# Joint Workshop of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour [WGFTFB] and the Working Group on Fisheries Acoustics Science and Technology [WGFAST] (JFATB)

Chairs: Stéphane Gauthier (Canada) and Mike Pol (USA)

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## List of presentations with abstracts.

### Opening Keynote: Echo sounder developments during my scientific life, from EK38 to EK80, with some significant steps.

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Over the last 42 years, I have used eight generations of echo scientific sounders, outside the ones I used in fishing, before I became a scientist. It has been a great journey, and I will try, mainly for the younger members, to summarize some of the significant steps in this development and end my talk with gazing into the crustal ball. I will start in 1934/35, but swiftly run to the first echo sounders I used at IMR, a EK38 kHz sounder with no TVG, removed from the vessels, but used experimentally. I will further show some of the problems with using these systems but also the first scientific echo sounder with TVG, tried and installed in 1968 on G.O.Sars, the EK38-S. The echo integrator and the need for calibration became obvious, and how it was solved. The EK400, and the ES380, with split beam needs some attention, and further to the fully digital word in EK500, EK60 and EK80, each with gradual, stepwise improvements, replay facilities and on-screen interpretation and multifrequency facilities. At last, I will talk a bit about the new broad band systems and what we have seen they can add to our knowledge.

### Fish passage rates prior to the cod end – a Smartrawl feasibility study

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Unwanted by-catch and discards of fish are a global concern, threatening the sustainability of fisheries through economic, biological and ecological losses. The European Landings Obligation seeks to bring about the elimination of discards in EU fisheries whereby all vessels are required to land all catches of all quota species. However, this is failing due to a lack of trawl selectivity in many multispecies fisheries. Since 2016, we have been developing technology to allow for the identification and grading of fish inside the trawl so that unwanted fish will not be caught. The "Smartrawl" uses stereo cameras and lighting in the trawl extension to obtain images of fish as they pass by. These images will then be analysed by an onboard computer to determine the size (and ultimately the species) of the fish. A signal could then

be sent to a gate located further back in the trawl extension to open or close depending on whether fish are wanted or not. A critical knowledge gap is the rate at which fish pass the camera to determine how quickly a sorting gate needs to operate. Here we report on fish passage rates based on trials conducted on a commercial fishing trawler in the North Sea.

### NepCon: image acquisition system for automatic Nephrops detection towards sustainable demersal fisheries

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In demersal trawl fisheries the application of video monitoring systems is challenged by low light conditions, mobilized sediment and scattering in murky waters. The NepCon aims to reduce the current limitations. It is an image acquisition system that includes a high-contrast background to enhance the visibility of the target object - *Nephrop*s (*Nephrops norvegicus*), compact camera and an artificial light source. The design concept of the NepCon is being developed towards an application in demersal trawls and the main objective is to increase the accuracy of *Nephrops* detection at the data acquisition level. To find the best contrasting background we evaluated the four different background colors under the experimental conditions. Edge-contouring, color agglomerative clustering, random forest classifier, and mask R-CNN segmentation algorithms were used to estimate which background color provides the best segmentation results. The background color with the best performance was used to evaluate computer vision and deep learning approaches for automatic detection, tracking and counting of *Nephrops*. For *Nephrops* directed trawl fisheries, which currently have no automated detection and counting technology and largely is conducted blindly, the developing approaches elevate the current F-score benchmark for automated estimation of *Nephrops* catch rate during fishing operation from 0 to 76.4%.

### Improving a Video Trawl Survey for Atlantic Cod (*Gadus morhua*) in the Gulf of Maine

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The SMAST video trawl system utilizes a video camera mounted inside the codend of an otter-trawl to collect catch data from tows made with the codend open, allowing fish to pass through unharmed. We are working on three improvements to this system that will make our data more informative for fisheries managers. First, stereoscopic cameras are being added to the system to obtain catch at length data from the open codend tows. We have expanded the spatial coverage of our survey in the Gulf of Maine, switching to a stratified random design based on the strata used by the NEFSC trawl survey. Finally, we are attempting to estimate the catchability of cod in the survey using a mark-recapture experiment conducted simultaneously with the survey. The resulting abundance estimate and the CPUE from the survey will be used to calculate catchability. To accomplish this, we have designed a Passive Integrated Transponder (PIT) tag detection system that can be operated from the codend of the net allowing us to collect recapture data during open codend tows. Here we present the preliminary results from the first two improvements and the methods to complete the third.

### Midwater trawl selectivity corrections for acoustic surveys in Alaska

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Sampling with midwater trawls is a necessary, but imperfect, component of acoustic-trawl fisheries surveys. Trawl catches are (often implicitly) assumed to represent the size and species composition of acoustically-observed fish aggregations. However, the process of capturing fish with a trawl likely introduces biases due to species- and size-specific escapement though the trawl meshes, or trawl selectivity. Over the past three years AFSC-MACE has used recapture nets (pocket nets) to estimate the size-dependent escapement of fishes from two midwater trawls, in order to correct size and species distributions for escapement of fishes through the trawl meshes during the capture process. We present the results of recent field sampling and discuss approaches for analysis of these data. Finally, we consider the impact of these corrections on acoustic-trawl survey abundance estimates.

