Visualizing Alaska pollock (*Theragra chalcogramma*) aggregation dynamics

Steven J. Barbeaux, Martin Dorn, Jim Ianelli, and John Horne

Commercial echosounders can now be used to collect acoustic data from fishing vessels during normal fishing operations. In the winter of 2003 we collected approximately 32,000 km of backscatter data from three commercial fishing vessels participating in the southeastern Bering Sea Alaska pollock fishery. Although these data were not collected on a systematic grid, their broad temporal extent combined with a high spatial resolution facilitates the investigation of the distribution and behavior of fished aggregations. Three-dimensional Kriging was used to produce three-dimensional snapshots of Alaska pollock distributions over the fishing season. Fleet movement and effort was tracked using vessel monitoring system data and on-board observer catch data. Integration of these data allows an unprecedented look at the four-dimensional distributional changes in Alaska pollock aggregations and how the behavior of the aggregations is reflected in the dynamics of the fishing fleet. Our snapshots reveal that Alaska pollock have a highly dynamic spatial structure, diurnally congregating to patchy dense aggregations and nocturnally dispersing to a few uniform low-density aggregations. Over the fishing season the diurnal distribution pattern successively weakens to a less dense and more uniform state. Changes in trawl tow duration and search patterns coincide with diel and successive changes in the Alaska pollock distributions. Qualitative results suggest that rapid changes in distributions and local densities of Alaska pollock aggregations occur in areas of high fishing pressure.

Keywords: 3-D Kriging, aggregations, Alaska pollock, Bering Sea, data visualization, diel, opportunistic acoustic data, spatial dynamics, *Theragra chalcogramma*.

Contact author:
Steven J. Barbeaux: Alaska Fisheries Science Center, 7600 Sand Point Way NE, Seattle, Washington, 98115, USA [tel: +1 206 526 4211, fax: +1 206 526 4066, e-mail: steve.barbeaux@noaa.gov].

---

Communication inside anchovy schools: a way to facilitate fast 3-D changes in school morphology and structure in response to predation, as observed using multibeam sonar on anchovy aggregations in Peruvian waters

Francois Gerlotto, S. Bertrand, N. Bez, and M. Gutierrez

Fish schools are assumed to be, among other reasons, an evolutionary answer of pelagic species to predation. They present complex internal structures and a variable morphology. These parameters are likely to be adaptive features allowing fast reactions to predator attacks. Obviously communication processes must lead these changes, considering the high number of individuals inside a single school.

We observed anchovy school movements and reactions to sea lion attacks during drifting stations in Peruvian waters. The major communication process consists in waves of agitation crossing a whole 100 m diameter school at speeds (7.5 m/s) much faster than the average 0.3 m/s at which schools are moving. Internal organizations of schools change completely after the communication waves have crossed them. Changes are described and measured using geostatistics (internal structure) and fractal dimension of the school edges. Results confirm the efficiency of communication processes in pelagic schools. They may reinforce the hypothesis of schools being adaptations to predation.

Keywords: fish behaviour, pelagic, schooling, anchovy, predation.

Contact author:
Francois Gerlotto, IRD, CRHMT, rue Jean Monnet, 34203 Sete cedex, France [tel: +33 499573205, e-mail francois.gerlotto@ird.fr].
Using Lidar to observe the acoustic surface blind zone

Eirik Tenningen

Modern research vessels are equipped with drop keels to avoid acoustic noise from air bubbles close to the surface and ship. This is a very effective method but creates a echosounder blind zone of up to 12 meters. In order to observe fish and other organisms close to the surface a lidar is mounted on the bow of the ship looking down at a 15 degree angle in the forward direction. The setup will be tested onboard M/S "Libas" during the mackerel survey in the Norwegian Sea in July 2005. This is an annual survey using two commercial vessels equipped with sonars, echosounders, and trawl. During the feeding season mackerel is known to be very close to the surface and only a limited percentage of the schools are therefore available for echosounder observation. The lidar should be able to operate from the surface and down to 30 m depth. The current Norwegian Lidar System (NLS) does not give a three-dimensional picture but the plans for building a scanning version will be presented.

Keywords: Lidar, echosounder, sonar, mackerel.

Contact author:
Eirik Tenningen: Institute of Marine Research, Nordnesgaten 50, P.O. Box 1870 Nordnes, 5817 Bergen, Norway [tel: +47 5523 8463, fax: +47 5523 8531, e-mail: eirik.tenningen@imr.no].

Three-dimensional distribution of Northeast Atlantic mackerel in the northern North Sea during autumn related to ambient temperature

Aril Slotte, Rolf Korneliussen, and Dankert Skagen

In September, after the summer feeding has ceased, the Northeast Atlantic mackerel (Scomber scombrus) stock tends to aggregate in northern North Sea before it in December-January migrates southwards towards the spawning grounds. In the present study we describe the three-dimensional autumn distribution of mackerel based on acoustic data from 1999–2004. The distribution related to ambient temperature is described with data from 2003-2004. In general the acoustic surveys demonstrated that the mackerel mainly was distributed in a narrow area along the western side of the Norwegian trench. The schools in this area were observed at various depths from the surface and down to more than 300 m depth in the trench. The three-dimensional mackerel distribution was clearly temperature dependent, where the average school depth followed a gradient of 9–10°C. The depth of this gradient may vary with the inflow of warm Atlantic water from the north, which generally follows the western side of the Norwegian trench.

Keywords: mackerel, distribution, depth, temperature.

Contact author:
Aril Slotte: Institute of Marine Research (IMR), P.O.Box 1870 Nordnes, N-5817 Bergen, Norway [tel: +47 55 23 84 22, fax: +47 55 23 86 87, e-mail: aril.slotte@imr.no].

