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Natural fish behaviour and catchability of groundfish

by

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ABSTRACT

Imprecision in estimates of abundance and population parameters obtained from trawl surveys could be reduced if the sources of variability were understood and properly described. Fish behaviour in relation to sampling gears has been widely studied, with the main goal of providing information which might lead to improved reliability of abundance estimates. However, the general applicability of the results may in many cases be questionable due to unidentified effects of natural behaviour of the fish on catchability. Variability of natural behaviour may affect catchability directly and, therefore, if aspects of natural behaviour are taken into account in design and analysis of bottom trawl surveys, the reliability of the information obtained from these surveys could be improved.

INTRODUCTION

During the last decade, much work has been carried out on issues related to fish behaviour and gear selectivity, and many such studies have been reported at ICES working group and statutory meetings. One of the principal objectives of this work has been to examine the effects of fish behaviour in the vicinity of survey vessels and sampling gears with the ultimate goal of providing information which might lead to improved estimates of stock abundance. Considerable progress has been made in this area, and, as a result, improvements have been

made to sampling gears and sampling procedures and the precision of the abundance estimates has undoubtedly increased.

Most of these studies have been directed towards the objective of obtaining accurate and precise estimates of size and species composition of the fish encountered by the sampling gear. Other aspects of fish behaviour are also of concern, however. In the following I will consider aspects of fish behaviour that are not associated with sampling gear or survey vessels but might influence sampling efficiency with respect to true density and composition of fish in the study area. This type of behaviour will be designated "natural behaviour".

NATURAL FISH BEHAVIOUR AND STOCK ASSESSMENT

One major problem in the reliability of time series obtained from standardized abundance surveys is unexplainable variability, which arises from variation in catchability (q) between years (Pennington 1985, 1986, Pennington and Godø 1994). Such variation in q may occur in extremely well standardized surveys such as the US groundfish survey on Georges Bank (Pennington and Godø 1994). Also, similar and unexpected changes in abundance of one stock has been observed simultaneously in different surveys covering the same area. For example long rough dab, an unexploited species in the Barents Sea, showed a variation in abundance and composition in both the Russian and Norwegian surveys from 1985-1990 that can only be explained if substantial changes in catchability occurred over time (Walsh and Mokeeva 1993). The noise created by this type of variability may seriously reduce reliability on abundance estimates, but will not be incorporated in standard estimation procedures when variance of the mean catch is used as a measure of precision (Pennington and Godø 1994).

In this paper I will discuss some aspects of natural behaviour of relevance for stock assessment as well as for comparability of trawl catch data. Both published and unpublished material is used in the presentation. Of the numerous factors which can be listed, I will concentrate on vertical distribution, diurnal changes in efficiency, and changes in efficiency due to distributional patterns.

After discussing these factors, I will consider issues relevant to improving the reliability of estimates obtained from trawl surveys.

RESULTS AND DISCUSSION

Vertical distribution

When the catch equation

$$n = qfN \text{ (where } n \text{ and } N \text{ are catch and stock abundance,}$$

q is catchability, and f is effort)

is considered relevant as a basis for trawl surveys, it is assumed that all fish or a fixed (constant) proportion is available to the trawl, and that the trawl operates with constant efficiency. The results from the Norwegian acoustic surveys for cod and haddock, demonstrate clearly the lack of validity of this basic assumption (Fig. 1). The degree to which violations of this assumption affect survey results is unclear because several factors are not well understood:

- The effective catching height of the trawl, as this may change due to fish avoidance behaviour associated with trawling noise (see Ona and Godø 1990)
- Areal and periodic variation in trawling noise avoidance reactions (Engås and Godø unpubl. data) and poor understanding of the causes of this variability.
- Possible effects on q of species and size specific vertical stratification.

Individual fish behaviour studies indicate that gadoids spend substantial time in the pelagic zone (Arnold *et al.* 1993). This phenomenon is also observed in typical demersal species as place (Fig. 2).

In the past effort has been concentrated on describing problems connected to vertical distribution and migration. Improved understanding of the dynamics of vertical distribution and migration is still needed, however, more important is quantitative information which can provide a basis for improving the reliability of surveys.

