USING ACOUSTICS TO IMPROVE THE PRECISION

OF BOTTOM TRAWL INDICES OF ABUNDANCE

by

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ABSTRACT

Acoustic measurements, which are correlated with fish abundance, can be made relatively cheaply over large areas as compared with bottom trawling. Based on this fact, methods are suggested that should produce more precise and cost efficient bottom trawl abundance indices. As an example, the technique is assessed using data from the Norwegian combined acoustic and groundfish trawl surveys. It appears that by using acoustics, the variance of survey indices could be considerably reduced in some situations.

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1.Introduction

The average catch per tow by a marine trawl survey is often used as an index of the relative abundance of a fish stock. But the spacial distribution of many species is highly heterogeneous and a few large catches determine, for the most part, the estimated mean and its variance. Thus estimates from marine surveys often have rather large standard errors. The problem is that the area in which a species' density is high is relatively small compared with the total survey area and this area of high density contains the bulk of the population. For random surveys the probability of sampling in these areas of high density is small and hence the catch per tow sampling distribution is usually highly skewed to the right. Or put intuitively, most of the sampling effort is spent in areas of low abundance and little effort in areas of high density.

One possible way to increase precision is to stratify the region into areas of high and low density and sample more intensely in the former. The strata are often based on past survey data. But the spacial distribution of fish changes dramatically over time and stratification based on past surveys is often ineffective for future surveys (Gavaris and Smith, 1987).

The spacial distributions of fish not only have large scale changes over time, but tows taken relatively close together can catch quite different numbers of fish which also contributes to the ineffectiveness of stratification.

Of course one way to improve survey precision is to increase the number of stations sampled. But this is expensive, resources are usually limited, and the basic

problem would remain: most survey effort would be spent in large areas of relatively low abundance.

Survey indices of abundance could be improved if the proportion of the area where density is high were known. What is needed in practice is a relatively inexpensive method to do this. The obvious candidate is acoustics which is successfully used by fishermen to locate suitable fishing grounds. In this paper we propose that as part of a standard trawl survey, acoustic readings over a broad area be used to improve the precision of trawl catch per tow indices. The increase in precision will depend on the correlation between trawl catches and acoustic readings. Based on data from the Norwegian combined trawl and acoustics surveys, the variance of the trawl indices could be reduced using acoustics by as much as two-thirds. In the discussion section a method is described to further improve trawl indices by basing the decision of whether to tow at a station on real time acoustic readings. This would in effect reduce the amount of effort spent in areas of low abundance.

2. Methods

Suppose measurements, x, which are correlated with the catch per tow, y_i, at a trawl station can be taken over a broad area relatively cheaply as compared with trawling. The y_i's may be the total catch or the catch of a subset of species. For simplicity suppose a large number of stations, n', are selected randomly in an area. At each station acoustic readings, which are correlated with the species of interest, are

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taken. At n of the n′ stations a standard trawl haul is made along with acoustic measurements. The n stations are selected randomly and the acoustic reading at these stations should not be affected by the trawl haul. That is, the acoustic readings at the selected trawl stations must be equivalent to those at stations where no trawl haul is taken. For example, the acoustic readings could be taken just before trawling starts.

A regression estimator (see, e.g., Cochran, 1977, p. 338) can be used to estimate the mean catch per tow for the trawl survey. Let:

$\bar{y}$ denote the average catch per tow at the n stations,

$\bar{x}$ the average acoustic reading at the n stations,

and

$\bar{x}′$ the average acoustic reading for the n′ stations.

Then the regression estimator of the mean catch per tow is

$$y_r = \bar{y} + b\,(\bar{x} - \bar{x}′),$$

where b is the regression coefficient of y on x. An estimate of b can be made from the joint values at the n stations or if appropriate, a value selected based on past experience.

The variance of y_r is given approximately by

$$\rho^2 S_y^2/n′ \; + \; (1 - \rho^2)S_y^2/n, \tag{1}$$

where ρ is the correlation between y and x and S_y^2 is the station to station variability in trawl catches. If y and x are uncorrelated, i.e., $\rho = 0$, then $Var(y_r) = S_y^2/n$, the usual variance of the trawl survey. For n′ large with respect to n,

$$Var\,(y_r) = (1 - \rho^2)S_y^2/n.$$

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That is, the trawl survey variance will be reduced in the limit by the factor $1 - \rho^2$.

3. An Example

Data from 45 bottom trawl stations are used to demonstrate the method. Most of these (33) are from the randomized bottom trawl survey for demersal fish in the Barents Sea. In addition, 12 stations from a comparative trawling experimental survey immediately following the survey are used.

All stations were sampled during the period February 17 - March 3, 1991 by R/V "Johan Hjort", (65 m, 3300 HP), using the standard Norwegian bottom sampling trawl, the Campelen 1800, equipped with rockhopper ground gear (Engås & Godø 1989), 6 m^2 WACO doors (1500 kg) and 40 m sweep length.