Acoustic information applied to implement environmental studies in the Baltic

Andrzej Orlowski

Since 1981, acoustic information, collected in a form of calibrated measurements of integrated echoes energy is applied in Sea Fishery Institute to observe the relationships among fish distribution and environmental factors. Data were collected during different seasons for each elementary distance units (ESDU) in standardized depth intervals to be compared to values of selected environmental parameters, measured parallel. Acoustic, biological and hydrological data were correlated in space and transferred to the complex data base. Analyses of data were made for different spatial and time structure (seasons, diel behaviour). Few methods and standards of comparisons explain how to improve a recognition of relationship between 3D spatial hydrologic gradients and fish distribution. Selected examples of dependence of fish (herring, sprat, cod) vertical and horizontal distribution on temperature, salinity, oxygen level, and
seabed type are described. Particular attention was given to indicate dependence of local fish biomass density on temperature structure in the sea.

Keywords: acoustics, environment, marine ecosystem, Baltic.

Contact author: Andrzej Orlowski, Sea Fisheries Institute, ul. Kollataja 1, 81-332 Gdynia, Poland [tel. +48 58 620 1728, fax: +48 58 620 2831 e-mail: orlov@mir.gdynia.pl].

ICES CM 2005/U:06

Characterizing the spatial distribution of a semi-demersal gadoid

Julian M. Burgos and John K. Horne

High-resolution, two-dimensional measurements of density are collected routinely during echo-integration trawl surveys. Echo-trace classification (ETC), the detection of aggregations within echograms, is used to describe and analyze spatial distributions of pelagic organisms. ETC is based on the delimitation of high density regions that satisfy a set of size and connectivity criteria. This approach is traditionally used for species that form discrete schools in the water column. Is the same algorithm also appropriate for species that also form demersal layers or diffuse pelagic shoals? For walleye pollock, the results from ETC are highly sensitive to threshold, minimum size, and connectivity criteria. In addition, a large proportion of the biomass may not be included within detected aggregations. As a comparison to ETC metrics, we use landscape indices to describe spatial distributions observed in echograms. Acoustic data from a transect or a fraction of a transect is considered a landscape. The echogram is represented as a categorical map in which each pixel is allocated to a density category. Areas of the map with relatively homogeneous densities are defined as patches. Landscape indices are calculated for each density category and for the overall landscape. Indices describe number, size and shape of patches, contagion and connectivity among patches and among categories, and diversity of density categories within a landscape. We compare results from ETC to landscape indices to evaluate approaches that characterize spatial distribution of pelagic nekton.

Keywords: Landscape indices, echo-trace classification, walleye pollock.

Contact author: Julian M. Burgos: University of Washington, School of Aquatic and Fishery Sciences, 1122 NE Boat St, Seattle, Washington 98105, USA [tel: +1 206 221 6864, fax: +1 206 685 7471, e-mail: +jmburgos@u.washington.edu].

ICES CM 2005/U:07

Seeing sound: visualizing acoustic backscatter from fish

John K. Horne

Interpreting acoustic backscatter requires the integration and understanding of how biology interacts with propagating pressure waves to produce single or multiple data channels. Visualizing acoustic data requires the presentation of complex objects in a way that is accessible and intuitive to a large audience. Backscatter visualizations incorporate representations of the acoustic beam; the shape and composition of targets; target behaviour — orientation (tilt, roll, yaw), movement of individuals and aggregations; and the resulting frequency-dependent backscatter. To illustrate by example, predicted backscatter from walleye pollock (Theragra chalcogramma) is portrayed as three-dimensional objects moving over interpolated bathymetry of the Bering Sea Shelf. Individual target strengths and group backscatter are displayed after each acoustic pulse. Individual fish can be selected to track orientation and backscatter in separate displays. Simultaneous viewing of backscatter sources and resulting data streams increases the understanding of how biological factors influence the intensity and variability of reflected sound.

Keywords: acoustic backscatter, visualization, walleye Pollock.

Contact author: John K. Horne, University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195, USA [tel: +1 206 221 6890, fax: +1 206 221 6939, e-mail: jhorne@u.washington.edu].
Non-lethal surveys for rockfish


Marine sportfishing in Southern California is a huge industry that must be monitored and managed by non-lethal fish surveying techniques if it, and the associated rockfish stocks, are to be maintained. The stocks of lingcod and six rockfish species, including four that are important to California anglers and commercial fishermen (bocaccio, canary rockfish, widow rockfish and cowcod), are estimated at or below 25% of their pristine levels. To assess the habitat and stocks of selected rockfish species in two marine conservation areas, the Southwest Fisheries Science Center is developing a non-lethal surveying technique to use in cooperation with the sportfishing fleet. Because numerous species of rockfish coexist in areas covering millions of square nautical miles, residing near or on the bottom at depths of approximately 80 to 300 m, and are low in numerical-density, the survey challenges are many. To overcome these obstacles, a combination of survey equipment is required. The challenge is first to identify the essential habitat for these rockfish, thus reducing the necessary survey area. This can be done with a combination of multi-beam sonar, sidescan sonar, multi-frequency echo sounders, and underwater video deployed from an ROV. It is also necessary to characterize the frequency dependence of sound scatter from the rockfish and coexisting species. This can be done by a combination of modeling, and both in-situ and ex-situ measurements. Finally, multi-frequency echo sounders, and underwater cameras can be used to acoustically survey the rockfish in their essential habitat and visually confirm the observations, respectively. Three-dimensional techniques for data imaging and integration are used.

