

Theme Session I

Quantifying, summarizing, and integrating total uncertainty in fisheries resource surveys

ICES CM 2006/I:01

Incorporating bottom type information into survey estimates of sea scallop (*Placopecten magellanicus*) abundance

S. J. Smith, M. J. Lundy, B. J. Todd, V. E. Kostylev, and G. Costello

The sea scallop (*Placopecten magellanicus*) population off Southwest Nova Scotia in scallop fishing area 29 has been monitored by an annual drag survey since the fishery started there in 2001. From 2002 to 2004, a stratified random survey design was used with management subareas used as strata. New strata based upon surficial geology maps from a recently completed multibeam bottom mapping and geology groundtruth project in this area were used for the 2005 survey. The results of this survey confirm that variations in scallop densities are related to surficial bottom type. As a result variations in annual trends in scallop abundance may be partly explained by annual variation in bottom type coverage by the survey. In this paper, we compare design-based, model-assisted design-based, and model-based methods for estimating annual estimates of scallop abundance that incorporate bottom type information.

Keywords: stock assessment, sample survey theory, Bayesian methods.

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ICES CM 2006/I:02

A Bayesian gear change: estimating and using a correction factor for survey catchability

Michael C. S. Kingsley, Kai Wieland, Michael Rosing, and Carsten Hvingel

The gear used in the West Greenland trawl survey for northern shrimp has recently been changed from a Skjervøy 3000 to Cosmos 2000. Calibration trials for catchability of northern shrimp were performed by fishing twice over the same track with either the same gear twice or with different gear. Relationship between first and second catches was not independent of the density of shrimp. A density-dependent model for the estimation of survey index was built and fitted using Bayesian methods. The resulting estimate of the change in the survey index, with its Bayesian posterior uncertainty distribu-

tion, was then available for use in fitting an assessment model by Bayesian methods. Bayesian priors could be provided both for the change in systematic survey error and for the random between-survey sampling error.

Keywords: survey error, Bayesian analysis, Bayesian assessment, Calibration trials.

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ICES CM 2006/I:03

Uncertainty in surveys carried out using non-independent sampling: quantifying and summarising

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Equiprobable sampling is the statistician's touchstone, but resource surveys often-even usually-depart from independent random designs. In comparing different design methods, we find that the expected true uncertainty of a survey estimate is negatively related to the expected estimate of survey uncertainty given by conventional expressions. Equiprobable designs offer unbiased estimates of error variance, for other designs, unbiased estimates are not usually available. Systematic or quasi-systematic designs, that under positive spatial autocorrelation have smaller true uncertainty than equiprobable designs, may at first sight appear more uncertain. The problem of estimating sampling uncertainty for non-equiprobable designs will be discussed and some practically useful methods of obtaining estimates of uncertainty will be offered.

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ICES CM 2006/I:05

Estimating end effect in trawl catches

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The end effect in trawl catches is defined as the proportion of fish caught during the shooting and hauling of the net, a period excluded from the nominal haul duration. If important, this effect will lead to biased abundance esti-

mates, as the swept area will be underestimated. An experimental survey was carried out to compare catch numbers obtained by standard 30 minute hauls to those from 0 minute hauls, in which the trawl was hauled as soon as the trawl geometry stabilised on the bottom. Average catch ratios (0 min/30 min hauls) ranged from 0.05 (s.d. 0.06) for sole (*Solea solea*) to 0.34 (s.d. 0.64) for hake (*Merluccius merluccius*), indicating that the end effect might be more important and more variable for highly mobile species. As a consequence, the bias in abundance indices derived from swept area estimates and which ignore end effects will be species-dependent.

Keywords: trawl survey, abundance index, bias.

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ICES CM 2006/I:07

Spatial scale and statistical variability found in fishery survey data

Daniel Kimura

We all know that survey catch data is highly variable, but what is the best statistical structure to place on sample catches? On the smallest scale, catches can be characterized as Poisson (mean=variance). However, when sampling is extended to even modestly larger scales, typical of trawl hauls, the sampling appears non-homogeneous. Early researchers realized this and derived "contagion distributions" among which the negative binomial has been the most useful (variance>mean). The negative binomial distribution has allowed researchers to derive useful information, such as the CV(catch) corresponding to a particular length of tow, or an optimal tow length. On larger spatial scales, variability can be characterized as spatial covariance, where the process being sampled is stationary, and the covariance function can be described as a function of distance between observations. This sort of spatial data has more recently been analyzed using such statistical models as kriging and random field linear models. When interpreting analysis from these spatial models, time scales in addition to distance scales become important considerations.

Keywords: survey sampling, spatial variability, kriging, random field linear models.

