RELATIONSHIP BETWEEN SURVEY INDICES OF RECRUITMENT AND VPA ABUNDANCE ESTIMATES FOR NORTH-EAST ARCTIC COD

by

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ABSTRACT

Survey estimates of abundance of recruiting and partially recruited age groups are important elements for tuning the VPA of north-east Arctic cod, both for estimating the present state of the stock and for future exploitation. The reliability of the assessment and prognosis is therefore dependent on the validity of the survey indices. In this paper, year-class abundances based on surveys are compared to estimated year-class abundances from a VPA.

The variability of the survey estimates, both within and between year-classes, is discussed in relation to observed changes in cod density and vertical distribution. It appeared that the catchability of recruiting age groups is density dependent. Specifically, catchability increases with increasing stock abundance. Furthermore, cod appear to be distributed more pelagically at high densities as compared with at low densities. The increase in catchability with density is found to override the expected negative effect on catchability of low availability at high density. As a consequence, a positive relation between catchability and reduced availability was found. Alternatives to a simple linear relation between survey and VPA abundance estimates are proposed.

INTRODUCTION

The validity and importance of commercial CPUE as a measure of stock densities for use in the assessment of commercially important demersal stocks in the Barents Sea have been reduced over the last few decades. For the main part, this is a result of increasing exploitation, changing fishing strategies and the fundamental shift in regulation regime following the extension to a 200 n. mile economic zones. Abundance indices from scientific surveys have gradually replaced the commercial CPUE data in assessments. Presently, the abundance of recruiting and partially recruited year-classes of north-east Arctic cod are mainly determined by survey data (ANON. 1994a).

The most important Norwegian surveys for assessments are the International 0-group survey (ANON. 1994b) and the Norwegian combined bottom trawl and acoustic survey in the Barents Sea. In this paper, the data from these surveys are analysed and compared with VPA abundance

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at age estimates. The validity of comparing survey and VPA abundance estimates for recent years can be highly questionable since the survey data are used to tune the current VPA (ANON. 1994a). The comparison becomes increasingly valid for VPA estimates further back in time.

MATERIAL AND METHODS

This paper is based on data taken from survey reports of the 0-group surveys (ANON. 1994b) and from the Norwegian combined bottom trawl and acoustic surveys (Mehl and Nakken 1994). VPA abundance estimates are from ANON.(1994a). All statistical analysis were done using SAS software (Proc Reg, Proc Anova, ANON. 1988).

These data from different sources were scaled by adjusting catchability (q) so that the estimates varied in comparable ranges throughout the time series. The bottom trawl survey indices have been increased by a factor of 2 and the 0-group indices by a factor of 1000. The relation between the survey and VPA abundance estimates is called R, where

R = Survey/VPA.

If VPA is assumed to be correct and stable throughout the time series, variation in R will reflect variation in q.

Three factors of importance for the reliability of survey estimates were studied.
Firstly, if it is assumed that q is constant, then the relation between the estimates of abundance from surveys and VPA estimates are expected to behave similarly independent of year-class, period etc.. The validity of such an assumption is examined by comparing changes in survey estimates of year-class abundance with age and VPA estimates. VPA abundance estimates of age groups below 3 for a year-class are set to the abundance at age 3.