Keywords: rockfish, non-lethal, survey, ROV, multi-frequency, echosounders, multi-beam, sonar, habitat.

Contact author: David Demer: Southwest Fisheries Science Center, 8604 La Jolla Shores Dr., La Jolla, California, USA, 92037 [tel: +1 858 546 5603, fax: +1 858 546 5608, e-mail: david.demer@noaa.gov].

Directions in three- and four-dimensional acoustic data visualisation and analysis

Matthew P. Wilson

The accelerated development of multibeam and scanning sonars together with the continuing increase in readily-available computing power has yielded new opportunities for the further use of acoustic instruments for exploring and quantifying various aspects of marine ecosystems. With these opportunities comes a need for primary tools that can be used to build the qualitative and quantitative analysis methodologies of the future. In turn, the key to the development of these primary tools is the ability to understand the nature of the available data and the interplay between data from a variety of sources. This understanding is greatly enhanced by the capability of software tools that read and display data from a variety of sources in a flexible and intuitive environment. SonarData's Echoview software currently reads acoustic data from a wide range of scientific sonar instruments. Echoview can display data from these instruments in a 3D 'scene' environment that can contain any number of georeferenced 3D objects such as fish schools, individual targets and 3D ocean floor surfaces that can be extracted from the sonar data. Import options for additional objects include georeferenced images, 3D surfaces and generic 3D objects. Support for scanning sonar data includes a 4D environment in which multiple instances of a moving 3D object can be detected, displayed and tracked. It is the ability to fuse data from these multiple sources into a single environment that provides scientists with new insight into marine ecosystems that will ultimately yield the analysis methodologies of the future.

Keywords: fisheries, acoustic, software, scanning sonar, multibeam sonar.

Contact author: Matthew P. Wilson: SonarData Pty Ltd, 110 Murray Street, Hobart, Tasmania 7001, Australia [tel: +613 6231 5588, fax: +613 6234 1822, e-mail: matt@sonardata.com].

How fish habitat suitability does shape the 3D spatial organisation of anchovy across scales?

Arnaud Bertrand, Mariano Gutiérrez, François Gerlotto, Pepe Espinoza, Sophie Bertrand, Jesús Ledesma, Roberto Quesquén, and Luis Alza
Functional relationships in marine ecosystems are complex as far as physical and biological parameters are concerned. Improving our understanding of ecosystem functioning requires the ability to observe in situ the interactions between physical and biological features. In this context, the Peruvian anchovy (*Engraulis ringens*) is an interesting case study as this species supports the highest worldwide landings and is know to present very high populational, distributional and even biological dynamics at different spatio-temporal scales. A specific behavioural ecology survey was performed in November 2004 to study 3D occupation of space by anchovy in Peru. This study was based on an integrated approach. Indeed, using a series of observation tools (Niskin, CTD probes, phyto- and zooplankton sampling, stomach content analysis, echo-sounder, multibeam sonar, birds and mammal observations) we assessed interactions between fish and most of the oceanographic and biotic environmental features possibly driving its behaviour. We could link levels of fish organisation (layer, school, shoal, cluster) according to different oceanographic and biological features: upwelling plume, plankton patches, water mass fronts, predators and others, varying in space and in time, particularly according to the diel cycle. We adapted the basin model framework to propose a conceptual model of environment impact on fish space occupation. Indeed, the small and medium-scale habitat favourability shaped the fish 3D spatial organisation.

Keywords: fish school behaviour, diel behaviour, predator-prey relationships, pelagic ecosystem functioning, spatial patterns, multibeam sonar.

Contact author: Arnaud Bertrand: Institut de recherche pour le développement, Centre de Recherche Halieutique, Avenue Jean Monnet, BP 171, 34203 Sète Cedex, France [tel: +33 (0) 4 99 57 32 00, fax: +33 (0) 4 99 57 32 95, e-mail: Arnaud.Bertrand@ird.fr].

ICES CM 2005/U:11

**Acoustic characterization of tropical tuna prey in the Western Indian Ocean in relation with local environmental conditions**

F. Ménard, J. J. Lévenez, M. Potier, J. F. Ternon, F. Baurand, O. Maury, and F. Marsac

From 2002 to 2004, four scientific cruises were conducted by the Institut de Recherche pour le Développement (IRD) in the Mozambique Channel (Western Indian Ocean), in order to study the pelagic habitat of large top predators such as tuna and tuna-like species. Acoustic data were recorded to study the spatial and temporal distribution of plankton layers and micronekton aggregations. Sea temperature, salinity, dissolved oxygen and fluorimetry profiles (not available for all the cruises) were carried out from the surface to 300 m using a Sea-Bird CTD. Sea water samples at different depth levels were filtered to characterize the photosynthetic pigments, and nutrients were analysed. Satellite data (ocean colour and altimetry) provided complementary information at a larger scale. In this study, we analyse the aggregative behaviour of schools and the dynamics of the scattering layers in relation with abiotic parameters at different spatial scales. We underlined the importance of meso-scale dynamics for the productivity in these areas (i.e., occurrence of cyclonic eddies in the Mozambique Channel) and the importance of the deep maximum chlorophyll for the distribution of the micronekton.

Contact author: F. Ménard: 1 IRD UR THETIS, CRH, BP 171, 34203 Sète, France [e-mail: menard@ird.fr].