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ICES CM 2006/I:08

Size and condition of mackerel in research vessel trawl hauls versus commercial purse seine catches: implications for acoustic biomass estimation

Aril Slotte, Dankert Skagen, and Svein A. Iversen

In September, after the summer feeding has ceased, the Northeast Atlantic mackerel (*Scomber scombrus*) stock tends to aggregate in ICES Area IVa before beginning to migrate southwards in December–February towards the spawning grounds. It is during this autumn period that the Norwegian purse seine fleet catches mackerel in the southern part of the Norwegian Sea and the northern part of the North Sea (IVa). Since 1999 IMR has also carried out annual acoustic surveys to estimate the biomass concurrently with this fishery. During these surveys the mackerel has been sampled with a small pelagic trawl (20-m opening) at a speed of 3–3.5 knots, and the age, length, and weight has been measured for use in the biomass estimation. In the present study we demonstrate that the size, both in terms of length (mean length and length-at-age) and condition (weight-at-length), of mackerel caught in the research vessel trawl hauls is significantly lower than that observed in the purse seine catches from nearby commercial vessels. By using data from purse seine-caught mackerel instead of the trawl-caught ones, the biomass estimates during 1999–2003 increased by 30% on average. These results also signify the importance of being careful using research vessel trawl haul samples when estimating abundance and studying variations in growth and condition of a high-speed swimming species like mackerel.

Keywords: mackerel, trawl, purse seine, acoustic, biomass, estimation.

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ICES CM 2006/I:09

Estimates of sampling and measurement error in acoustic surveys of Antarctic krill

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Combined sampling and measurement error is estimated for acoustic estimates of Antarctic krill abundance. First, some potential sources of random and systematic error in generic echo-integration surveys are reviewed. Then, some of the primary sources of measurement error specific to krill surveys are explored. The error in system calibration is evaluated in relation to the effects of variations in water temperature and salinity on sound speed, sound absorption, and acoustic-beam characteristics. Variation in krill target strength is estimated using a distorted wave Born approximation model fitted with measured distributions of animal lengths and orientations. The variable effectiveness of a two-frequency species classi-

fication method is also investigated using the same scattering model. Because most of these components of measurement error are frequency-dependent and covariant, the total random error in acoustic estimates of krill abundance can be estimated from a Monte Carlo simulation. This strategy assumes that independent estimates of krill biomass are derived from acoustic backscatter measurements at multiple frequencies (e.g. 38, 120, and 200 kHz). Doing so, the overall coefficient of variation is generally not significantly different from the sampling variance alone. That is, the measurement variance is negligible relative to the sampling variance due to the large number of measurements averaged to derive the ultimate biomass estimate. However, on different time- and space-scales, errors can switch from being random to being systematic, or vice-versa.

Additionally, potential sources of systematic errors (e.g., stemming from uncertainties in the target strength model, the species classification method, the krill length-to-weight model, bubble attenuation, signal thresholding, and survey area definition) are shown to be more appreciable components of measurement error. The methods used here are applicable to estimating total error (random and systematic sampling and measurement error) in acoustical survey estimates of other species.

Keywords: random and systematic error, measurement uncertainty, acoustic surveys.

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ICES CM 2006/I:10

Acoustic extinction in dense herring layers, measured from a bottom-mounted transducer

Kjell R. Utne and Egil Ona

Herring is often found in dense aggregations or schools, and acoustic shadowing is thus a problem in acoustic survey estimates. Knowledge of the attenuated echo intensity in herring aggregations is essential for correcting the measured area backscattering coefficient for extinction. The attenuation is measured through the extinction coefficient (σ_e/σ_b), which can be found by analyzing the reduction in echo intensity from a reference target while different densities of fish are located between the transducer and the reference target. In this study, the transducer was bottom-mounted and the sea surface was used as a reference target. The paper will present new data on the extinction coefficient for herring, as well as its variability. This variability has further been used to estimate the uncertainty in the correction algorithms for a typical herring survey.

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Seasonal variability in cod target strength

Egil Ona

The acoustic target strength of adult cod (*Gadus morhua*) was measured *ex situ* in a large, 4500 m³ experimental net pen at the IMR Austevoll aquaculture station in eight periods between November 1996 and May 1998. A calibrated Simrad EK500 split beam echo sounder was used to collect the acoustic data from a vertically observing transducer, positioned in the middle of the 21-m deep net pen. Groups of about 20 individual cod were transferred from the control storage population in each measurement series, but moved in every other aspect freely within the experimental net pen during the acoustic measurements. Natural variations in gonadosomatic index as well as changes in condition factor from an enforced starvation was monitored and correlated with changes in target strength. A General Linear Model (GLM) was used to estimate the functional relationship between the target strength at 38 kHz and important biological parameters. The significant ones were: Condition factor (CI), Liver index (LI), the spread of the tilt angle distribution (SDTILT), while the gonadosomatic index (GSI) mean swimming angle (MT) and the swimbladder index (SI) were not significant. For cod between 50 and 60 cm size, the target strength relationship is suggested to be:

$$\langle TS \rangle = 20 \log L - 64.0 - 0.099(\text{SDTILT}) + 2.44(\text{LI}) - 1.86(\text{CI}),$$

where the effect of the tilt angle may be converted to a day/night effect. With a normal liver index and condition factor, the new mean target strength is slightly higher than the one used in the surveys, but corresponds well to the experimental nighttime observations. The *ex situ* data are compared with recent *in situ* target strength measurements.

