

CHANGES IN ACOUSTIC ABUNDANCE - A SIGNAL INDICATOR FOR
STOCK DYNAMICS OF COD (*Gadus morhua*)

By

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ABSTRACT

To be able to take the proper and timely management actions, it is crucial to reliably detect major changes in trends of fish stock abundance. For the assessment of Northeast Arctic cod, the Norwegian bottom trawl survey is important for tuning the VPA (Virtual Population Analysis). The indices are auto-correlated and the time series show maxima with vaguely defined peaks. This might lead to a delay in detection of the first signs of stock reduction.

Norway has conducted combined acoustic and bottom trawl surveys for the main demersal fish stocks in the Barents Sea since 1982. The idea of combining the results from the two surveys into one estimate of abundance has been explored, but a number of confounding factors related to natural and affected fish behaviour has until now prevented the establishment of a reliable method for combining the two indices. The acoustic indices receive less weight or power during the tuning process than those based on the bottom trawl survey. There are, however, specific differences in the dynamics of the indices of the two time series that have not yet been exploited. In this paper these differences are analysed with the aim of extracting patterns that can serve as a signal for changes in trends of stock development. Application of the results for monitoring the stock is discussed.

Keywords: Acoustic survey, bottom trawl survey, fish behaviour, cod, combined assessment.

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INTRODUCTION

The motivation for running acoustic surveys for cod is the fact that this species is often pelagically dispersed and periodically distributed out of reach of the bottom trawl (Godø and Wespestad 1993). The Northeast Arctic cod stock has been surveyed with both methods since 1981, and the fraction of the acoustic abundance found above the bottom zone (10 m) has varied from about 15% to 75% (see Jakobsen *et al.* 1997 for overview). In the present assessment procedures for this stock, bottom trawl and

acoustic survey estimates are considered to be independent indices of abundance for tuning of the VPA (ICES 1999) even though they are likely to be highly correlated.

A major problem for the management of this stock has been caused by the fact that the applied analytical assessment has not been able to identify a declining trend in stock size early enough for taking proper management action (ICES 1999).

Intuitively, a method combining the acoustic and bottom trawl survey numbers to produce one estimate of abundance for tuning the VPA would be preferable, such as the combined index developed for Alaska pollock (Karp and Walters 1993). For Northeast Arctic cod, a simple additive procedure has been considered unreliable due to behavioural effects in the sampling process (see e.g. Godø 1994, Aglen 1996). Alternatively, the temporal dynamics of the two time series might provide signals that can be used for assessing present stock size and the probable development in the near future. If variation in the vertical distribution dynamics is linked to abundance, as suggested by Godø and Wespestad (1993), more fish are expected to be distributed pelagically under high than under low abundance levels. Further, if this is valid in general, a reduction in the acoustic abundance is expected to take place before any significant reduction occurs in the bottom trawl assessment. In other words, the pelagic distribution might serve as a reservoir for the bottom zone and a substantial reduction in the bottom trawl indices of abundance is, under this hypothesis, not expected before the pelagic reservoir is exhausted. In this paper we explore the possibility of extracting signals from a comparison of the two survey time series that could be utilised in the current analytical assessment.

MATERIAL AND METHODS

An assessment based on the acoustic and bottom trawl as, well as VPA assessments, are available in ICES working group documents ICES(1999). Acoustic and bottom trawl survey data for ages 3-6 are compared. These are further compared with VPA stock estimates in numbers for the same age range. Older fish are excluded due to the migration of the mature fish from the survey area to the spawning ground in spring.

If the bottom trawl and acoustic survey indices are independent estimates of abundance, they should show a high degree of correlation, and the residuals should be randomly distributed. Regressions, with the bottom trawl survey as the independent variable, are carried out and the distribution of the residuals is studied in relation to the variation in VPA estimates of abundance. Due to the uncertainty of the survey estimates of ages 1 and 2 fish, which is related to the sampling efficiency over time (Godø and Sunnanå 1989), and to variability within a survey (Hjellvik *et al.* 1999), these age group are not included in the analysis at this stage.