ICES CM 2005/U:12

**Three-dimensional distributions of pelagic fish detected with an echo-sounder and environmental parameters around the Seamount, Hachirigase, in the Sea of Japan**

Hideaki Tanoue, A. Hamano and T. Komatsu

The seamount contributes to coastal ecosystems providing pelagic fish with feeding and resting grounds. Heterogeneous distributions of fish and environmental parameters around the seamount require visualization of their three-dimensional distributions to understand its ecosystem. Our objectives are to elucidate spatial distributions of pelagic fish schools around the seamount, and to explore a relation between distributions of fish schools and those of environmental parameters. The seamount, “Hachirigase”, 60 km distant of the shore is an important fisheries ground in the Sea of Japan. This seamount protruding 100 m high above the bottom at 120 m deep is 13 km and 6 km distant in the longitudinal and transversal directions, respectively. Acoustic, CTD and fishing surveys were conducted in June 2000. Three-dimensional images obtained with GIS were used to analyze parameters with relation to fish school. Most of fish schools appeared close to the bottom. Threeline grunt (*Parapristipoma trilineatum*) was the most abundant species at
the seamount (more than 63% of total fishes in number). Statistical analysis revealed that the fish schools were significantly distributed in a layer of the seamount shallower than a depth of 70 m. This layer of the seamount has steep bottom consisted of rock and stone. In this layer, 90% of fish schools were distributed on the west side of the seamount where mean current velocity was 0.3 knots faster than on the east side. The fish schools preferred upstream to downstream area of the current around the seamount suggesting relation to prey distributions.

Keyword: seamount, fish school, acoustic, three-dimensional distributions

Contact author:
H. Tanoue: Division of Marine Bioscience, Ocean Research Institute, University of Tokyo, Minamidai, Nakano-ku, Tokyo 164-8639, Japan. [tel: +81 3 5351 6520, fax: +81 3 5351 6542, e-mail: htanoue@ori.u-tokyo.ac.jp].

ICES CM 2005/U:13

Fine structure of fish aggregations: methods of study, effect on acoustic characteristics and fishing gear catchability

Mikhail L. Zaferman

The study of the fine structure of fish aggregations showed that they consisted of microgroups containing 2–5 individuals, having the internal well-ordered structure, but unordered location in the aggregation. The known ratios of the distance between individuals and their length relate to not the aggregation as a whole, but microgroups. The density of microgroups varies depending on the state of an aggregation (calm or stress). When studying fine structure the acoustic methods play an auxiliary role, since their resolution is inadequate and the echo signal may be interpreted ambiguously, subject to the extent of structure orderliness. The adequate data on fine structure may be derived by means of visualization (stereo photos or video) with the measurement of the fish spatial coordinates. The technology of synchronous using acoustic and video (primarily, laser, as more compatible with the acoustic instruments) equipment might become the most suitable to study the structure. A fine structure as the ordered microgroups was found in the pelagic fishes (herring, capelin), but some data from underwater observations indicate that it is possible in bottom fishes (cod), probably, in the two-dimensional variant. The availability of such structure may lead to the two consequences: 1) the appearance of coherent component in echo, in the case of aggregation transition to the stress state, for instance, due to vessel impact; 2) acceleration of fish adaptation to trawl resulting in decrease in efficiency. The adaptation of fish to trawl was found during the study of trawl efficiency for cod.

Keywords: acoustic methods, echo coherent component, fine structure, fish adaptation to trawl, fish aggregations, microgroups, visualization.

Contact author:
Mikhail L. Zaferman: Polar Research Institute of Marine Fisheries and Oceanography (PINRO) 6, Knipovich Street, Murmansk, 183763, Russia [tel: + 7 8152 4743 20, Fax: + 7 8152 47 33 31, e-mail: zaferman@pinro.ru].

ICES CM 2005/U:14

Evolution of the aggregation pattern in pelagic fish echotraces during spring acoustic surveys in the Bay of Biscay, 1989–2004

Héctor Villalobos, Jacques Massé, Pierre Petitgas, and Pierre Beillois

Regular acoustic surveys have been carried out in the Bay of Biscay since 1983. More, acoustic data were digitised and stored at ping rate since 1989. Identification of echotraces was performed during each survey by pelagic trawl hauls and main species biomass were estimated all along transects. This allows to analyse the geographic distribution and aggregation patterns during the last fifteen years and the 3D evolution of main pelagic species at spring in this area. Two approaches are considered in this study i) a coding of the echotraces by expert based on diffused and close to bottom (D1), well defined mid-water schools (D2), typical shelf-break structures (D3), or dense sub-surface schools (D4), ii) a characterisation of echotraces by replaying digital echograms school by school using Movies-Plus software. Both, horizontal aggregation patterns and vertical profiles of distribution of schools were obtained and compared year to year. Although the vertical structure was rather consistent through the period analysed, the major changes were in the species composition and the occurrence frequency of particular echotrace categories. Some species presence are fluctuating (anchovy, sardine) whereas some others increase over the period (horse mackerel). Some aggregation types are more an more present like surface schools and even new types appeared such as horse mackerel dense shoals. A working hypothesis is discussed that the aggregation pattern (i.e., echotrace category) in Biscay is little species dependent but in some way could be more related to environmental or ecosystem conditions.
In this work we aim at characterizing the spatial and temporal dynamics of pelagic fish aggregations distributed around moored Fish Aggregating Devices (FADs) in Martinique, in relation to environment and commercial fishing. We combined various observation techniques: scientific echosounder, underwater video, fishing and abiotic environment sensors. Radial and vertical acoustic surveys were conducted to sample a cylinder of 1500 m radius and 600 m height around 2 moored FADs. Echo integration by shoal was used to extract the fish aggregations and compute morphological and density descriptors. The inner dynamics of the fish aggregations were described through target strength analysis and video observations. Multivariate analysis were applied to assess the prominent morphological descriptors and propose a typology of the fish aggregations. Fish density estimates and associated variances were calculated by universal krigging in the sampled area. The temporal dynamics of the fish density and of the main morphological descriptors of the aggregations were analyzed with multiple and generalized linear regression methods to i) identify the temporal patterns ii) assess and compare the influence of social behaviour, environment and fishing on the aggregation process. During the day, the biomass was mainly distributed within 400m around the FADs, in the mixed layer (0–120m), in the form of a large 50 cm FL tuna aggregation. The density of the aggregation followed a diel cycle, reaching a maximum around noon and a minimum at night. Surprisingly, these tuna exhibited a low vulnerability to the gears of the local commercial fishermen, who specifically targeted scattered large predators.