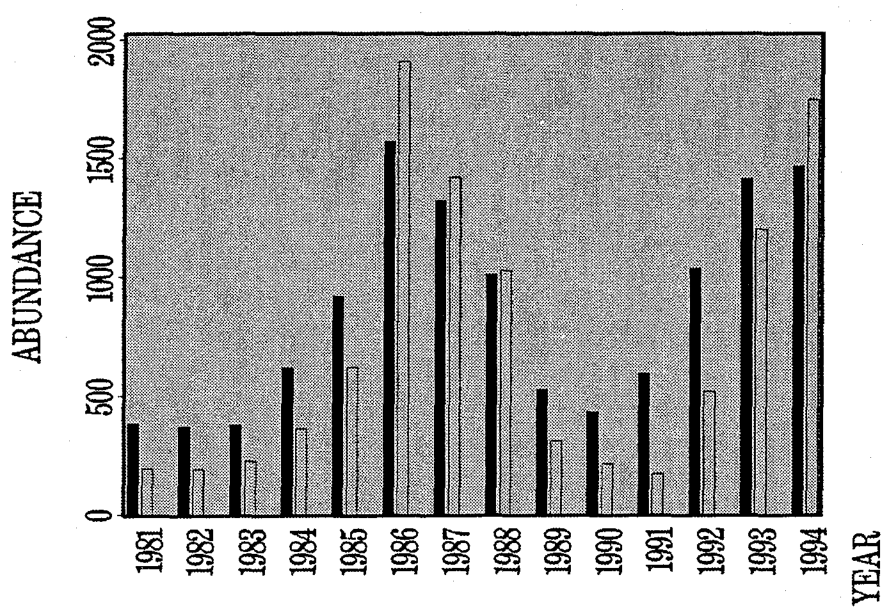

Figure 1 Estimates of the abundance of age 3-5 cod for 1981 through 1994 - survey indices (open columns) and VPA estimates (black columns).

Secondly, information about fish vertical distribution from the simultaneous acoustic sur vey is used to study the possible association between fish availability to the survey trawl and the disagreement between survey abundance and VPA estimates (Godø and Wespestad 1993). The percentage of the acoustically recorded fish found in a 10 m channel above the bottom is used as a measure of the availability of fish to the survey trawl (Mehl and Nakken 1994, Table 5.2) Finally, alternative relations between survey abundance estimates and VPA are considered.

RESULTS

Comparison of survey and VPA abundance estimates

A comparisons of the VPA and survey abundance estimates of the partially recruited age groups (ages 3-5) for the survey time series is in Fig. 1. The two time series show a similar pattern. However, the survey abundance estimates tend to be lower than the VPA at low stock