Diurnal effects on q

Day - night effects are more or less automatically considered when analysing experimental trawl catches. In some surveys exclusively day or night catches are used for abundance estimation, while, in other surveys all catches are used assuming that the effect of day - night differences is similar in all years. Normally, day catches are higher than night catches. The difference may vary between areas and periods by size and species (see Engås and Soldal 1992).

This type of behaviour creates uncertainties in results from trawl experiments and in survey abundance estimates. The dynamics of diurnal behaviour are, however, poorly known, and, hence, the effects difficult to predict. Factors of major importance for diurnal variation in q are:

-light conditions

-current

Light conditions are of utmost importance for the fish behaviour associated with the catching process (Wardle 1986), and are also an important stimulus in the natural behaviour of the fish. Firstly, diurnal vertical migration might be triggered by the light level (Beamish 1966, Engås and Godø 1986), and thereby create diurnal variation in availability. Also, day-night changes in activity are observed, e.g. Clark and Green (1990) observed that cod off Newfoundland altered between an active day period in one area and a passive phase at night on a resting location.

Tidal currents have been demonstrated to have strong influence on vertical distribution of single fish (Fig. 2). Migrating fish may utilize tidal currents to save energy during long migrations (Arnold *et al.* 1993). Michalsen (1993) found that tidal currents affected vertical distribution of cod and haddock just as much as light, by examining variation in the observed acoustic density in the bottom zone (Fig. 3).

A major constraint for the understanding of day-night differences in trawl catches is the possible interaction of several factors, of which light and tidal current are probably the most important. When the observed effect (e.g. vertical migration) is a product of two independent stimuli, the influence of which may be seasonal, and size and species dependent, the dynamics become complex.

Distribution patterns and efficiency (social behaviour)

A relatively stable population exposed to a constant exploitation pressure is expected to produce limited variation in CPUE throughout the year and between years. Fig. 4 indicates monthly CPUE trends for cod in the Barents Sea trawl fisheries during three different years. The graph demonstrates dramatic changes in CPUE from season to season. The overall patterns are similar in 1974 and 1987, but differ substantially in the 1960s. Much of the difference may certainly be due to changes in distribution of effort on species, by period and area. However, changes in q by season can be important, as expressed by a Norwegian fisherman: 'In periods the Norwegian

trawler effort may be distributed over great areas and daily reports from all of them reveal small catches and nothing to observe on the echo sounder for the entire fleet. Suddenly, overnight, we may start pulling in large catches, and then the strange thing happens; simultaneously, reports of good catches are received from our companions from several geographic areas'. Do these types of stories arise from incidental circumstances, or, alternatively, is this an example of abrupt changes in q due to environmental changes? My working hypothesis is that the phenomenon is due to abrupt changes in q which can be explained by changes in the distribution pattern of the fish. How can variation in CPUE as observed in Fig. 4 be explained by variation in distribution pattern?

Selection is often strongly size dependent and is described by a simple sigmoid curve, as illustrated for fish escapement under the ground gear of sampling trawls (Fig. 5). Replacement of bobbins with a heavy rockhopper is an efficient technique for reducing such escapement (Godø and Walsh 1992). Studies of cod escapement under a sampling trawl equipped with rockhopper ground gear have, in contrast to Fig. 5), indicated irregular selection by size (Fig. 6, Engås and Godø, unpublished data). In this case trawl efficiency was substantially higher for intermediate sized fish than for smaller or larger fish (Fig. 6). The intermediate size groups dominated the population in the experimental area, as is evident from catch by length (Fig. 6). The same pattern, i.e. irregular efficiency by size, appears from another experiment with a different size composition. Here it also appears that escapement varies with fish density, i.e. efficiency is particularly low at low densities (Fig. 7, Engås and Godø, unpublished data). Direct observations have indicated that these types of selection curves might be due to behavioural differences between the more abundant sizes forming schools and individuals from the less abundant groups occurring alone (Engås and Godø, unpublished data). A solitary fish will swim in front of the ground gear and continuously search for escape routes, while schooling fish lift from the bottom and try to remain between the wings well in front of the ground gear, reducing escapement under the trawl. It was also observed that a fraction of the school may suddenly fall back into the trawl, often a direct following of the break out of a single individual.

