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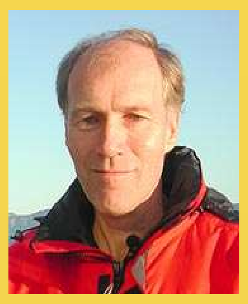
Can the precision of bottom trawl indices be increased by using simultaneously collected acoustic data? The Barents Sea experience

V. Hjellvik[1], O.R. Godø[1] and D. Tjøstheim[2]

V. Hjellvik



O.R. Godø

D. Tjøstheim

[1] Institute of Marine Research, Bergen, Norway
[2] Dept. Of Mathematics, University of Bergen, Norway

Introduction

During the combined acoustic and bottom trawl winter survey for demersal fish in the Barents Sea, trawl stations are taken every 20th or 30th n.mile, about 2-300 stations each year. Acoustic registrations are taken continuously, typically about 5-8000 n.mile. The on-station acoustic registrations and the trawl catches are correlated. Hence, the acoustic registrations taken between stations contain extra information in addition to the trawl catches, and hopefully this information could be used to increase the precision of the trawl estimate.

Materials and Methods

Data from 1997 to 2002 were analysed. Each acoustic observation is the echo abundance of cod (*Gadus morhua*) integrated over 1 n.mile. The method used is related to "double sampling" (Cochran 1977) where a frequently sampled auxiliary variable (here: acoustics) is used to increase the precision of the estimate of the mean of a more scarcely sampled main variable (here: trawl catches). Additional explanatory variables can be included, and autocorrelation in the auxiliary variable is allowed for.

The procedure is as follows:

Step 1: Fit a GAM (generalised additive model) to the on-station log-transformed data to remove large scale trends:

$$\log(T_i+1) = f_T(\mathrm{lat}_i, \mathrm{lon}_i) + z_i, \quad i = 1,\ldots,n_{\mathrm{ON}}$$
$$\log(A_i+1) = f_A(\mathrm{lat}_i, \mathrm{lon}_i) + e_i, \quad i = 1,\ldots,n_{\mathrm{ON}} \qquad (1)$$

Step 2: Define acoustic residuals on and between stations as

$$\varepsilon_j = \log(A_j+1) - f_A(\mathrm{lat}_j, \mathrm{lon}_j), \quad j = 1,\ldots,n_{\mathrm{ALL}} \qquad (2)$$

Step 3: Calculate the combined index as

$$I_C = \bar{T}_{\mathrm{ON}} + b_{\mathrm{ON}}(\bar{\varepsilon}_{\mathrm{ALL}} - \bar{e}_{\mathrm{ON}}) \qquad (3)$$

where b_{ON} is the is the estimated regression coefficient in the linear regression $z_i = a + b_{\mathrm{ON}} e_i + u_i$ (a linear relation between trawl and acoustic residuals on the trawl stations is assumed).

Step 4: The combined index I_C has variance

$$\mathrm{var}(I_C) = (1-\rho_{e,z}^2)\,\mathrm{var}(\bar{z}_{\mathrm{ON}}) + b^2\,\mathrm{var}(\bar{\varepsilon}_{\mathrm{ALL}}) \qquad (4)$$

where $\rho_{e,z}$ is the correlation between the residuals from step 1.

Reference: Cochran, W.G. 1977. Sampling techniques. Wiley, New York .

Results and Discussion

The variance reduction obtained in the Barents Sea case was close to zero (Fig 1a). The potential variance reduction is mainly determined by two factors: the on-station correlation between trawl and acoustic residuals in eq. (1), and the autocorrelation in the acoustic residuals in eq. (2) (Fig 1b). For a higher order autoregressive process (which better describes the Barents Sea data), the situation is even worse than depicted in Fig 1b, since the autocorrelation decreases less rapidly as the lag increases. For the cod data, the 1st lag autocorrelation was typically close to 0.9 (Fig 1a).

In addition, the between-station acoustic variation was on average higher than the on-station variation, leading to a smaller variance reduction, and the between-station acoustic mean was lower than the on-station mean, leading to lower indices.