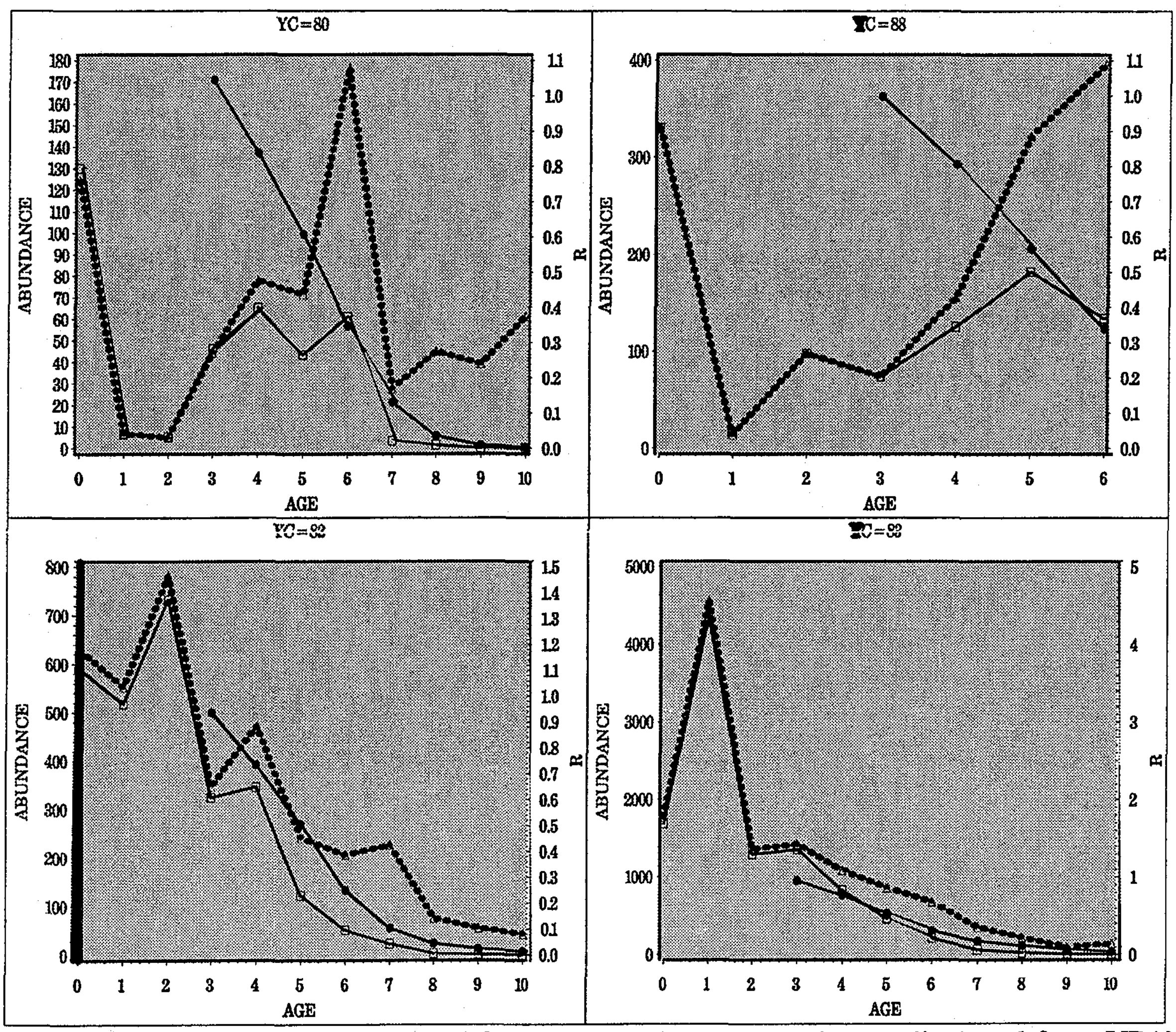

Figure 2. Cod abundance estimated from surveys (square, continuous line) and from VPA's (dot, continuous line), and the R ratio (triangle, dotted line) by age for low abundance situation (year-classes 1980 and 1988) high abundance situation (year-classes 1982 and 1983).

abundance and higher than the VPA when abundance is high.This tendency is more closely studied by following year-classes from periods of high and low abundance. The estimates of abundance for year-classes 1980 and 1988, which recruited when abundance was low, drop substantially from the 0-group index to age 1. Thereafter the survey indices increase until ages 4-5. The ratio, survey/VPA (R) remains below 1 until age 6 where a maximum occurs (Fig. 2). In contrast, during a period of good recruitment, the survey indices for year-classes 1982 and 1983 decrease from ages 1-2 and onwards, i.e. the pattern in abundance for a year-class which is expected due to mortality. R is continuously decreasing from age 1 (Fig. 2). Due to maturation and migration out of the survey area, R is expected to decrease after ages 6-7, which is observed in most cases. Observe also that R for age 0 is below 1 for the poor recruitment period and well above 1 during the period of good recruitment. In Fig. 3. are plots of R for all year-classes 1979 - 1989 for ages 2-9, which clearly demonstrate the difference between rich and poor recruitment periods, indicating that the variation in q for recruiting and partially recruited age groups is related to stock abundance