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Timely evaluation of stock status based on scientific surveys, an update

Michael Pennington and Odd Nakken

The usual method for assessing a fish stock for which scientific surveys and commercial catch statistics exist is to use the survey series to 'tune' a VPA-type model. Such assessments are often subject to rather large revisions as more catch data for cohorts remaining in the fishery become available. It is conjectured that one reason VPA abundance estimates for cohorts still tend to be variable in the fishery and are often biased is that the relation between the age composition of the commercial catch and the actual population is unknown, and this relation likely varies from year to year. It is suggested that

for some species a more stable method for assessing the current condition of the stock would be to reverse the roles played by survey and catch data. That is use abundance estimates based on historical catch data (*i.e.* catch statistics for cohorts that are no longer in the fishery) to calibrate the survey series. As an example, converged VPA-type abundance estimates of Northeast Arctic cod (*Gadus morhua*) during a calibration period were used to 'tune' a yearly bottom trawl survey of this stock. For the two age groups considered in this paper, the survey-based procedure generated estimates of subsequent converged VPA estimates that were usually more precise than the annual estimates. Since survey-based estimates will not be revised and would be available as soon as the survey is completed, it is concluded that they would form a timely basis for developing and implementing a stable management strategy.

Keywords: survey calibration; survey variability; virtual population analysis; Northeast Arctic cod.

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Estimating and decomposing total uncertainty for survey-based abundance estimates of Norwegian spring-spawning herring

Magne Aldrin and Anders Løland

We demonstrate how the total uncertainty of the abundance estimate and abundance-at-age estimate of Norwegian spring-spawning herring are affected by uncertainty in the parameters of vessel avoidance, shadowing, and depth-dependent target strength, and uncertainty from trawl hauls and spatial-temporal coverage. The total uncertainty is decomposed into the sum of the contribution from each source separately. In addition, we highlight the potentially dramatic combined effect of correcting for vessel avoidance, shadowing, and depth-dependent target strength on the abundance estimate. The main framework is believed to be a promising tool for focusing the effort for reducing the uncertainty in the abundance estimates. The method is applied to data from surveys on the over-wintering stock in the Vestfjord system and Vesteraalen in northern Norway in November/December in the years 2001–2004.

Keywords: total uncertainty, uncertainty decomposition, abundance estimation.

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ICES CM 2006/I:14

Estimating uncertainty in Baltic acoustic survey results applying geostatistic techniques and simulation

S. M. Kasatkina and P. S. Gasyukov

Baltic acoustic surveys provide major information for the assessment of abundance indices applied in tuning integrated statistical methods of fish stock assessment. Therefore, abundance indices should be accompanied by uncertainty estimates and this uncertainty must be incorporated into assessment models. In this work the methods developed for quantifying and summarizing components of sampling survey uncertainty are considered. On the basis of acoustic survey data processing algorithms and simulation with the Monte Carlo method, the total survey uncertainty in biomass and abundance values as a function of major affecting factors are estimated. The spatial variability of the acoustic index NASC ($\text{m}^2/\text{m.mile}^2$) and species-length structure of fish within the survey area, as well as uncertainty in the target strength estimates were chosen as the uncertainty sources. This method was improved by including a geostatistical approach for NASC values. It was stipulated by the results of the NASC spatial structure analysis using the appropriate variograms. The latter revealed that NASC fields cannot be represented by independent random values and should be treated as coherent spatial formations. Practical application of both developed methods is demonstrated in the example of the Baltic acoustic survey. The effect of different sources stipulating uncertainty in fish abundance indices is discussed showing statistical characteristics of corresponding estimates obtained within individual ICES statistical rectangles and within the total studied area. Finally, we show that the proposed simulation method can be used not only for estimating the survey uncertainty, but can also be applied to look for ways to reduce these uncertainties by means of improvement in survey sampling strategy and data processing.

Keywords: uncertainty, acoustic survey, simulation method, geostatistical approach.

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Evaluating the uncertainty of abundance estimates from acoustic surveys using geostatistical conditional simulations

Mathieu Woillez, J. Rivoirard, and P. Fernandes

Linear geostatistics, *i.e.* geostatistics based on the variogram, provides methods for estimating a spatially distributed abundance with its estimation variance. However, in complex situations, such as combining acoustic

and biological data (mean length, proportion at age), these methods are limited. As an alternative, geostatistical conditional simulations which allow reproducing the spatial variability of a variable, are particularly helpful to combine the different sources of variability.

In this paper, we investigate the uncertainty of acoustically surveyed Scottish herring estimates using a specific multivariate model. This includes highly skewed distributions for the acoustic as well as relations between depth, mean length, and proportion at age. Conditional simulations, i.e. simulations which honour the data values known at the data points, are used to generate multiple realisations for acoustic, fish mean length, and proportion at age. These are combined to produce multiple realisations of herring density over the sampled domain. All realisations also provide the error structure for the global abundance estimate at age. The method is used to assess the uncertainty from acoustic surveys on Herring for each year during the period 1989–2003 and then to track significant variations of abundance over the time-series.

Keywords: geostatistics, simulations, acoustic survey, herring.

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The effect of missing acoustic observations (dropped pings) on mean area density estimates of Antarctic krill (*Euphausia superba*)

Martin J. Cox, Jonathan L. Watkins, Monique L. MacKenzie, and Andrew S. Brierley

Acoustic surveys typically sample continually along transect, and line-transect theory is applied to determine mean area density and variance estimates. When the water column under a hull-mounted echosounder transducer becomes aerated or the transducer orientation changes rapidly, for example during rough weather the continuous data are interrupted as pings are dropped. The purpose of this investigation is to determine if missing pings bias area density estimates of Antarctic krill (*Euphausia superba*).