RESULTS

The two series of indices show similar variation over time for the commercially exploited stock of immature fish (age 3-6, Figure 1). It is well known that good recruitment of Northeast Arctic cod is periodic (Sætersdal and Loeng 1987) and the two peaks represent such rich recruitment periods. The acoustic survey indices tend to

start the decline earlier than the corresponding index generated by the bottom trawl survey. The same tendency is apparent when comparing the indices by age, although they are more variable than those for the combined ages.

If the two index series represent independent sets of information on stock abundance, we would expect a high degree of correlation between them. This is also apparent from the regression between the two series (Figure 2, $r^2=0.77$). It is though, interesting to observe that the descending parts of the curve of the acoustic index occur earlier than for the respective bottom trawl index. In the 1990s the decline of the acoustic index started one year earlier and are apparently more in line with the converged VPA estimates. A closer look at the residuals from this regression, reveal a non-random distribution, and strong autocorrelations, i.e. sequences of positive and negative residuals occur (Figure 3). When the VPA indicates peaks in abundance, the residuals move from highly positive values to their negative minima. It is thus suggested that sudden jumps in the relationship between the two series, as demonstrated by the abrupt shifts from positive to negative residuals, might serve as a strong signal of a change from a positive to negative trend in stock abundance.

DISCUSSION

The assessment of Northeast Arctic cod has in recent decades been through two periods of unexpected severe drops in stock size and subsequent periods of strong recruitment and increasing stock size. Present assessment methodology (ICES 1999) has not been able give early warnings of culminating or of negative stock development and, thus, in subsequent years when more information has become available, historical estimates of abundance has been reduced. Nakken(1999) shows how the interpretation of the stock situation has systematically changed with time and accumulated information and stresses the need for improved methodology. Based on the ICES advice, the optimistic perspectives in 1986 and 1995 resulted in non-optimal management, which negatively affected the fishing industry and reduced the total yield. Any information in the available database should thus be exhausted in attempts to establish an improved methodology.

Although the bottom trawl indices normally show better correlation with the converged VPA than the acoustic indices (ICES 1999), the available data in our analysis indicate that the acoustic survey provide a stronger signal of an approaching negative development of the stock. This has until now not been utilised but may potentially serve as an additional tool for predicting future stock development. We are certainly aware of the limitation of the present database which represent only two peaks in abundance – the one fuelled by the 1983 year class and the second one by the 1990 and adjacent year classes. We are further dependent on a non-converged VPA for the later part of our time series. However, according to earlier experience this will rather strengthen than undermine our conclusions (see e.g. Nakken 1999). We are thus quite confident that the presented documentation can be useful in future evaluations of stock size and its development for two reasons. Firstly, biological evidence supports our results. The vertical distribution of cod shows a positive relationship with density and thus an increasing proportion of the biomass will become pelagically distributed as strong year classes enter the stock (Godø and Wespestad 1993, Jakobsen *et al.*

1997). Consequently, since the bottom trawl is restricted to measure what is available in the bottom zone, the density dynamics in the pelagic zone might be lost. On the other hand, the overall performance of the acoustic survey may be negatively affected by limitations in the bottom zone (Ona and Mitson 1996), but performs well under high abundance and pelagic distribution. It is thus reasonable to believe that the acoustic survey will track stock changes around stock maxima better than the bottom trawl survey. Assuming that the preferred habitat of cod is the bottom zone, a conceptual presentation of the vertical dynamics related to stock abundance and its effect on the two surveys is introduced in Figure 4 (the pyramid hypothesis). The hypothesis still need to be proved, but this should not prevent the utilisation of the presented evidence with the aim of avoiding too optimistic stock predictions in the most critical periods of stock development.

A reliable quantitative interpretation of the presented evidence that could be used in stock assessment is at present difficult. The simplest application would be to consider taking special actions when highly negative residuals occur. Further, with improved understanding of the dynamics of the two series, a combined approach, where the bottom trawl survey determines the dynamics under low stock conditions and the acoustic survey when the stock is abundant should, be tested.