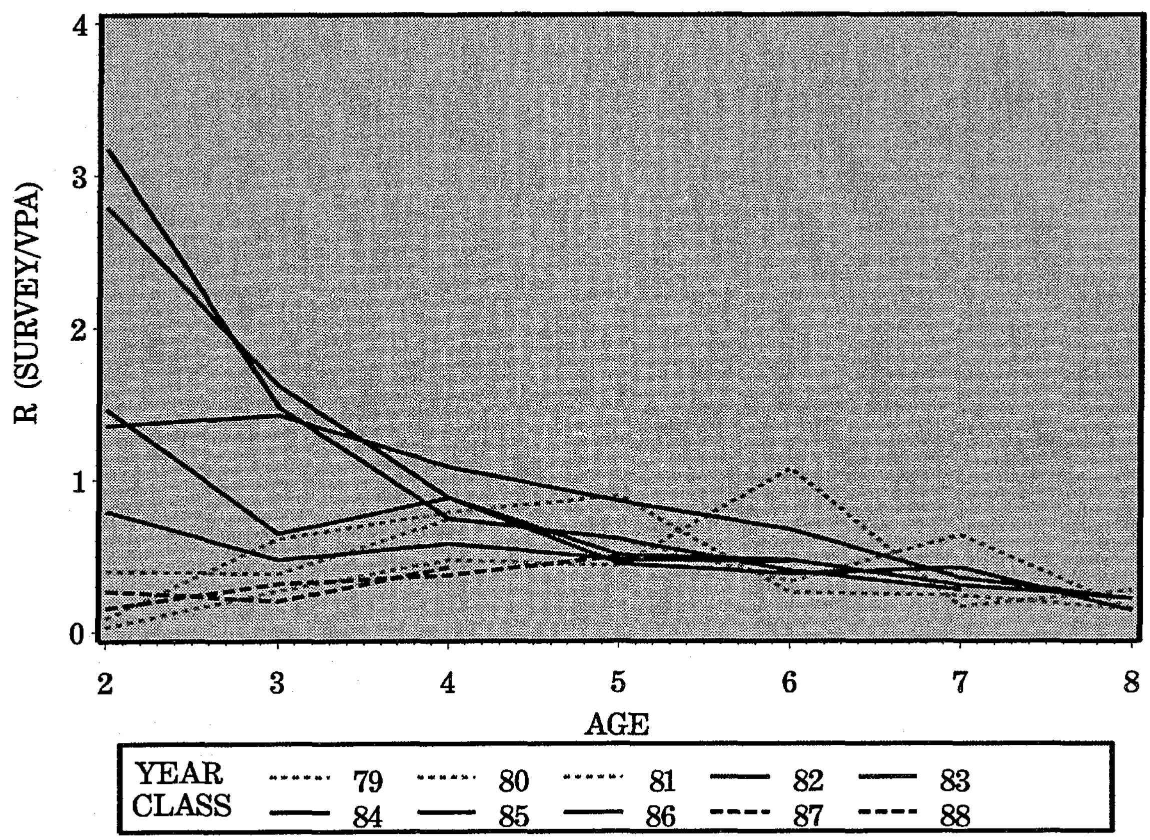

Figure 3. R versus age for the year-classes 1979, 1988.

Survey abundance estimates and availability

If the vertical distribution of cod varies amongst years, then the stock abundance should be underestimated during years when fish are pelagically distributed compared to years when the stock is concentrated close to the bottom. But the relation between survey and VPA abundance estimates of ages 3-5 cod (R) and availability indicate that there is a tendency for the opposite to occur (Fig. 4). Although the regression model does not explain more than 25% of the total variability, it does indicate that there is an inverse relation between R and availability (significant at the 90% level) and not a positive relation as expected.

Survey/VPA relation

The above results indicate a density dependent variation in q for young cod in the Norwegian surveys, and more surprisingly, an inverse relation between availability and q (R, which reflect changes in q). To study this more closely, various regressions and variance analysis were made (Table 1). The R-squares show that the log linear regression gave the best fit (Table 1, Fig. 4). To study the effect of availability, the percent of fish in the bottom channel (PCT) was added as a factor in the regressions (the statement in Proc reg was