Acoustic survey data collected during three consecutive years were assessed. Data were collected from the RRS *James Clark Ross* at South Georgia (54°S 35°W) as part of a British Antarctic Survey long-term monitoring programme. Mean density ranged from 9.81 g/m² (CV=33.6%) to 48.54 g/m² (CV=12.1%), the lowest being during the worst weather. The perception is that bad weather might negatively bias mean density estimates: the ship is able to continue operating in conditions essentially too poor for acoustic surveying. Missing pings were identified visually from 38 KHz echograms. The

proportion of missing pings in each 250-m integration interval was used to inflate the krill nautical area scattering coefficient (NASC), and these inflated NASC values were used to recalculate mean krill density and variance estimates, using the standard Jolly and Hampton approach.

For all three years, the mean krill area density estimates increased by a maximum of 5.14% (95% confidence intervals: 2.53 to 9.84%), when missing pings were inflated. Simulations removing varying proportions of integration intervals showed that the proportion of missing pings encountered during the three survey years considered here did not bias mean area krill density estimates significantly.

Further work is required to develop techniques to identify missing pings objectively. Given the spatial heterogeneity in krill density, the effect of missing pings at smaller scales should be considered.

Keywords: Antarctic krill, missing pings, mean area density estimates.

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ICES CM 2006/I:18

Biomass estimation using the new scientific multi-beam echo sounder ME70

Valerie Mazauric, Laurent Berger, and Verena Trenkel

Multibeam echo-sounders and sonars are increasingly used in fisheries acoustics due to their ability to sample a much larger area than traditional vertical echo-sounders. They have been used much to study school structure and behaviour, and to some extent for school abundance estimation by school counting and school area to school biomass conversion. Recent research conducted at Woods Hole has led to the proposal of a protocol for calibrating generic multibeam echo-sounders in order to use them directly for biomass estimation.

However, the quality of the data of existing multibeam echo-sounders is not comparable with classical single-beam echo-sounders used for biomass estimation. The signal to noise ratio remains too low for advanced quantitative biomass estimation due to the technical principle used for forming the beam in these equipments. In order to solve this problem, Ifremer and Simrad AS have in 2003 started the development of a multibeam echo-sounder (ME70) which improves the quality of the data for biomass estimates.

Preliminary biomass estimation has been carried out using multibeam data collected onboard the FRV “Tha-

lassa" in the Bay of Biscay in February 2006. First comparisons with single-beam data collected at the same time on small pelagic species (horse-mackerel, mackerel, ...) confirms the similarity in the type of data. Gains in sampling coverage and higher resolution of the data are analysed to propose a preliminary biomass estimation method.

Finally, potential bias in biomass estimates of existing methods based on single-beam echo-sounders is estimated for comparison.

Keywords: fisheries acoustics, multibeam echo-sounder, single-beam echo-sounder, sampling coverage, resolution, biomass estimation method.

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An overview of sources of bias and uncertainty in fisheries surveys

Hans Gerritsen

Sources of error in fisheries surveys are identified and gaps in the literature are addressed using data from groundfish surveys carried out around Ireland. Much of this work is driven by the requirement for precision estimates under the EU Data Collection Regulations 1637/2001 and 1581/2004.

Error estimates are quantified for the following estimates:

- Length measurements. Spatial variation in length distributions is addressed as well as operator bias. Additionally, a method is presented to quantify the error of a length distribution, incorporating the uncertainty at each length class.
- Length-weight relationships. The spatial variation in length-weight relationships is often ignored, but significant differences were found between adjoining stocks of haddock.
- Sex ratio. Due to differences in behaviour, migration, and growth, sex ratios can be difficult to estimate. An example is given of megrim, whose sex ratio in the catches is strongly dependent on the depth.
- Maturity. Operator error is potentially a significant source of error for the assignment of maturity stages. The results of an inter-rater reliability study on plaice and whiting gonad staging are presented. Migration patterns during the spawning season can be another source of bias, which is illustrated using the proportions mature-at-age of Irish Sea cod.
- Age. Operator error in ageing has received much attention and an overview of the literature is given. Spatial patterns in the age-length struc-

ture are illustrated using west of Scotland haddock. These patterns can result in significant bias if they are not taken into account in the sampling design.

Keywords: precision, bias, survey, operator error, spatial variability.

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ICES CM 2006/I:20

Uncertainty in *in situ* target strength measurement of blue whiting (*Micromesistius poutassou*)

Geir Pedersen, O. R. Godø, E. Ona, T. Torkelsen, and R. Pedersen

In situ target strength measurements of blue whiting were performed during the annual survey of the main spawning areas of blue whiting west of the British Isles from 2003–2006. Additional data has also been collected on a separate methodology cruise. The measurements were performed using Simrad EK60 echosounders with pressure stable transducers (38 and 120 kHz). In order to obtain high quality target strength data several different submersible measurement platforms were used in these experiments, ranging from simply a stationary submersed transducer to a large moving towed body. Potential platform effects on the results from these experiments are considered in terms of the platform influence on the fish, in addition to depth effects on fish and measurement system. The effect on the results caused by different platform stability as well as day/night difference in the observed target strength of blue whiting is also considered. The goal is to quantify the uncertainty related to the target strength of blue whiting and to obtain a new target strength relationship for this species for use in stock assessment.

Keywords: acoustic, methodology, uncertainty, target strength.