If these observations are valid, catching efficiency will be reduced if the population is made up of individual fish scattered throughout their habitat compared to a situation when the population is concentrated in patches. This may compare to low and high abundance situations for a stock, i.e. abundance could be negatively biased when stock density is low compared to when it is high (see Godø 1994). When comparing abundance estimates of cod from a Norwegian trawl survey and VPA, it is evident that a density dependent variation in catchability exists (Fig. 8).

Catchability may also change during the year or between years if distribution patterns vary.

Analysis of the effects of natural behaviour are difficult to perform systematically. I think, however, that modern observation techniques provide new possibilities for more improved observation of fish behaviour both on individual basis and on a large scale. In the future data obtained from this type of work, and also from continuous monitoring natural behaviour during surveys (Godø and Wespestad 1993), may provide considerable insight which could lead to major improvements in the reliability of survey abundance estimates.

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REFERENCES

- Arnold, G.P., Greer Walker, M. Emerson, L.S. and Holford, B.H. 1993. Movements of cod (*Gadus morhua* L.) in relation to the tidal streams in the southern North Sea. *ICES J. mar. Sci.*, in press.
- Clark, D.S. and Green, J.M. 1990. Activity and movement pattern of juvenile Atlantic cod, *Gadus morhua*, in Conception Bay, Newfoundland, as determined by sonic telemetry. *Can. J. Pool.* 68: 1434-1442.
- Engås, A. and Godø, O.R. 1986. Influence of trawl geometry and performance and fish vertical distribution on fish sampling with bottom trawl. *J. North. Atl. Fish. Sci.* 7: 35-42.
- Engås, A. and Godø, O.R. 1989b. Escape of fish under the fishing line of a Norwegian sampling trawl and its influence on survey results. *J. Cons. Int. Explor. Mer* 45: 269-276.
- Engås, A. and Soldal, A.V. 1992. Diurnal variation in trawl catch rates of cod and haddock and their influence on abundance indices. *ICES J. mar. Sci.* 49: 89-95.
- Godø, O.R. and Walsh, S. 1992. Escapement of fish during trawl sampling - implication of resource assessment. *Fish. Res.* 13: 281-292.

Godø, O.R. and Wespestad, V.G. 1993. Monitoring changes in abundance of gadoids with varying availability to trawl and acoustic surveys. *ICES J. mar. Sci.* 50: 39-51.

Godø, O.R. 1994. Relationships between survey indices of recruitment and abundance estimates from VPA of northeast Arctic cod. Contribution to The sixth Russian-Norwegian symposium, Bergen, 14-17 June 1994. "Precision and relevance of prerecruit studies for fisheries management related to fish stocks in the Barents Sea area and adjacent waters". Paper no. 4.5. Institute of Marine Research, Bergen, Norway.

Michalsen, K. 1993. Døgnvariasjon i trålfangster av torsk (*Gadus morhua* L.) - et resultat av vertikalvandring og fødeopptak (Diurnal variations in trawl catches of cod (*Gadus morhua* L.) - a result of vertical migration and food intake). Cand. Scient.-Thesis, University of Bergen, Bergen, Norway, 53 pp + XII Appendices.

Ona, E. and Godø, O.R. 1990. Fish reaction to trawling noise: the significance for trawl sampling. *Rapp. P.-v. Reun. Cons. int. Explor. Mer* 189: 159-166.

Pennington, M. 1985. Estimating relative abundance of fish from time series of trawl surveys. *Biometrics*, 41: 197-202.

Pennington, M. 1986. Some statistical techniques for estimating abundance indices from trawl surveys. *Fish. Bull.* 83: 519-525.

Pennington, M. and Godø, O.R. 1994. Measuring the Effect of Changes in Catchability on the Variance of Marine Survey Abundance Indices. *Fish. Res.* (submitted).

Walsh, S. and Mokeeva, N. 1993. Changes in abundance and distribution of the Barents Sea long rough dab, *Hippoglossoides platessoides* (Fabricius) during the period 1980-1992. *ICES C.M.* 1993/G: 36.