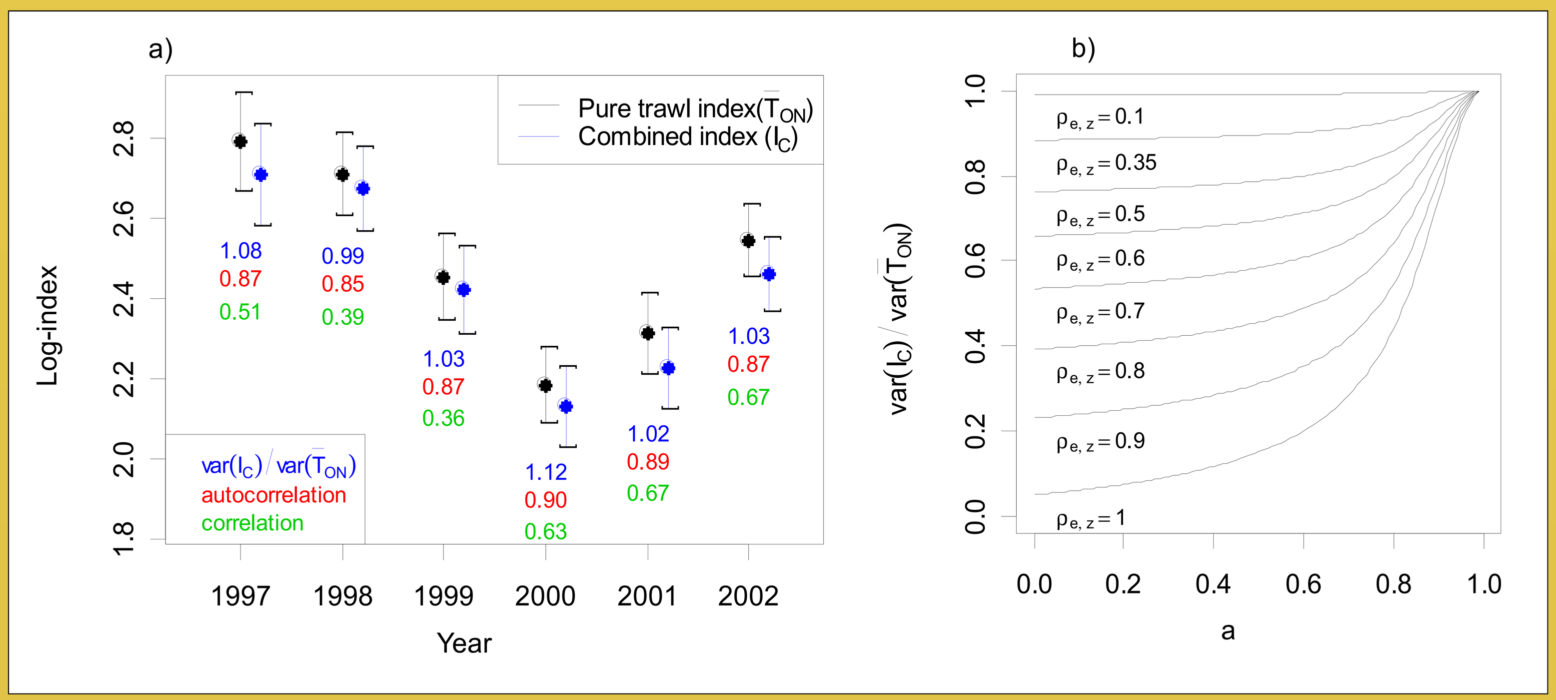


Figure 1. (a): Indices (mean(log-catch) ± 2 std.errors) for cod (*Gadus morhua*). The blue points are combined indices calculated from eq. (3) with std.errors calculated from eq. (4). Red numbers indicate the 1st lag autocorrelation in the acoustic residuals (eq. 2), and green numbers indicate on-station correlation between trawl and acoustic residuals. **(b):** The expected variance reduction for the combined index I_C if one trawl sample is taken for each 20th acoustic sample, the correlation between trawl and acoustic residuals from eq. (1) is $\rho_{e,z}$ and the acoustic residuals in eq (2) follow a 1st order autoregressive process with autocorrelation a.