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Diurnal variation in acoustic abundance of blue whiting (*Micromesistius poutassou*) – an effect of tilt angle distribution?

Espen Johnsen and Olav Rune Godø

Annual Norwegian acoustic surveys are carried out west of the British Isles to assess the abundance of the blue whiting in the northeast Atlantic during their spawning aggregation. Analyses of the NASC values of 38 kHz

data indicated that the echo abundance of blue whiting at daytime is on average 20% higher than at night, and it was hypothesized that the bias was caused by diurnal variation in the tilt-angle distribution. The directivity pattern of swimbladdered fish show that the target strength sensitivity to tilt angle increases with frequency. We analysed blue whiting data from EK500 18 and 38 kHz and found that the frequency response $[\text{NASC}_{38\text{kHz}} \times (\text{NASC}_{38\text{kHz}} + \text{NASC}_{18\text{kHz}})^{-1}]$ varied with depth and altitude of the sun and increased with fish density. As the structure and polarization of fish within a school tend to increase with density, the results seem to be consistent with our hypothesis that the tilt-angle distribution is likely to become narrower with higher school structure. Furthermore, we discuss the results in relation to present procedures for interpreting the acoustic data and evaluate the potential of approaches to compensate for a diurnal bias in the survey estimates.

Keywords: acoustic, blue whiting, diurnal variation, frequency response, tilt angle.

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ICES CM 2006/I:22

Correcting for avoidance in acoustic abundance estimates for herring using a generalized linear model

Vidar Hjellvik, Nils Olav Handegard, and Egil Ona

When a research vessel passes over a herring school, the herring avoid the vessel by swimming downwards and sideways, and the echo abundance seen on the echo sounder does not reflect the true density of the school. The avoidance is strongest in the upper parts of the water column. This avoidance behavior has been quantified in experiments where a submerged transducer has been used to measure the changes in echo abundance during the passage of a survey vessel. In this paper a generalized linear model is fitted to the data from several experiments and it is shown how the model can be used for correction purposes. Since the parameters are estimated with uncertainty, this uncertainty can be taken into account when the fitted model is used for correcting standard survey data. However, the parameter estimates were different for the different experiments, so the model fit from one particular experiment should not be applied uncritically to correct standard survey data.

Keywords: Acoustics, uncertainty, avoidance, correction, generalized linear models.

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ICES CM 2006/I:23

Diurnal variation in frequency response of gadoids in the Barents Sea

Olav Rune Godø, Vidar Hjellvik, and Dag Tjøstheim

Earlier studies have demonstrated substantial diurnal variation in acoustic abundance of fish. Both the level and the uncertainty of abundance estimates from surveys carried out around the clock are affected. It has been hypothesized that diurnal variation in acoustic densities is caused by a diurnal variation in tilt angle. As the directivity of fish is higher at higher frequencies a diurnal variation in tilt angle will affect the acoustic recordings more for higher than for lower frequencies.

This hypothesis is tested through an analysis of the frequency response of acoustic recordings of cod and haddock from 18, 38, 70 and 120 kHz EK 60 echo sounders. The results demonstrate, as expected, a systematic diurnal change where the reduction in acoustic densities during nighttime is more prominent for higher frequencies. The result is expected since gadoids are visual feeders being active with a more directed swimming pattern at daytime than during night when they have a more relaxed swimming with more variable tilt angle. Applications of the results for improving the quality of survey abundance estimates are discussed.

Keywords: Frequency response, diurnal variation, gadoids, abundance, uncertainty.

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ICES CM 2006/I:24

How many trawl hauls, and how many fish from each haul are needed to obtain a given precision in the age structure estimate for Norwegian spring-spawning herring? A bootstrap approach

Vidar Hjellvik

The Norwegian spring-spawning herring is assessed each year from an acoustic survey. The age structure in the stock is estimated from trawl samples. The uncertainty in the age structure estimate depends both on the number of trawl hauls and the number of fish for which the age is measured within each haul. In this paper a bootstrap approach is applied to data from the Vestfjord survey in December 2002 to estimate the number of hauls/fish needed to obtain a given precision. The effort needed for a given age depends on the fraction that this age constitutes of the total number. For most age groups containing more than 1% of the total number, 45 hauls with 25 fish sampled from each haul gave a CV of about 0.05, and a doubling of the number of fish measured at each haul allowed for a 20–30% reduction in the number of hauls needed to obtain the same precision. For the mean length, a doubling of the number of fish measured al-

lowed for a reduction of about 15% in the number of hauls.

Keywords: age structure, herring, bootstrap, uncertainty, trawl sampling strategy.

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Comparing data from hull-mounted and ROV acoustics: impact on acoustic density measurements of different target-to-sensor distances

Carla Scalabrin, J. Y. Coail, G. Bavouzet, J. P. Vacherot, M. Le Goff, and J. Morard

A fisheries acoustics payload was developed to fit out platforms like the AUV ASTER-X, the ROV Victor 6000, or the ROV EROC. According to the platform or the survey objectives, the fisheries acoustics payload can be fitted with one or two echo-sounders looking up and/or downward through the water column. This paper presents results from several dives carried out during a 2006 winter survey in the Bay of Biscay with R.V. “Thalassa”. For this survey, the fisheries acoustics payload was fitted with a Simrad ER-60 200 kHz echo-sounder looking downward and mounted on the ROV EROC. The vessel is equipped with 5 similar echo-sounders operating at 18, 38, 70, 120, and 200 kHz frequencies.