Wardle, C.S. 1986. Fish behaviour and fishing gear, pp 463-495. In: T.J. Pitcher (Ed.) *The Behaviour of Teleost Fishes*. Croom Helm, London.

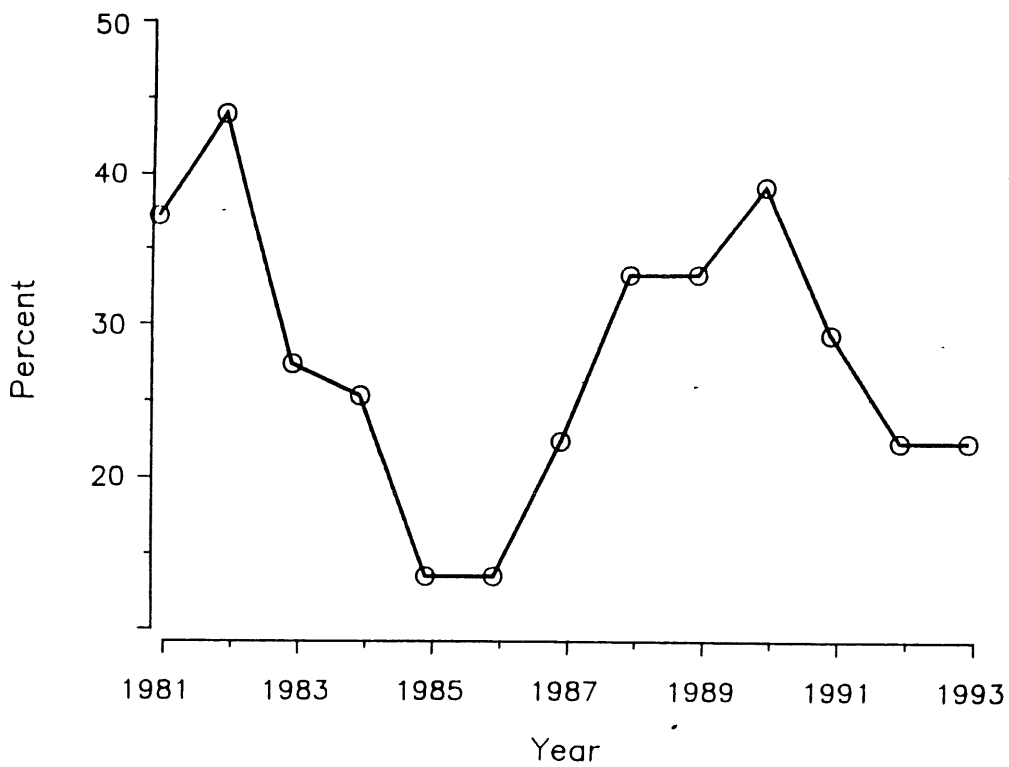


Figure 1. Variation in availability of northeast Arctic cod and haddock, given as the percent of the acoustic abundance found in a bottom zone 10 m thick.