Keywords: tuna fisheries, aggregative behavior, FAD, echosounder, geostatistics.
ecosystem can be identified. This information may significantly increase the accuracy of acoustic survey estimates of fish and to some extent also for zooplankton. Multi-frequency split beam echo sounders with nearly identical and overlapping acoustic beams have been regularly used in acoustic surveys for direct generation of new, synthetic echograms, based upon the measured or modelled relative frequency response of the targets is one of the most useful features of the systems. The result of the categorisation process is used to show the spatial distribution of different acoustic categories in a single synthetic echogram, or to keep some and remove other acoustic categories in echograms at a single frequency.

Keywords: categorisation, species identification, synthetic echograms, relative frequency response, 3D, 2D.

Contact authors:
R. J. Korneliussen: Institute of Marine Research, P.O. Box 1870, 5817 Bergen, Norway [tel: +47 55 23 85 00, fax: +47 55 23 85 84, e-mails: rolf@imr.no].

ICES CM 2005/U:18

Employing nested survey techniques to identify the relationships between benthic and pelagic environments within a 3-Dimensional framework

John Breslin, Paul Connolly, Noel Dumortier, Edward Fahy, Fiona Fitzpatrick, Veronique Jegat, Angela Morando, Terry McMahon, Glenn Nolan, Francis O'Beirn, Fabio Sacchetti, David Stokes, and Guy Westbrook

There is an emerging requirement for improved understanding of patterns of biodiversity, at local and regional scales, and the interaction and relative controls of broad scale biogeophysical processes affecting pelagic and benthic habitat populations and distribution of ecological patterns. The Marine Institute of Ireland assembled a multi-disciplinary group to carry out a nested survey of two adjacent areas, off southern Ireland; a known herring spawning ground and a dredge spoil dumpsite. The program specifically targeted several critical questions which would improve our ability to implement and manage effective conservation strategies: (i) what are the most useful biophysical parameters (e.g., topography, sediment type, water masses) for resolving biotopes at EUNIS Level 3 and herring spawning habitats, (ii) what are the responses of the identified habitats to anthropogenic impacts (fishing and dumping), (iii) which acoustic or direct sampling technology are the most effective in defining both pelagic and benthic habitats and what are the advantages and restrictions of the tools and, (iv) what are the logistical constraints to planning, executing and quantitatively interpreting a multi-resolution survey. Surveys were carried out from the “R.V. Celtic Voyager” utilizing a combination of multibeam and dual-frequency single beam echo sounder, acoustic ground discrimination systems, pinger sub-bottom profiler, video traverses, plankton hauls, grab and dredge sampling and oceanographic measurements. This paper discusses the adopted 3-Dimensional approach to data interpretation and demonstrates the success, repeatability and applicability of nested surveys, such as this for identifying relationships between the benthos and associated pelagic environment.

Keywords: nested multi-disciplinary surveys; habitat mapping; oceanography.

Contact author:
Fiona Fitzpatrick, Marine Institute, Parkmore, Galway, Ireland [tel: +353 (0)91 730 400, Direct: +353 (0)91 730 484, Cell: +353 (0)87 2458 143, e-mail: fiona.fitzpatrick@marine.ie].

ICES CM2005/U:19

The three-dimensional GIS using sonar information for coastal fisheries

Akira Hamano and Hideaki Tanoue

The imaging of acoustic data in 3D is an effective tool for examining the target distributions, and shoal behavior. In this study, the sector-scanning sonar was used for collecting the distribution of fish schools. The echo data as the base information of the present study were collected in November 2000 from the coastal area around the southern Japan Sea. Furthermore, the GIS technique was used to demonstrate the spatial distribution of the schools on a three-dimensional map. In order to extract the school area from the sonar image, the binarization method of discriminant analysis was used for determining the threshold value. The 3D view used this school area could be drawn using the GIS spatial analysis. This 3D view can provide the animation image for us, the images of fish schools could be easily observed from a different perspective, angle or altitude. From this visualization, it was found that (1) the distribution of schools were concentrated around the seamount and artificial reef areas, (2) about 56% of the fish schools are distributed in the layer from 20 m to the sea bottom, (3) the number of school images was 344 on the starboard side, 129 on the port side, and
119 below the ship. The combined use of information from the GIS spatial analysis and acoustic method has provided a significant step in determining the real features of schools in the waters.

Keywords : 3D-GIS, sonar information, binalization method, artificial reef.

Contact author:
Akira Hamano: National Fisheries University, 2-7-1, Nagata-honmachi, Shimonoseki, 759-6595, Japan [tel +81 832 86 5111, fax: +81 832 86 7432, e-mail: ahamano@fish-u.ac.jp].