Dives were carried out after trawling operations over the same track at altitudes around 20–30 m from the bottom, while the bottom depth could span from 60 to 200 m. Simultaneous vessel and ROV acoustics data were acquired, allowing comparison of density measurements from different target-to-sensor distances. The impact of target-to-sensor distance on biomass estimates and fish aggregation patterns as seen by acoustics will be discussed.

Keywords: fisheries acoustics, AUV, ROV, biomass estimates, acoustic fish shoal.

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Quantifying error sources in deepwater acoustic surveys

Ian Doonan

Research surveys are important because they provide stock sizes that are fisheries-independent and they are a major input for stock assessments, from which management advice is usually based. Resource survey series for stock assessment using acoustics need to assess several

error sources. Potential error sources include sampling error from backscatter and catches, physical processes like aeration of the seawater below the transducer and transducer motion, assumptions as in the trawl catchability of target species relative to others caught or target strength, and the like. Depending on the circumstances, not all effects are relevant and others have a low variability. Further, if the indices are used as a relative series in the stock assessment, then some sources need to be adjusted since certain bias components cancel out. Within the context of the stock assessment, year-to-year variations are accommodated as process error on the index series catchability. Individual sources can be estimated using either non-parametric or parametric bootstrapping. Currently, the parametric bootstraps are based on subjectively assigned distributions and so are simply best guesses. Individual sources can be combined assuming independence and that they combine in a multiplicative way. This appears to work reasonably well in practice. Examples are given for deepwater resource acoustic surveys (e.g., orange roughy (*Hoplostethus atlanticus*) and smooth oreo (*Pseudocyttus maculatus*)).

Keywords: Quantifying error sources, acoustic survey.

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An attempt to reduce species mis-identification in acoustic assessment by using school descriptors, including multi-frequency indices

Jacques Massé, Verena Trenkel, Caroline Kosticky, and Sonia Mehault

Specific identification of echoes is still the main bias factor in biomass estimates of fish by acoustics. A database of school descriptors has been constituted within the frame of SIMFAMI European project, based on 4 years of acoustic surveys. A regression tree analysis was carried out for a subset of the database in order to relate species identification to school characteristics, bottom depth, and time of day.

Schools were considered in areas where one species represented at least 80% of the catch during pelagic hauls. Four species were selected: anchovy, horse mackerel, sardine, and sprat. The most important variables for explaining the dominant species were first bottom depth, then time of day. These are mainly indicators of species-specific behaviour.

Different attempts were carried out and a confusion matrix was calculated by cross-validation on the final regression tree. The main species confusion seems to occur between anchovy and horse-mackerel (24% of anchovy classified as horse-mackerel), but also horse-mackerel and anchovy or sardine. Correct classifications ranged from 71% for horse-mackerel to 97% for sprat. During

the spring cruise PELGAS06, new acoustic data was collected with transducers set up to allow comparison of responses at different frequencies. A new regression tree analysis was therefore carried out in order to see if a parameter based on the 5 available frequencies (18, 38, 70, 120, and 200 kHz) can reduce the mis-identification of species according to school parameters.

Keywords: acoustic assessment, echo identification, school descriptors, regression tree.

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Evaluating the management implications of different types of errors and biases in fisheries resources surveys using a simulation-testing framework

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Many fish stocks are heavily exploited in Europe and stock assessments are highly dependent on fishery-dependent data. One problem is that this approach tends to ignore potential biases and errors in observations due to misreporting. The purpose of this research is to evaluate the potential merits of utilising mainly fishery-independent data in fisheries management. With this in mind, a simulation-testing framework consisting of an operating model, an observation error model, and a harvest control rule model has been developed. Different potential types of errors and biases are modelled in an observation error model. Advice provided by harvest control rules based on fishery-dependent data only, a combination of fishery-dependent and independent data, and fishery-independent data only is compared to evaluate whether the fishery-independent methods can supply a viable alternative fisheries management approach to fishery-dependent ones. The case study is the North Sea herring (*Clupea harengus*) fishery.

Keywords: fishery-independent data, harvest control rules, management procedure, North Sea herring, observation error model, operating model, simulation.

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Sequential geostatistical simulation methods to assess the error distribution function for biomass determined from acoustic survey data

Paul Walline

Sequential Gaussian and indicator geostatistical simulation methods can be used to calculate empirical confidence intervals and error distribution for biomass determined from acoustic surveys. Such simulation methods have several advantages: precision can be estimated in the presence of autocorrelation and non-random sampling, the combined variance of the acoustic and fish length-frequency measurements can be estimated empirically rather than analytically, an empirical probability density function (pdf) of the abundance estimate is generated by simulation, and can be used, for example, in power calculations. Furthermore, because the simulations are spatially explicit, it is possible to examine the precision of indices that characterize spatial distribution, such as center of gravity and inertia. Examples from the Eastern Bering Sea and the Gulf of Alaska will be presented. The method can be extended to include other sources of variance so that the total error is more closely approximated.

Keywords: error distribution, sequential geostatistical simulation, acoustic survey.