3.1. *Trawl hauls*

A standard trawl haul is defined as a 30 min tow at 3 knots starting when the trawl has reached the bottom, as indicated by the Scanmar height sensor on the headline. The tow length is defined as actual sailed distance calculated from the GPS receiver at set and retrieval. The catch rates have been normalized to kg/nautical mile by adjusting for actual tow lengths.

3.2. *Acoustic observations*

The Simrad EK-500, 38 kHz split beam echo sounder, connected to the Bergen echo integrator BI-500 were used continuously during the survey. For this first approach, only the output from the internal EK-500 echo integrator has been used, as the BI-500 is considered an expert system which is generally not available or in use during trawl surveys.

The echo recordings were split into 50 m parallel surface locked integrator channels with one 10 m wide bottom locked channel. The integrator worked with a 0.5 m backstep from the point at which the bottom echo exceed SV = -55 dB. The integrator output used in the comparison with the catch data is the area back scattering coefficient, s_A with unit $[m^2/nm^2]$ ($s_A = 4\pi 1852^2 s_s$) measured in the bottom channel, where s_s is the usual backscattering coefficient.

During the survey, the output period was 5 nautical miles, and the data previous to, or at the station were used depending on the degree of change in bottom and fish distributions. If the bottom depth changed more than 20 m from the station to the previous output, the data during the haul were selected. During the experimental survey, three successive outputs during the tow, each accumulated over 0.5 nautical miles, were averaged.

The data can further be improved by removing the effect of fish size, depth of the trawl station, and by using the expert system BI-500, which has a finer resolution both in the pelagic zone and close to the bottom (Foote et al., 1991).

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3.3. *Correlation between catch and acoustic readings*

In figure 1 is a plot of the total catch (mainly cod - 60%) versus the acoustical measurements. The estimated correlation between the two variables is .79 and the least squares estimate of b is 4.1 (se = .5). Thus the possible reduction in variance to be had by using acoustics as a covariate over the entire area approaches $1 - .79^2 = .38$.

As a further example, figure 2 is a plot of the catch of haddock versus acoustic measurements in the Barents Sea (see Wu, 1990 for details). Again the correlation between the readings appears to be rather high (.78).

4. Discussion

In the methods section it is assumed that the acoustic readings were taken at randomly selected stations. Ideally, the best estimate of the abundance index would be obtained if the acoustic mean of the entire area were known. Since acoustic readings can be made quickly at many stations, the effective sample size of the acoustic measurements should be relatively large and hence the first component in equation (1) should be relatively small. In contrast, if acoustics are used to generate an index of abundance, the readings are always adjusted for length and species composition from trawling results assuming a catch efficiency for all species and lengths of one. Since this is probably not true, and length and species compositions vary considerably from station to station, the variance of an acoustic index can be quite large.

The key is to use whatever acoustic readings are most highly correlated with trawl catches for the species of interest. For example, use of an expert system such as the Bergen echo integrator (Foote et al., 1991) may improve the correlation for a particular species. What drives the correlation is the ability of the acoustic readings to discriminate between areas of high and low density (figures 1 and 2).

The values of b and ρ will vary from year to year due to changes in species composition and length distribution. These changes in parameter values could also be due to yearly variability in catchability (Pennington, 1985) and may be of use to further adjust the trawl index.

One survey problem that remains is that most trawling is done in areas of low abundance. A way to sample more efficiently would be to base the decision of whether or not to tow at a preselected station on real time acoustic readings. For example, if the acoustic measurements indicate low abundance at a station, then using a random number generator (or a multifaced die) a tow would be made, say, 1 out of 20 times. If, based on the acoustics, density seems to be high then a tow could, perhaps, be taken every time. Since the probability of selecting a particular station is known, unbiased estimators of the index could be easily calculated. This would effectively increase the sampling intensity in areas of high abundance and lower it in areas that contribute little to the total biomass of a stock.