ICES CM 2005/U:20

Visualisation of coastal internal waves in plankton scattering layers during fisheries acoustic surveys

Juan Zwolinski, Paulo Oliveira, and Yorgos Stratoudakis

Internal waves (IWs) are ubiquitous wherever strong tides and stratification occur in the neighbourhood of irregular topography such as the continental shelf break. Although their effect in coastal marine communities has seldom been studied, their propagation can induce turbulence and mixing of the coastal waters, fertilising the depauperate stratified waters. Their study is usually performed using satellite imagery analysis and/or oceanographic instruments deployed on fixed moorings that are able to measure the vertical displacements of water properties over time. Nevertheless, the signature of IWs can often be identified in echograms at the frequencies regularly used for fisheries acoustic surveys. During the Portuguese acoustic surveys directed to sardine, IWs are frequently visible within the planktonic superficial scattering layers. Here, we present a preliminary description of IWs detected on the Portuguese continental shelf by a scientific Simrad EK500 at 38 kHz. Echogram signatures are analysed in conjunction with the vertical density structure of the water column obtained from CTD casts, namely the characteristics of the pycnocline layers where most IW energy propagates.

Keywords: Internal waves, Portuguese continental shelf, vertical stratification, echosounder.

Contact author:
Juan Zwolinski: INIAP/IPIMAR, Av. de Brasilia 1449-006, Lisboa, Portugal [tel: +351 213027120, fax: +351 213015948, e-mail: juan@ipmar.pt].

ICES CM 2005/U:21

Analysis of spatial distribution characteristics of fishing species as the important factor in stock management

S. M. Kasatkina, V. F. Ivanova, and Yu. V. Kadilnikov

In this paper the results of research fulfilled during the last decade at AtlantNIRO on the problem of pelagic commercial species spatial distribution characteristics integration into the procedures of fishery analysis and fishable biomass monitoring are summarized. The system of distribution characteristics assessment of fish schools in two- and three-dimensional space using acoustic observations is presented. The effect of fish spatial distribution parameters on the technical accessibility of fishable biomass to the fisheries systems (trawl catchability, catch per hour of trawling) is considered. The possibility to detect potential fishing grounds and to estimate the fishable biomass and the size of possible catches from these grounds on the basis of incorporating the analysis of fish spatial distribution parameters into the acoustic survey practice is demonstrated. The results obtained in the Scotia Sea and Southeastern Pacific Ocean are presented as illustrations.

Keywords: characteristics of fish spatial distribution patterns, acoustic survey, accessibility of fishable biomass to the fisheries systems, detection of potential fishing grounds.

Contact author:
S. M. Kasatkina: Atlantic Research Institute of Marine Fisheries and Oceanography (AtlantNIRO), 5 Dm. Donskoy Str., Kaliningrad, 236000 Russia [tel: +7 112 225 769, fax: +7 112 219997, e-mail: ks@atlan.baltnet.ru].
The Humboldt Current Ecosystem (HCE) is mainly characterized by a predominance of pelagic species that have adapted to high variability on the hydrological conditions and frequent changes in the composition of plankton communities. Along the Peruvian coast anchovy (*Engraulis ringens*) is the most abundant fish whose general spatial patterns of distribution are known though details of its aggregative dynamic have rarely been described nor its relationships with the identity and local abundance of zooplankton. One of these zooplankton species is the likewise abundant munida (*Pleuroncodes monodon*) that is a crustacean not endemic to the northern region of the HCE though its distribution greatly overlaps with anchovy. We hypothesize that presence of munida inhibits or modifies the aggregative dynamic of anchovy. To address these relationships an acoustic survey on behavioral ecology was performed during November 2004 over two small zones with different features. The survey was designed to determine interactions and diel patterns of aggregation and lasted 28 hours in each zone, and was followed up by trawling, biological samplings and oceanographic casts over the same time period. We produced 3D echograms to facilitate comparisons of echo traces and to determine analogies and differences between the zones. In the first zone (Pucusana) both anchovy and munida were recorded. The second zone was useful for comparative purposes because anchovy alone was detected. Among other aspects it was observed that formation of anchovy schools at dawn was faster in areas where the munida was scarce or absent.

**Keywords:** echo-sounder, diel cycles, behavior, school, layer, aggregation, dispersion

**Contact author:**
Mariano Gutierrez: Peruvian Marine Research Institute - IMARPE, Esq. Gamarra y Valle s/n Chucuito, Callao, AP22, Peru [fax: +51 (1) 429 1858, e-mail: mgutierrez@imarpe.gob.pe].

---

**ICES CM 2005/U:23 - Withdrawn**

**ICES CM 2005/U:24**

**Uncertainty in acoustic estimation of abundance in a unstable multi-species environment**

Juan Zwolinski, Paul G. Fernandes and Yorgos Stratoudakis

The Iberian sardine (*Sardina pilchardus*) stock is regularly monitored by acoustic surveys for assessment purposes. In the Southern Iberia Peninsula, which accounts for around 20% of the stock landings, adult and juvenile sardine co-exist with several other pelagic species like chub mackerel (*Scomber japonicus*), anchovy (*Engraulis encrasicholus*), bogue (*Boops boops*), horse mackerel (*Trachurus trachurus*). Estimates of the abundance and distribution of sardine are, therefore, sensitive to the methods by which the acoustic data are allocated to this and/or other species. The method that is commonly used is to partition the acoustic data on the basis of trawl catches. Generally a good number of trawl hauls are obtained, but there is a distinct lack of geographical species preference, and hence a lack of homogeneous strata. Preliminary studies have shown that the overall sardine abundance would change by up to 25% of it's original value, if a single trawl catch was removed. In this work, we analysed recent acoustic surveys in the Cadiz region and, with the use of a jackknife procedure on the trawl hauls, we obtain variance estimates of sardine abundance due to the allocation of species proportions according to the trawl hauls. This procedure is combined with spline-based modelling of the acoustic energy, using positional, biological and oceanographic descriptors. This enables the construction of confidence intervals for sardine biomass estimates accounting both for variation due to acoustic sampling and the allocation of energy to species.

