagic species: who are they and how can we study them

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Mesopelagic fishes are typically considered exclusively pelagic. However, some of them can undergo ontogenetic shifts, becoming permanent members of the benthopelagic fauna. Other species are always associated to land masses and difficult to catch with pelagic nets. Although often commented in the literature (with different names), the relevance of this community has not been discussed in detail. This study firstly summarizes which species could be described as benthopelagic-mesopelagic according to the literature. Then, two case scenarios (the Western Mediterranean and North Atlantic) with both pelagic and demersal sampling are investigated. The suitability of demersal sampling is further analyzed with a global dataset. Benefits and pitfalls of using these data as well as potential future studies including climate change, extreme weather effects, behavioural and trophic studies or benthopelagic coupling are discussed. This review aims to provide a comprehensive understanding of mesopelagic fishes associated with benthic habitats, offering an in-depth examination of their ecology to establish a conceptual framework for future research.

**Keywords**: benthopelagic ; mesopelagic; shelf; slope; seamounts; demersal

### 3.23. Use of artificial intelligence in the analysis of industry echosounder data

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Recently, deep learning models have been introduced in fishery acoustics. In visual data analysis, convolutional neural networks found an application in acoustic echogram processing while interpreting them as images. The expert labels acoustic survey data into different categories using acoustic backscatter intensity. Without using deep learning this data scrutinisation process is time-consuming and prone to error because of the large data sets involved.

In this study, we processed 10 years of blue whiting acoustic data from 7 different fish trawlers during 38 trips. The fish schools and the sea-bottom were annotated on LSSS. To process the large amount of data to address its variability, we have developed a custom library to process and train from labelled echograms. The final algorithm had a F1 score of 0.74 and the comparison with the manually labelled NASC had an agreement of 64%.

This method can be used to efficiently process and label large acoustic datasets. Convolution neural networks have the potential to ease the scrutiny process and provide more consistent data analysis. This could work towards quantifying uncertainties introduced by operator biases through manual scrutinising resulting in consistent values of fish stocks and better fishery management.

**Keywords**: Deep learning ; data processing ; industry data

### 3.24. Combining autonomous observation platforms, remote sensing, and simulation modelling to monitor the copepod *Calanus finmarchicus*

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*Calanus finmarchicus* is a low-trophic level, widespread copepod with high nutritional value, currently harvested at ca. 0.1 % of their annual quota in Norwegian waters. However, harvesting the patchy *Calanus* surface swarms has high-operational carbon-emissions, fluctuating harvesting efficiency, and raises by-catch concerns. During the spring of 2024, we deployed a USV (Sailbuoy) and a glider (Seaglider M1) equipped with echosounders and optical sensors, and used satellite observations (ocean colour and LiDAR) together with simulation modelling to monitor the *Calanus* stock in the Norwegian Sea. Here, we present preliminary results from this spring survey, in particular focusing on the synergies between data types, instrumentation, and methodologies. For example, acoustic data was used to parametrize the *Calanus* simulation model and ground truth the satellite observations, whereas information from remote sensing and simulations was used to help refine the design of the autonomous vehicles survey. We also worked on the transmission of decimated echograms in near real-time to an online visualization portal, to showcase our results to relevant industrial and managerial stakeholders. By harnessing the potential of low-carbon-emission autonomous marine monitoring technologies coupled with remote sensing and simulation modelling, we aim to advance the Norwegian Sea *Calanus* fishery as a sustainable climate-neutral blue resource.

**Keywords:** USV, gliders, ecosystem monitoring, zooplankton, low-trophic level fishery, simulation modelling

### 3.25. OceanStream: A cloud-native platform for hydroacoustic data processing and analysis

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We present OceanStream, an open-source platform designed to address the growing demand for cloud-native solutions in fisheries acoustic data analysis. The proposed framework facilitates creating automated workflows using Python-based tools (echopype, xarray, zarr), deployed across distributed cloud computing clusters to generate analysis-ready datasets.

OceanStream is built to handle large volumes of raw acoustic data, convert it into SONAR-NetCDF4 compliant echodata, compute calibrated Sv, apply mask filters (e.g. for denoising), and finally store the refined datasets as Zarr repositories in cloud buckets. Echopype was selected as the primary processing backend due to its adherence to community-driven standards and interoperability with tools such as xarray.

In a pilot application of OceanStream, we processed, visualised, and catalogued a dataset recorded by a Saildrone USV carrying a EK80 38/120kHz echosounder with long and short pulse configurations. The mission was part of the NOAA and UW 2023 Pacific active acoustic survey which evaluated the use of Saildrones to study air-sea interactions and to obtain backscatter data down to 1000m depth.

Metadata and positional information are stored in a PostgreSQL database with PostGIS for geospatial query capabilities and a web-based map viewer was built to visualise survey trajectories alongside NASC values.

**Keywords:** Python; digital platform; data processing; cloud; automation; docker

### 3.26. Deep learning methods for acoustic target classification

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This presentation provides an overview of our work on automatic methods for acoustic target classification based on deep learning.

We first developed a method for acoustic target classification in multifrequency echosounder data based on deep convolutional neural networks. This was a supervised model for detecting and classifying sandeel, which was later improved by incorporating depth as an auxiliary variable. We have tested the models' predictions by replacing the manual annotations in the index calculation and comparing the resulting indices. These models have shown good results, but they require precise, manually annotated fish schools for training which are time-consuming to create and not available for most surveys. Current work is therefore focused on less label-dependent approaches.

We are developing an approach that enables learning from "weaker labels" in the form of summed backscatter over larger regions. This approach is currently being tested on herring. Another approach leverages recent advancements in self-supervised learning, allowing the model to learn initial data characteristics directly from the

acoustic data without labels. Our goal is to pre-train a model on multiple surveys without annotations and adapt it to various downstream tasks with less annotated data than would be required to train a model from scratch.

**Keyword:** Acoustic target classification, deep learning

### 3.27. Combining Forces: Using Acoustics and Environmental DNA Metabarcoding to Investigate Mid-Trophic Level Organisms in the Ross Sea

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At present, data on mid-level trophic organisms such as fish and zooplankton in the Ross Sea is limited. These species are commonly studied using a combination of active acoustics and net sampling. Net sampling has several drawbacks: high costs, time and effort, need for specialised trawl gear, and gear bias. Given the Ross Sea's status as a marine protected area, employing more environmentally sustainable technologies is important. Environmental DNA (eDNA) offers a feasible, less impactful alternative for ground-truthing of acoustic data than traditional net-based methods.

In 2024, we conducted a pilot study in the Ross Sea, seeking to combine acoustics and eDNA. Continuous acoustic data were recorded aboard the RV *Laura Bassi* and seawater samples were collected from acoustic marks and analysed for DNA from key Antarctic fish and zooplankton taxa. Initial results highlighted the importance of targeting acoustic marks accurately to avoid low eDNA abundance. We also found issues with commonly used primers, such as MiFish 12S, which didn't perform as expected. During the 2025 season aboard the RV *Tangaroa*, we optimised protocols for filtration, reduced contamination, increased sample size, and improved primer selection. In this presentation, we will share key insights and recommendations from combining eDNA with acoustics.

**Keywords**: eDNA, acoustics, Ross Sea, Antarctica, biodiversity, fish, zooplankton

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