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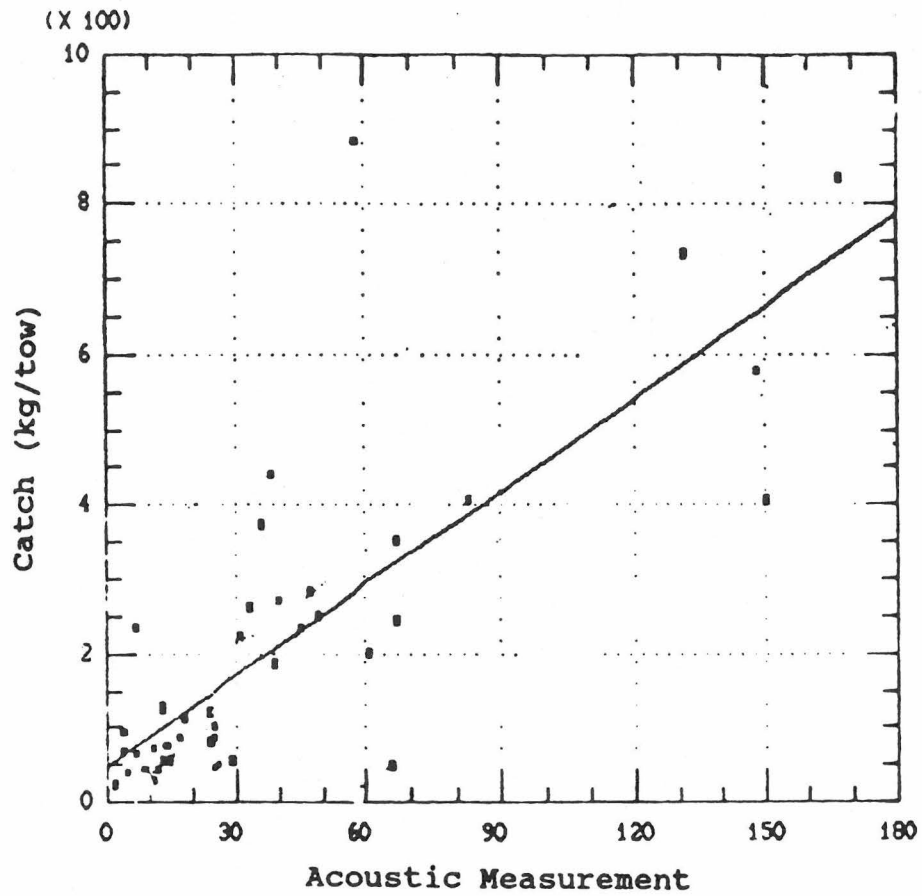
Figure 1. Total catch per tow (mainly cod and haddock, 68%) versus acoustic measurements.

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(X 1000)

Catch (num./tow)
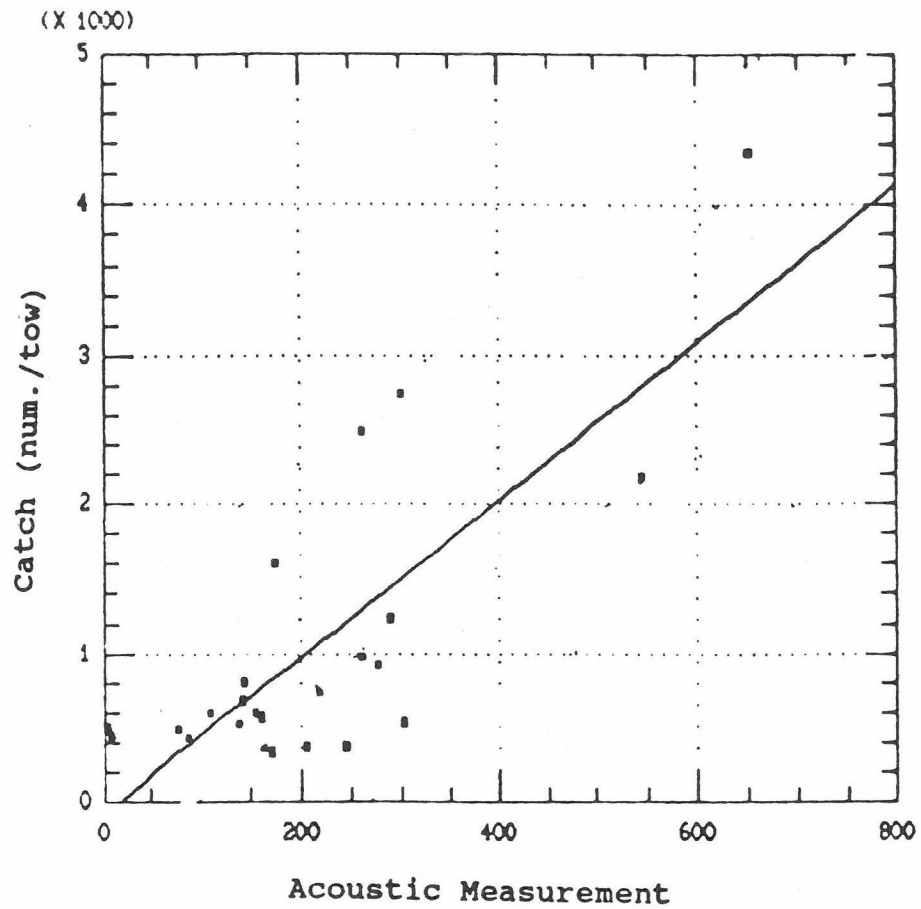
Acoustic Measurement

Figure 2. Catch per tow of haddock versus acoustic measurements (from Jin, 1990).