### Helix Twine Off-Bottom Trawls: A New Twist to Target Eastern Georges Bank Haddock

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The massive biomass of Eastern Georges Bank haddock (*Melanogrammus aeglefinus*) is difficult to target without capturing less robust groundfish stocks like Atlantic cod (*Gadus morhua*) and some flatfish species. Specialized semi-pelagic haddock trawls that raise the mouth of the nets off-bottom have reduced bycatch but the very poor status of Atlantic cod prioritizes even greater reduction. Raising all the fishing gear off-bottom may further reduce bycatch while eliminating benthic impacts, expanding access to grounds previously off-limits to demersal trawls. We tested an off-bottom trawl (OBT) to harvest Eastern Georges Bank haddock while reducing catches of overexploited stocks. This pelagic net has extremely large front-end meshes made with "helix" twine that self-spreads while towed due to hydraulic forces. We set a target footrope height of 1 m off-bottom and monitored the net using an assortment of mensuration sensors/loggers and cameras. The OBT successfully caught similar amounts of haddock and reduced some bycatch more than a standard bottom "Eliminator/Ruhle trawl", but also caught fish of the same lengths despite the smaller mesh codend of the OBT. The OBT represents a potential new gear type in the region with opportunities to expand harvest of the healthy haddock stock.

### Modifying a survey trawl to better retain small Arctic fishes

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Pelagic fishes in the Chukchi sea are small (<12 cm) in size, which makes them difficult to capture with trawls. A herring trawl was initially modified by installation of a fine-mesh codend liner to quantify size and species compositions during an acoustic-trawl survey. Subsequent experiments with recapture nets mounted on the outside of the trawl suggested that escapement of small fishes from this net remained substantial, particularly in the aft section of the net. The trawl was modified again, based on the recapture net results, to have a longer and finer-mesh intermediate section, which substantially increased retention of small fishes. This work highlights the importance of conducting experiments to quantify estimates of trawl selectivity for nets used during surveys. It also demonstrates that midwater survey trawls can, and should, be modified to improve performance for specific applications (e.g., acoustic-trawl surveys).

## Keynote: The pelagic trawl, the challenges of catching small with a big gear

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Most of the fishing gears used for commercial fisheries or sampling for research purpose are gears developed over many decades, or even thousands of years. We can point to hooks, and gillnets, and even bottom trawls. Pelagic trawls are among the youngest developed fishing gears in use today. The development started soon after the Second World War with several drivers spurring the development of this important fishing gear both for commercial fisheries and scientific work. The pelagic trawl is still in the developmental stage, where most parts of the trawl are under study. Mainly development is connected to the commercial fishery, but some developments are still only meant for sampling. But sampling lifeforms in an unbiased manner with pelagic trawls can be challenging. And now when the mesopelagic layers are under interest, many questions about how we should sample are raised, and possibly we need to rethink the structure of the pelagic trawl. This presentation will start with a brief overview of the development story and discuss each part of the trawl and important operational tools, and include underwater videos and how the commercial fishery is using these gears that can teach us much about collecting unbiased samples.

## Big trawls for little organisms: Development of non-graded trawls for macroplankton and micronekton organisms

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Plankton nets and pelagic trawls have generally been used to sample macroplankton and micronekton organisms, however, both gears have limitations. Plankton nets have very small mesh sizes which retain smaller organisms while larger organisms can avoid the slowly towed net. Pelagic trawls, on the other hand, are graded trawls aimed at catching pelagic nekton. Though these trawls can be equipped with fine-meshed codend liners to retain micronekton and macroplankton, the different sizes of mesh throughout the trawl creates challenges when estimating the densities (numbers per volume water filtered) of organisms in the area. Therefore, there is a need to develop specific quantitative sampling methods for macroplankton and micronekton organisms. The Institute of Marine Research has developed and tested five non-graded trawls ranging from mouth opening areas of 12 $m^2$ to 792 $m^2$ and with mesh sizes of 3 x 3 mm and 7 x 7 mm light opening. Here, we discuss the five non-graded trawls and our approach to estimate densities of the most abundant macroplankton and micronekton species in coastal Norwegian waters and the open North Atlantic.

## Challenges associated with linking the acoustic-estimated spatial extent and abundance of mesopelagic fishes to dynamical oceanographic processes within the California Current Ecosystem

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Midwater ecosystems are chronically under sampled, leading to uncertainty in the relationship of mesopelagic communities to their physical environment. Such uncertainty is particularly important in the context of the increasing interest by commercial fisheries and potential vulnerability of these populations to climate change. Utilizing multi-frequency echosounder data collected from 2000-present as part of a long-term ecosystem assessment survey (not designed to sample midwaters), I plan to discuss challenges associated with the classification of acoustic signal as "mesopelagic fish," uncertainty in developing relevant threshold values and difficulty obtaining physical oceanographic data at midwater depths. The overarching goal of this work is to resolve the 3D structure of mesopelagic fishes over a broad range of spatial and temporal scales and link this distribution and abundance to the physical variability experienced by mesopelagic fishes within the California Current.