**Keywords:** Acoustic estimation, echo-integral partition, trawl composition, variance.

**Contact author:**
Juan Zwolinski: INIAP/IPIMAR, Av. de Brasilia 1449-006, Lisboa, Portugal [tel: +351 213027120, fax: +351 213015948, e-mail: juan@ipmar.pt].
Tidal front dynamics and Pacific sardine aggregations in Bahia Magdalena, south west coast of Baja California, México

Carlos J. Robinson and Jaime Gómez-Gutiérrez

We observed the association of high abundant zooplankton standing stocks, Pacific sardine schools and top predators (pelicans, dolphins, and sea lions, among others) with the tidal-front dynamic in Bahia Magdalena (BCS, México) using a split bean echosounder (SIMRAD EY-60, 120 kHz), an underwater video-camera, an ADCP, several continuous subsurface sensors (temperature, oxygen, fluorescence, turbidity, and nitrates) and standard CTD oceanographic data. Tidal fronts were first visually located during the day (and corroborated by continuous sensors) on board the “RV El Puma” and we followed the evolution of the front during two complete tidal cycles (48 h) in most part of the Magdalena Bay basin. Cross-front high resolution observations show that the fronts are formed when warm, well oxygenated and productive waters from the bay are confronted with the cold, low-contend oxygen up-welled waters from the continental shelf. The fronts were strong and move until the middle part of the bay during periods where tidal currents exceed 100 cm s⁻¹ (-0.5 to 2 m tide range) having SST ranging between 14 and 17°C in all the bay and fronts were weak near the mouth during periods with current speeds < 70 cm s⁻¹ (<1 m tide range) with SST ranging between 18 and 22°C indicating a significant change in the environmental conditions in the bay caused only by the tides. During the strong front-ontogenesis period the current velocity and direction of the bay’s water is slower (southeast) than oceanic water (northwest), the friction and the non parallel current flow induced an upwelling event along the front, which was evident only in the first 10-15 m depth. High concentration of zooplankton (copepods mostly from the continental shelf) and red crabs (*Pleuroncodes planipes*) were physically accumulated near the surface, where active predation occurred by small pelagic fish (pacific sardine, pacific mackerel) and top-predators from the area. Phytoplankton (fluorescence and cell counts) usually was larger in the bay’s water mass than in the shelf’s water mass while nitrate concentration had the opposite trend. We show how physical environmental conditions, phytoplankton and zooplankton biomass variability caused by the tidal currents affect the trophodynamic of the bay with similar or even stronger variability than the previously observed in seasonal and year-to-year scales. Thus, our understanding of the small pelagic dynamics population in this region could significantly improved if we understand the variability imposed in period similar or smaller than sardine embryo development with a narrower environmental window than adults.

Contact author: Jaime Gómez-Gutiérrez: Departamento de Plancton y Ecología Marina, Centro Interdisciplinario de Ciencias Marinas, Av. IPN s/n, A.P. 592, C.P. 23096, La Paz, Baja California Sur, México [e-mail: jagomezg@ipn.mx].

TS measurement of capelin (*Mallotus villosus villosus*) in situ at 38 kHz frequency in the Barents Sea

Vicheslav. A. Ermolchev and T. M. Sergeeva

The relationship of target strength and fish length TL: TS = 19.1 log(TL)–74.0 is used in the trawl-acoustic surveys (TAS) for assessment of capelin (*Mallotus villosus villosus*) stock. In this paper we present the results of TS measurement of capelin with different length TL *in situ*, at the frequency of 38 kHz in the different areas of the Barents Sea. The investigations were conducted by the research vessels (RVs) “Persey–3”, “AtlantNIRO”, “Smolensk” and “Fridtjof Nansen” equipped with SIMRAD EK500 and EK60 research echo sounders with the split-beam transducer for direct measurements of fish target strength during the trawl-acoustic surveys in 2000-2004 (aboard RVs “Smolensk” and “Fridtjof Nansen” EK60 echo sounders have been used since August 2004). The echo sounders are connected to an IBM PC with the specially developed LTSD100 (Length and Target Strength Distributions) and FAMAS (Fisheries Acoustic Monitoring & Analysis System) software developed in PINRO and TINRO, respectively, to collect and process the results of measuring fish target strength. Based on the processing of the data on capelin target strength in the fishing zone and this fish length composition in the catches derived was the acoustic target strength relationship for capelin with length of 4.4-18.7 cm: TS(PINRO) = 21.4 log(TL)–75.4. In our opinion, using the current relationship TS = 19.1 log(TL)–74.0 instead of that one obtained by us leads to the underestimation of capelin target strength and the overestimation of abundance and biomass values.

Keywords: abundance, biomass, capelin, cod, fish length, target strength *in situ*.

Contact author: Viacheslav A. Ermolchev: Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Str., 183763, Murmansk, Russia [tel: +007 (8152) 47 35 83, fax: +007 (8152) 47 33 31, e-mail: eva@pinro.ru].
The importance of smoothing in estimating swimming speed from hydroacoustic fish tracks

Karl Øystein Gjelland, Frank Reier Knudsen, and Helge Balk

Swimming speed estimates obtained from non-smoothed hydroacoustic data are likely to be overestimated due to instability in single echo detections. In the present study, field and experimental data was used to derive swimming speeds from tracks detected with stationary split-beam hydroacoustics. Swimming speeds were estimated from both smoothed and non-smoothed tracks to investigate the effect of smoothing. Smoothing was performed using a robust locally weighted regression for each dimension, giving a 3-D smoothed swimming trajectory. Fish tracks from field observations were used to explore the shape of the swimming trajectories and the effects of smoothing with different widths of the smoothing window. The overall best smoothing window from the fish track analysis was then applied to experimental data obtained with a calibration ball at different speeds and ranges. The results showed that the estimated swimming speeds of non-smoothed fish tracks can be heavily biased. Whereas the bias increased with range and ping rate, it was inversely related to the true swimming speed. We conclude that hydroacoustic fish tracks should be smoothed to yield reliable swimming speed estimates.