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Sampling fisheries with high levels of accepted relative error may lead to overestimation of the statistical power of trend detection

Leo A. J. Nagelkerke and Iyob Tsehaye

In many fisheries in the tropics detailed biological studies are lacking and the only source of information is fishery statistical data from a catch and effort data recording system (CEDRS). The CEDRS is often designed to sample data with a specific level of accuracy, expressed as the maximum accepted relative error (mre) from the true value. However, the choice for a particular level of mre in an individual data-point may have an effect on the sensitivity to detect trends in a time-series of such data-points. We investigated these effects using data from the CEDRS of the Eritrean Red Sea fishery. This CEDRS is based on total enumeration of all catches and therefore has an mre of 0, meaning that we know the 'real' data-points and time-series. We studied the effects of mre levels from 1 to 50%, by calculating the trends in time-series, which were simulated by randomly drawing values from the chosen mre interval of each data-point (10,000 replicates). We found that accepting higher levels of mre may lead to finding time-series which have

lower variability around the trend than the 'real' time-series, resulting in an estimated higher statistical power for trend detection. Since reliable trend detection in fishery data is of high importance when independent biological data are lacking, we argue that when designing a CEDRS not only the mre of yearly estimates is taken into account, but also the potential effect of the chosen mre on trend detection.

Keywords: catch effort data recording system, statistical power, time-series, trend detection, variability.

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ICES CM 2006/I:32 – Poster

How resilient is Lake Victoria? Accounting for states, trends and processes of its fisheries and environment in a data limited situation

Jeppe Kolding and Paul van Zwieten

The predator *Lates niloticus* became dominant in the fishery of Lake Victoria after the shift to a simplified foodweb in the 1980s. Effort is now 7 times higher than the 1960s; yields have risen by a factor 6.5. Average standing biomass and average overall catch rates show large decadal fluctuations, but have remained stable over the past 30 years. Between 1984 and 2005 no significant or biologically meaningful changes were observed in length-based indicators derived from two independent time-series of experimental trawling. Stock assessment methods based on steady-state assumptions—still used in the region to advise management—indicate serious overfishing and stock collapse, for which no evidence exists. The apparent resilience of the exploited stocks to rapidly growing fishing pressure could be due to increasing nutrient loadings, resulting in increased primary productivity (a factor 2 with a 6- to 10-fold increase in algal biomass since 1969) that has cascaded up in the simplified food chain. However, this process may eventually reverse into an accelerated decrease that would bring economic disaster to the region.

An evidence-based understanding of the processes that drive changes in the productivity of stocks as a result of different lake wide anthropogenic effects in the Lake Victoria ecosystem could only be obtained after a systematic compilation and consolidation of available data over as long a time frame as possible and into a large number of indicators. These cover the physical environment, the primary and secondary biological levels, the fish faunal composition, life-histories and abundance, the fishery in terms of yields, effort and catch rates, economics, and management. We surmise that a regional (bi)-annual report, alias "The state of Lake Victoria 20xx", based on a selected set of indicators will be a powerful

tool in guiding co-operation between scientists and managers of the different countries involved, and a powerful aid in fisheries and environmental decision-making.

Keywords: Lake Victoria, *Lates niloticus*, productivity, indicators, environmental decision-making.

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ICES CM 2006/I:33 – Poster

Combination of trawl results during acoustic surveys – CASE STUDY

Rainer Oeberst and Eberhard Götze

Acoustic surveys have been carried out in the Baltic Sea in October since 1978 to estimate fisheries-independent stock indices of herring and sprat. In the eighties and then again since 2001 additional surveys have been carried out in spring to estimate abundance of sprat.

During both surveys herring and sprat are distributed in scattered layers and in small schools. Besides herring and sprat other species like cod, whiting, etc. were captured in the scattered layers. Fishing stations were used to estimate the relative species and length distribution because separations of the acoustic signals in components of species were not possible based on the acoustic measurements. Combination of the results of the fishing stations were many times discussed in different ICES working groups and the arithmetic mean of the results of the control hauls were used until now. A new model for combining the results of control hauls was developed which analyses in the first step the relations between the Sa-values of all species using the data of the control hauls. Depending on the observed relations between the species the stock indices are estimated. The advantage of the new model is that assumptions concerning the relations between the species are not necessary, and biased estimates are not possible when the assumptions are not fulfilled. Data of the acoustic surveys in spring 2003 and 2005 were used as a case study to estimate stock indices based on both methods, to check whether the differences of the stock indices are large and which of the models describes the reality more appropriately.

Keywords: acoustic surveys, Baltic Sea, combination of control hauls.

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Trap survey on the fishery boats as a promising way for stock assessment of red king crab (*Paralithodes camtschaticus*) in the Barents Sea

Vasily Sokolov

Red king crab was introduced in the Barents Sea by Soviet scientists in the 1960s and it became one of the largest world populations of this species. Data on stock abundance of red king crab in the Russian part of the Barents Sea are usually obtained using a stratified, random trawl survey, conducted annually in August or September since 1997. Trawl surveys generally occur at depths greater than 60–100 m in the areas where soft bottom predominates. In 2004 a commercial crab fisheries began in the Russian Economic zone. Six diving surveys and four trap surveys were conducted by Russian Federal Research Institute of Fisheries and Oceanography (VNIRO) in co-operation with fishers in 2003–2006. Stock assessments of different sex-size group of crabs were made based on the results of trap surveys by using a new software product designed in VNIRO applying different mathematic methods for interpolation of spatially distributed data (Kriking, spline-approximation, Delaunay Triangulation, and Voronoi Diagram). The maps of distribution of red king crab on the basis of trap and trawl surveys were analyzed. From the results of the trap and diving survey in 2003–2005 the stock of red king crab in the Russian zone of the Barents Sea was estimated at approximately 100 million specimens, including 40–50 million mature specimens. It is shown that results from the trawl survey in August–September led to systematic error in stock assessment of red king crab.