### Combined trawl-mounted optic and acoustic methods to study the mesopelagic ecosystem

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Acoustic methods may oversample mesopelagic fishes due to uncertainties in resonance, the proportion of backscatter due to siphonophores and population characteristics. On the other hand, nets may under sample due to trawl avoidance and poor retention of small individuals. In the work presented, a stereo camera system (Deep Vision) mounted in the extension of a pelagic trawl was used in combination with a self-contained wide-band echosounder (SIMRAD WBAT) in the trawl's opening as a tool to compare catch and acoustic estimates and improve understanding of the mesopelagic ecosystem. Estimates from the WBAT (counting acoustic targets) and the Deep Vision (counting the organisms in the pictures) show similar patterns in vertical distribution and densities over time for the mesopelagic organisms encountered, providing an enhanced sampling method for mesopelagic species by verifying acoustic targets in situ and establish their vertical distribution. Images and the trawl's path through the water column from the Deep Vision system can also be imported directly into the LSSS (Large Scale Survey System) software to verify acoustic scatterers in echograms. Finally, machine learning methods are being developed and tested to automate species identification and length measurement from the Deep Vision stereo images.

### Intelligent autonomous acoustic and optic characterization of mesopelagics in the Gulf of Mexico

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Characterization of mesopelagic communities in remote areas of the ocean for extended periods is enhanced through increased use of uncrewed systems. We are combining vessel and glider-based acoustics with a National Geographic Labs buoyancy-controllable stereo camera system to characterize distributions and constituents of mesopelagic layers in the Gulf of Mexico. In a Slocum glider, we use a WBT-mini and an ARM-based computer to provide glider-time data products and backscatter visualization. Processed backscatter and density distribution metrics can now be included in the glider science data communicated back to shore on surfacing. The glider data combines layered acoustic backscatter to ranges of 80 meters along with glider position and motion, and environmental data. We will use backscatter visualization in combination with density and distribution metrics to direct stereo camera for imaging of mesopelagic constituents. An autonomous, calibration rig was designed and used to calibrate the glider echosounder independent of the vessel. A mission is planned for August 2021 to combine the glider echosounder with the stereo camera to characterize mesopelagic scattering layers in the Gulf of Mexico. Acquiring backscatter and target strength characteristics at close range will assist in discriminating members of this complex community.

## Closing keynote: Biology of Fish Vision

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Fish vison is evolved in a very different optical environment than air. Thus, to understand the biology of fish vison one must know something about how sunlight and its different wavelengths propagate in water. Light is absorbed and scattered by particles in the water (e.g. humus, silt, plankton) as well as the water molecule itself, this causes a great variation in light conditions between different parts of the ocean. Blue light travels best in water, as the water molecule itself absorbs the longer wavelengths (red, yellow and green). Humus and alga absorb shorter wavelength (blue light). Nutritious coastal or brackish water is therefore dominated by green, yellow and red light, while clear oligotrophic oceanic water is dominated by blue light. In clear oceanic water the light limit for photosynthetic activity is at ca 200m, while limit for fish vision is at ca 800-1000m depth. The latter is of cause dependent on fish species. It is important not to underestimate available light at fishing depth. It is easy to trust todays PAR sensors that shows no light below 100 to 200m depth, though these sensors are only measuring photosynthetic available light (Photosynthetically Active Radiation =PAR). Deep sea fish are proposed to be 100 times more light sensitive than humans. In general, the light sensitivity of a species matches the dominant wavelength and light intensity in its natural habitat. Mesopelagic fish, living at the depth limit for sunlight, are known to follow a given light intensity (isolume) in their diel vertical migration.

To better understand the may adaptations in teleost's vision, I will give a simplified cartoon description of the structure and function of the teleost eye. How the lens focusses light (photons) on to the retina, and how the photoreceptors in the retina change the energy from electromagnetic radiance (photons) to nerve impulses transmitted, via the optic nerve, to the optical lobe in the brain, where the image is perceived. The photoreceptors are triggered by single photons, thus we should measure light in Einstein's (E), as 1 E = 1 mole of photons. I will shortly explain visual acuity, scotopic threshold and flickering fusion threshold and how these can be measure behaviourally by using optomotor response. An important thing to remember is that both eye size (growth, age) and ambient temperature has a great impact on visual resolution in fish, except for swordfish, tuna and some sharks that have heated eyes. As light intensity quickly diminishes and get more monochromatic by depth, the most important visual task for marine organisms is to detect differences in contrast, between an object and its background. Thus, most marine animals have developed a visual system that enhance contrast detection (of their prey) against the ambient light. Likewise have prey and predators developed surface camouflages that degrades their contrast against their background light, e.g. by having dark dorsal and light ventral colour, reflecting silvery sides, counter illumination (bioluminescence) or transparent body. Accordingly, the evolutionary arms race has evolved visual detection of UV - and polarized light in some fish, a trait that enhances detection of silvery or transparent prey.