Keywords: Hydroacoustics, swimming speed, smoothing techniques.

Contact author:
Karl Øystein Gjelland, Department of Aquatic BioSciences, University of Tromsø, 9037 Tromsø, Norway [e-mail: Karl.Gjelland@nfh.uit.no].

Direct spectral calibration of an experimental wideband echosounder. Procedures and results

Bo Lundgren and J. Rasmus Nielsen

This paper describes a part of on-going experiments aimed at using wideband acoustic instrumentation in order to increase the possibility to directly recognize and discriminate between various species in-situ. This would mean progress in mapping the three-dimensional distributions of fish and plankton layers needed both in fisheries research and for resource and echo system management. Preliminary results of ex-situ measurements of wideband (80 – 220 kHz) acoustical backscattering from free-swimming juvenile gadoids have previously been presented. To carry out the measurements an experimental echosounder was constructed. The paper describes the various procedures used to calibrate the wideband sounder, among them the use of the standard copper sphere technique. Calibration results are presented, and the uncertainties involved are discussed. Some suggestions for improved procedures are also discussed.

Keywords: Broadband acoustics, wideband echosounder calibration, species recognition, TS, target strength, 3D-localization.

Contact author:
Bo Lundgren: Danish institute for Fisheries Research (DIFRES), Gear Technology Section, North Sea Centre, P.O.Box 101, DK-9850 Hirtshals, Denmark [tel: +45 33963200, fax: +45 33963260, e-mail: bl@difres.dk].

On measurements of cod target strength in situ in the Barents and Norwegian Seas

Viacheslav A. Ermolchev

During the acoustic surveys for cod stocks in the Barents and Norwegian Seas the relationship of target strength (TS) and the fish length (TL) are used: TS = 21.8 log(TL) - 72.7 and TS = 20 log(TL) – 68. This paper presents the results from the investigations of cod target strength TS in situ depending on length TL at 38 kHz frequency in the different areas of the Barents and Norwegian Seas. The investigations were carried out in 1998-2004 by RVs “Persey-3”, “AtlantNIRO”, “Smolensk” and “Fritjof Nansen” in the course of the trawl-acoustic surveys to estimate the cod stocks using “SIMRAD” EK500 and EK60 research echo sounders equipped with split beam transducers providing for direct measurements of the target strength (aboard RVs “Smolensk” and “Fritjof Nansen” the echo sounders have been applied since August 2004).

The echo sounders were connected to IBM PC with special LTSD 100 (Length and Target Strength Distributions) software developed in PINRO and FAMAS (Fisheries Acoustic Monitoring and Analysis System) software elaborated
in TINRO for collection and postprocessing of fish target strength marine measurements. Based on the processing of acoustic and biological data, we obtained the following target strength relationship for cod 5–123 cm in length:

\[
TS(\text{Cod}) = 24.6 \log(TL) - 73.5.
\]

In our opinion, the use of current cod target strength relationship leads to the underestimation of their biomass and abundance.

Keywords: abundance, biomass, cod, fish length, target strength in situ.

Contact author:
Viacheslav A. Ermolchev: Polar Research Institute of Marine Fisheries and Oceanography (PINRO), 6 Knipovich Str., 183763, Murmansk, Russia [tel: +7 (8152) 47 35 83, fax: +7 (8152) 47 33 31, e-mail: eva@pinro.ru].

ICES CM 2005/U:30 – Poster

Planned observations of interactions between Antarctic krill “Euphausia superba” and predators using a multi-beam sonar

Martin J. Cox and Andrew S. Brierley

We are investigating predator-prey interactions between Antarctic krill and air breathing predators. To enhance an existing dataset comprising concurrent split-beam echosounder data and surface based predator observations we plan to deploy a multi-beam imaging sonar (Simrad EM3002, 300 KHz). Multi-beam data will be collected from the RRS James Clark Ross along ship transects as part of a British Antarctic Survey multi-disciplinary cruise around South Georgia (54°S, 35°W) in November 2005. The multi-beam head will be mounted on a through-hull gate valve pole system and inclined to insonify a volume of water from sea surface to below the vessel. This will allow us to overcome two problems with the existing data collection regime. Firstly, the region of the water column from the surface to a depth of 10 m is not sampled by conventional hull-mounted echosounders. These multi-beam data will allow assessment of the interactions between krill and air breathing predators that are constrained to forage in the top few metres of the water column. Secondly, visual predator sightings were recorded in an area to the front of the vessel. Conventional echosounders only insonify a fraction of the water column below this area, which could lead to an apparent disassociation of predator-prey activity.

Multi-beam data will overcome this problem by sampling a swath to the side of the ship. This may lead to improved understanding of krill-predator spatial relationships.

Keywords: Antarctic krill, multi-beam echosounder, predator-prey interactions.

Contact author:
Martin J. Cox: Pelagic Ecology Research Group, CREEM, The Observatory, Buchanan Gardens, University of St Andrews, Fife, KY16 9LZ, Scotland, UK [tel: +44 (0) 1334 461819, fax: +44 (0) 1334 461800, e-mail: mjc16@st-andrews.ac.uk].