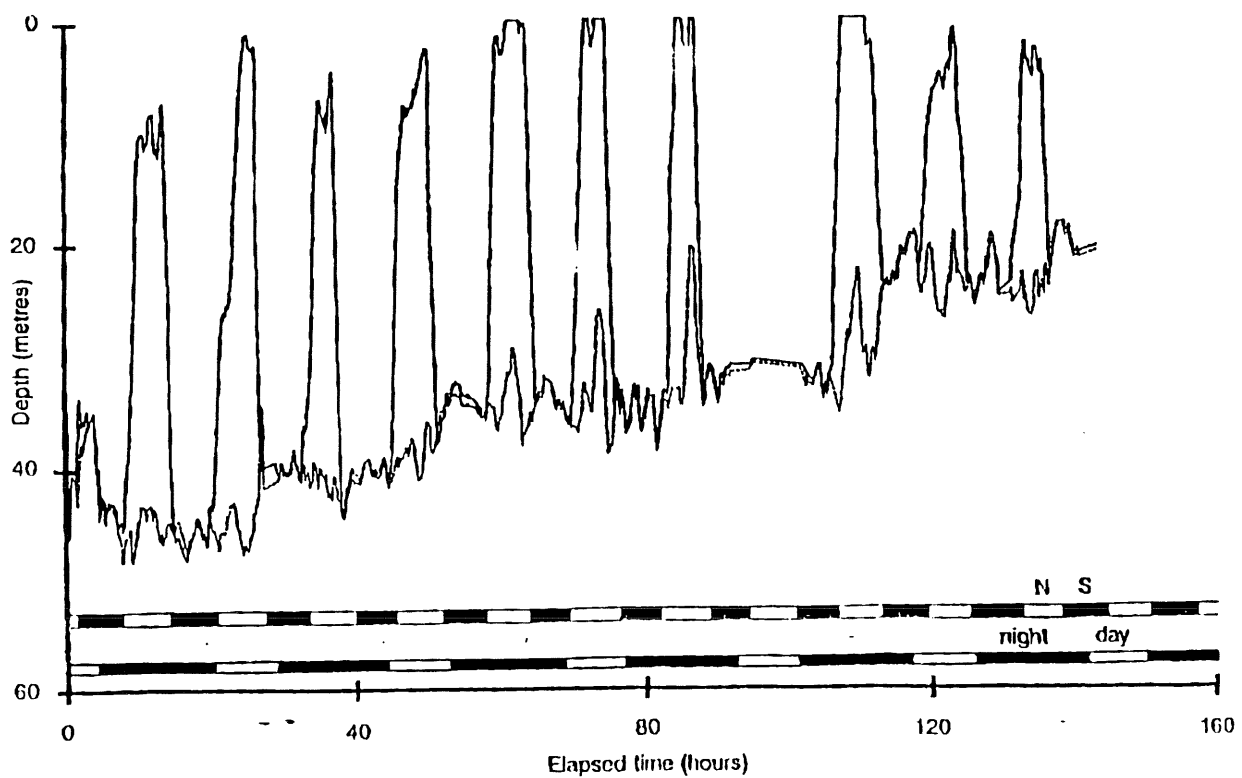


Figure 2. Vertical migration of place in the North Sea in relation to day/night and tidal currents. Adapted from Arnold (personal comm.).