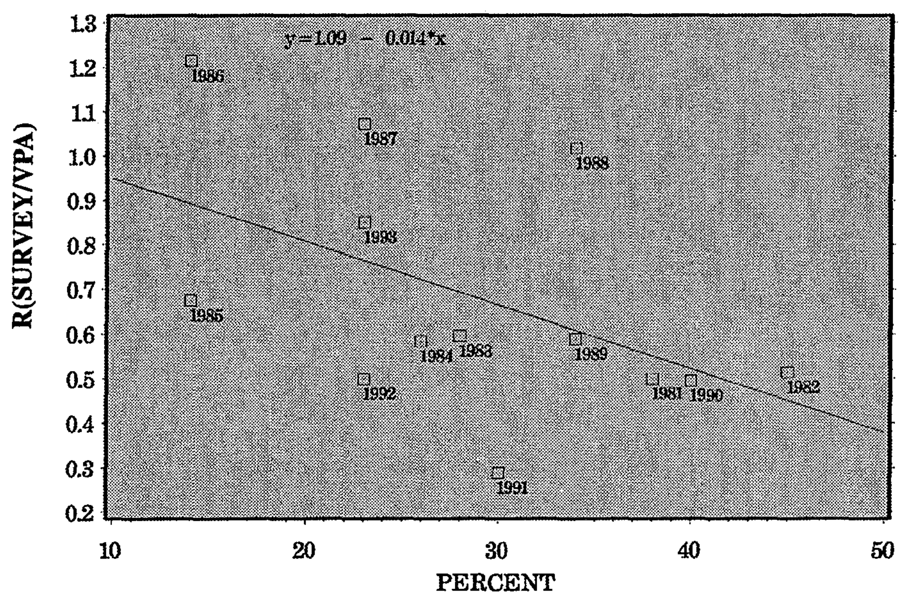

Figure 4. The survey/VPA relationship (R) against availability (percent of fish in the bottom channel).

"Model VPA = survey pct /options"). The two last columns in Table 1 demonstrate that all fits are improved. The effect is clearest for the linear regression through the origo and insignificant for the log-linear regression. When adding availability to the model, the R-squares are all similar. This indicates that availability effects and density dependent effects are not independent, which is also demonstrated in Fig. 5.

Table 1. Regressions models relating survey and VPA abundance estimates. In the two last columns are the parameter estimates (PCT-eff) and R-square values (R-square2) for the regressions which include PCT as a factor. Data are from the period 1981-1990.

Reg. type	Formula	R-square	Prob>F	PCT-eff	R-square2
Linear through origo	vpa=0.96*sur	0.9382	0.0001	6.8498	0.9804
Linear with intercept	vpa=300+0.7*sur	0.9663	0.0001	-6.5354	0.9808
Log linear	$vpa=14.83*sur^{0.2}$	0.9813	0.0001	-0.0047	0.9854