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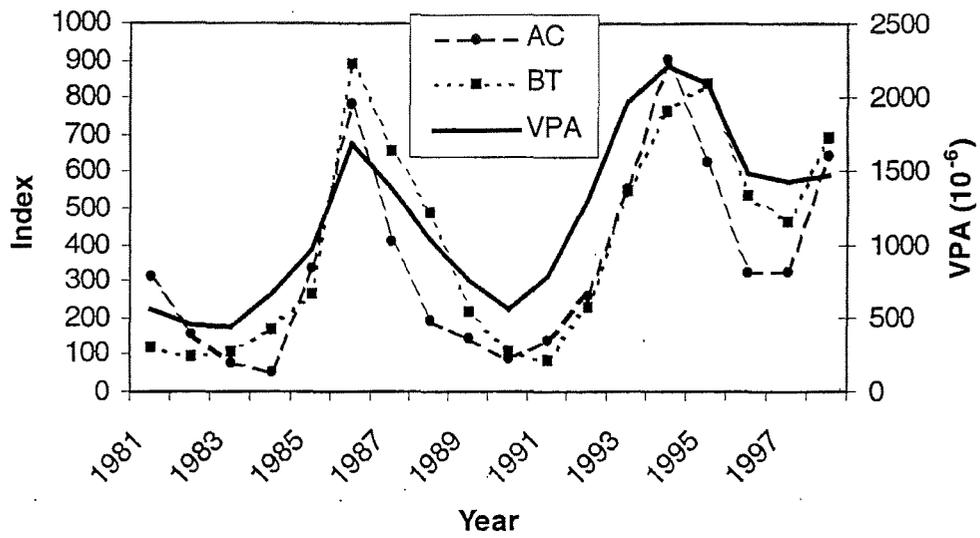


Figure 1. Comparison of the bottom trawl (BT) and acoustic (AC) survey abundance indices by numbers and the respective estimates from the VPA for ages 3-6 cod.

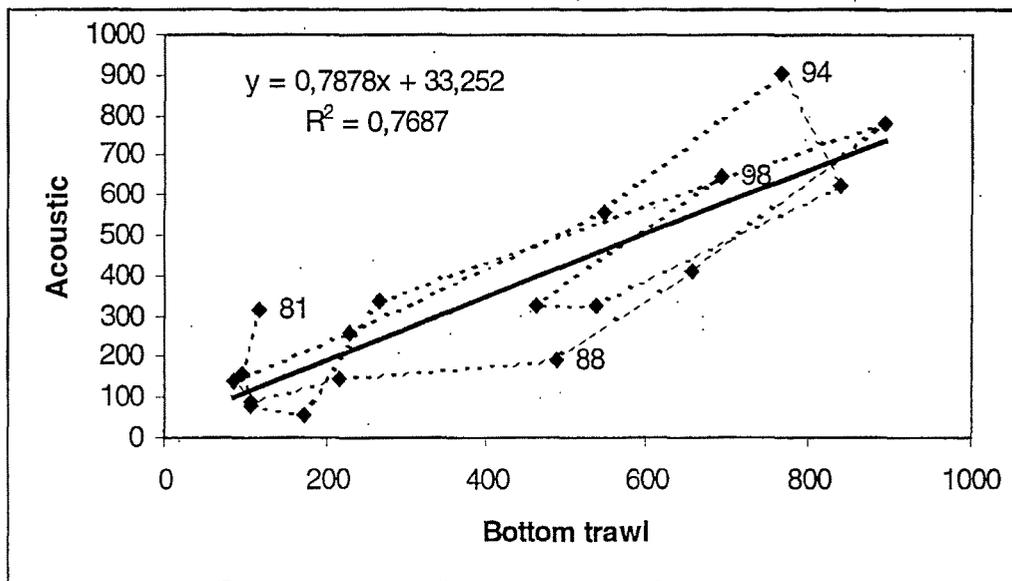


Figure 2. Regression line between bottom trawl (BT) and acoustic (AC) indices of abundance of age 3-6 cod. Year of observation is indicated for 1981, 1988, 1994 and 1998.