Keywords: Red king crab, survey, stock assessment, trap, fisheries, Kriking, approximation.

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Can the precision of bottom trawl indices be increased by using simultaneously collected acoustic data? The Barents Sea experience

Vidar Hjellvik, Olav Rune Godø, and Dag Tjøstheim

During the winter survey for demersal fish in the Barents Sea, acoustic data are recorded continuously. A method is presented for using the information from the acoustic recordings between trawl stations in an attempt to increase the precision of the trawl estimate. The method is a generalization of the double sampling regression estimation, where information from a frequently sampled auxiliary variable (e.g. acoustics) that is correlated with the main variable (e.g. trawl) is used for the purpose of increasing the precision in the estimate of the population mean of the main variable. The version of double sam-

pling presented here allows for additional explanatory variables, and for autocorrelation in the main and the auxiliary variables. However, when applied to the Barents Sea data, no variance reduction is obtained. The main reasons for this are: i) a high autocorrelation in the acoustic data, ii) a relatively low correlation between trawl and acoustics on trawl stations, and iii) higher between-station than on-station variation in the acoustic data. Another unexpected result is that the acoustic density during trawling is significantly higher than in between trawling stations.

Keywords: acoustics, autocorrelation, bottom trawl, double sampling, explanatory variables, general additive models.

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Autonomous bottom moored acoustic observatory for fish resources monitoring

Carla Scalabrin, V. Trenkel, and D. Choqueuse

Usually fisheries resources monitoring is based on synoptic surveys covering the stock distribution area during a minimum time period. Nevertheless, some questions cannot be addressed using only vessel platforms to acquire data, especially those requiring a continuous sampling of resources abundance. Continuous or semi-continuous sampling might be required for monitoring the impact of underwater installations like artificial reefs, offshore oil exploitation, offshore wind turbines, or aquaculture structures. It might also be interesting to observe migration paths, seasonal abundance variability, or night and day behavior differences. Over recent years, technological developments required for automatic acquisition of acoustic data from biological targets have increased both in terms of sensors and platforms. The on-going technology has been sufficient to provide a wide range of experiments deploying acoustics on buoys or land cable linked observatories. This paper describes a technological development project in charge of deploying an autonomous bottom-moored acoustic observatory in May 2005 within the Bay of Biscay coastal zone. The observatory should provide monitoring of fish abundance around an artificial reef over a period of 5 years. Rough sea conditions related to winter time period and small depths of the zone lead to require an operating autonomy of 6 months for the observatory. Sensors fitting out the observatory consist of one Simrad ER-60 echo-sounder for acoustic data acquisition and a NKE for temperature. A multiplexing system controls the sounder allowing to run sequentially three 120 kHz split-beam transducers. Frequency choice and particular sampling rates adopted will be discussed in relation to environmental factors, autonomy and biomass abundance based upon results from a similar operating system deployed off the Sainte Anne coastal zone in Brest in October 2004.

Keywords: acoustic observatory, biomass variability, artificial reef, sampling rate.

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ICES CM 2006/I:38 – Poster

A novel approximation (ICE) for tuning the VPA

Einar Júlíusson

A simple formula (Indices and Catch Equation) is presented that can be used to tune the Virtual Population Analysis with what is considered here to be unprecedented accuracy. The formula is simple to implement in Excel, and while it does not strictly need any survey at all it should be especially simple and useful when one has long time-series of a multitude of different surveys of unknown accuracies, as for instance for the Arctic cod. If catch and survey data are available for that stock at the time of the meeting the result of the formula will be compared to the official calculation. Otherwise results for the Icelandic and the Faroe Plateau cod will be shown, both of which have two sets of survey indices collected in the spring and in the fall.

Keywords: stock assessment, VPA, tuning.

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Trophic food web and ecosystem attributes of the Eastern English Channel

Maria Concepcion Villanueva, B. Ernande, and A. Carpentier

A network model of trophic interactions within the Eastern English Channel (ICES area VIIId), a shallow zone of continental shelf separating England and France, was developed with the objective to coherently quantify state variables as well as matter and energy flows between system components. Structure of flows and their distribution within and between trophic levels were analysed by aggregating single flows into combined flows for discrete trophic levels. The distribution of energy and the poor structure of the flows suggest that the network is able to reflect prominent features of the ecosystem such as effects produced by eutrophication processes. Direct and indirect effects and dependencies between system components such as nekton, benthos, and primary producers are quantitatively described. Predation pressure amongst system components is discussed. As part of nekton, ichthyological fauna emphasising commercially exploited fish species was included in the model to also show the potential use of the trophic network for purposes of fisheries and other human activities (e.g. effect of dredging, wind farms, etc.), impact assessment, and management.

Keywords: Eastern English Channel, Ecopath, trophic structure, fisheries, human activities, impact assessment.

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