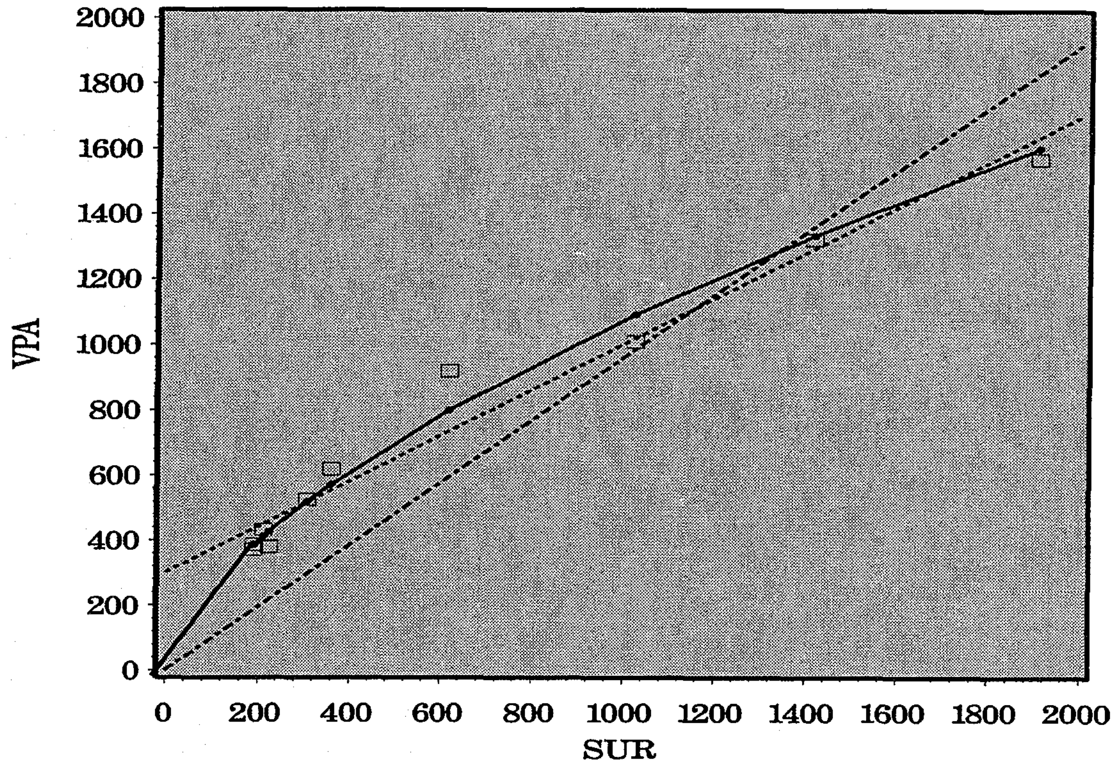

Figure 5. Survey abundance estimates (sur) versus VPA estimates for the period 1981 -1990 for ages 3-5. Squares indicate the data points, dotted and broken lines show regressions with and without intercept and continuous line estimated abundance with the log model (Table 1.).

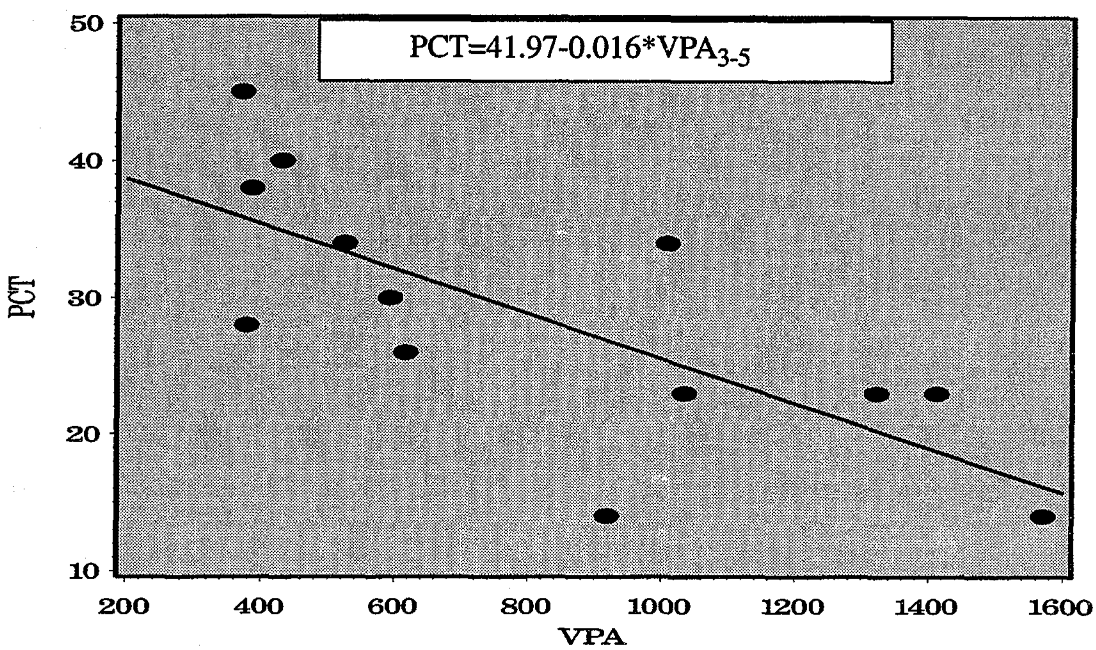

Figure 6. The relation between availability(PCT) and stock abundance (ages 3-5, VPA) for the years 1981-1994.