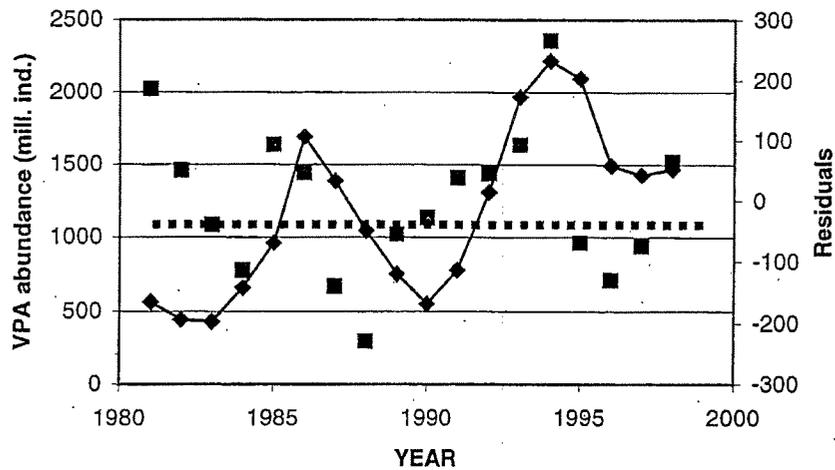


Figure 3. Residuals from the acoustic and bottom trawl survey regression (squares) compared to stock development as given by the VPA (continuous line).

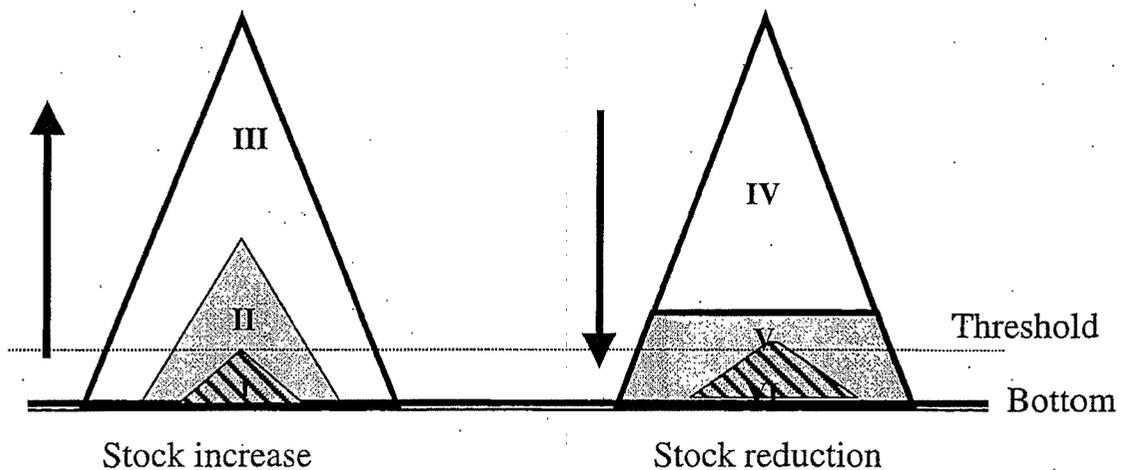


Figure 4. Schematic presentation of the 'pyramid hypothesis' suggesting a discrepancy in performance of the bottom trawl survey and acoustic survey under stock increase and stock reduction: When stock increases from a low level, the bottom trawl survey will reflect this change through higher density and wider horizontal distribution (I-II). When above a certain level (threshold), an increase in abundance will mainly occur in the pelagic zone and the bottom trawl indices will give an inferior reflection of the real stock dynamics (II and III). An increase in abundance beyond the threshold will be optimally distributed for the acoustic method. Assuming that the preferred habitat for cod is the bottom, it is reasonable to believe that a reduction in stock size is first reflected in reduced abundance in the pelagic zone with minimal effects on density in the bottom zone (remove IV). When reaching step V and VI the bottom trawl will again be able to track changes in stock size through reduced densities and shrinking horizontal distribution but probably too late to maintain an optimal management. To avoid any confusion between the acoustic 'dead zone' (Ona and Mitson 1996) and the 'threshold', it should be stressed that the latter refer to a level in abundance at which a shift in performance of the two survey occurs and is not associated with their minimum detection level.