DISCUSSION

The validity of the analysis might be lessened by several shortcomings of the data, which should be more closely examined:
Firstly, the time series is short and contains only one period of rich recruitment. Furthermore, most of the time series is adjusted for a size dependent loss of fish under the trawl (see Godø and Sunnanå 1992, Aglen and Nakken 1994). Such compensations may be susceptible to variability and bias over time, due to, e.g. density dependent factors affecting escapement (Godø 1994). It should, however, be noted that the adjustment factors are based on several experiments conducted in the period 1985-1989 and are assumed to provide a representative mean. There is no reason to believe that the time series should represent a less accurate data base than the original data (Godø and Walsh 1992). If escapement is strongly density dependent as suggested by Godø (1994), the result would be that low estimates of abundance are underestimated compared to the high estimates as observed.
Secondly, the VPA is assumed to represent the truth in the present analysis. Since the survey abundance estimates are used to tune the VPA's, the latest VPA estimates and survey abundance estimates are not independent. Therefore, data after 1990 was not used in the statistical analysis. Also, a VPA is liable to errors caused by unreliable port sampling and catch reports by the industry. It is, however, difficult to find any explanation of how such errors may have caused the present findings. A VPA assumes a constant natural mortality (M) over time. If M is strongly density dependent, then this may, to some extent, level out the differences between survey and VPA estimates (Fig. 1). The difference in the pattern of the survey indices for an ageing year-class under low and high abundance situations (Fig. 2) is, however, a problem independent of M, and of great importance for the reliability of recruitment estimates.

Originally I intended to study the reliability of pre-recruit estimates of cod, and develop methods to improve them. But because of the low efficiency of the pre-1989 standard trawl to catch small fish, the reliability of the adjustments of ages 1 and 2 fish will be lower than that for the partially recruited age groups (3-5) (Godø and Sunnanå 1992). The present findings also indicate that these young age groups are most susceptible to density dependent changes in catchability. Further analysis of the effect on q for a year-class caused by varying abundance of preceding and succeeding year-classes should be carried out with the aim of developing models which may improve the reliability of prerecruit abundance estimates. Such models also need to take into account possible changes in M.

In spite of the above mentioned shortcomings of the data, I think that the analysis highlights important features of the time series, which can be used to improve the reliability of assessments and management. The most plausible explanation of the findings is probably found in density dependent differences in social behaviour as described by Godø (1994). At low densities cod will behave as individuals and search all possible ways to escape during trawling. At high densities, cod organize in schools and behave as schooling fish, i.e. when one individual in the school react to a stimulus, the whole school or part of it will follow. This kind of social behaviour will improve herding and reduce escapement in the catching process. For recruiting age groups with limited migratory capacity, the probability that an individual is part of a school, is assumed to increase with increasing stock abundance. This tendency appears to decrease with age, e.g. the relation found in Fig. 6 was clearest for ages 3-4 cod and was absent for fish above ages 5-6. Apparently, the phenomenon may affect 0-group catches, giving high R for rich and low R for poor year-classes. The standard pelagic sampling trawl has low q due to loss of fish through the large meshes in the front part (Godø *et al.* 1993). When schools of fish enter the trawl, the catchability will be improved compared to a single- fish-entrance-situation because the school are warned and stimulated (herded) when the first individuals are observed to respond after collision with the meshes. Catchability of larger fish (age 5+) may probably vary more independent of stock size. Large fish may use their migratory capacity to concentrate in small areas, and hence give high densities and high q independent of stock size.

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