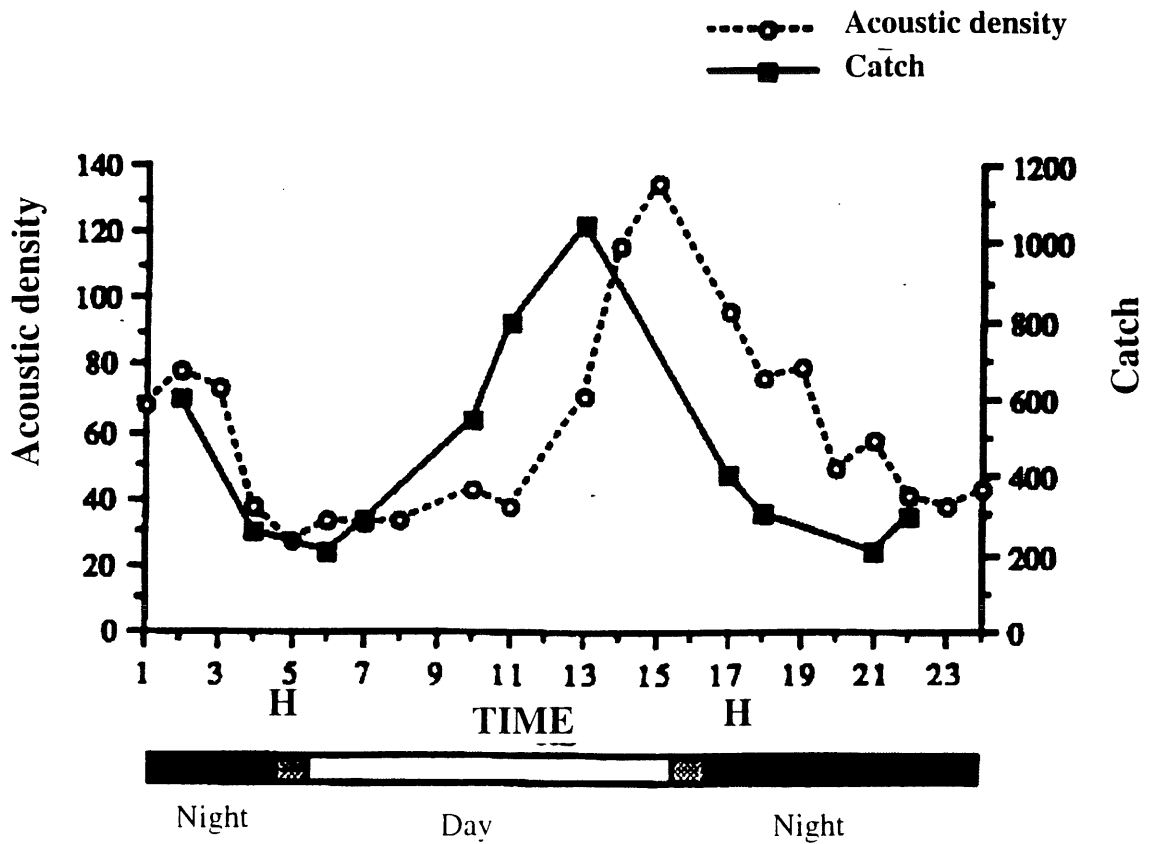


Figure 3. Mean of acoustic density in bottom channel and bottom trawl catches by hour. Day and night and high-tide (H) are indicated. Adapted from Michalsen (1993).-

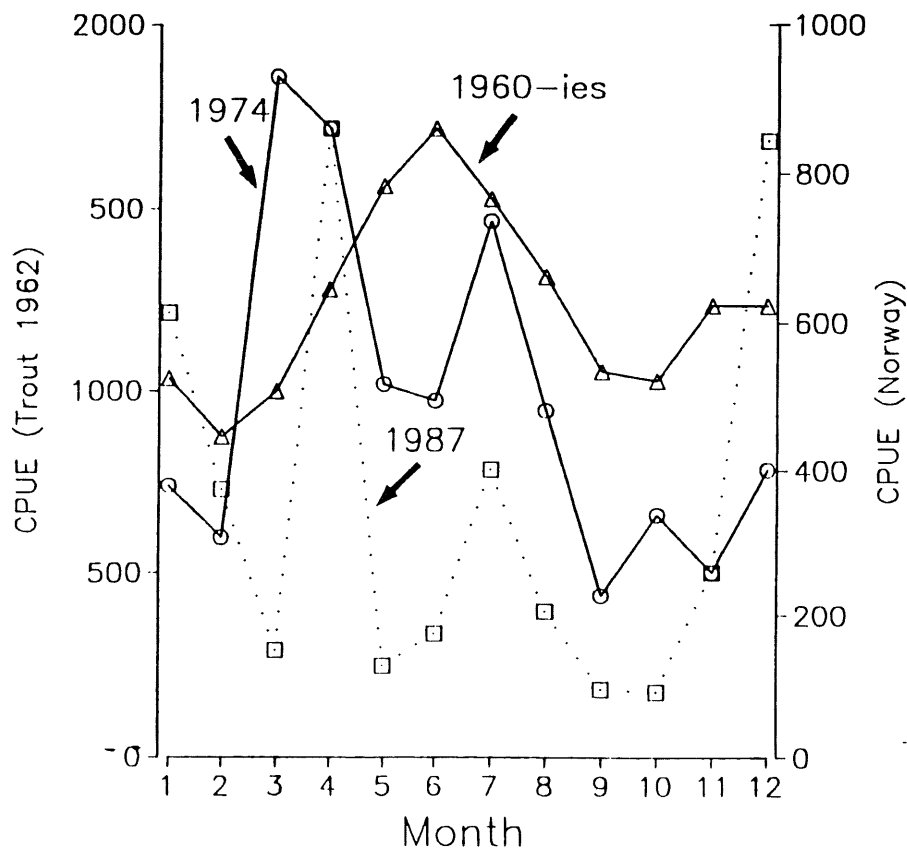


Figure 4. Seasonal variation in CPUE (kg per hour trawling) in the eastern Barents Sea from the early 1960s (adapted from Trout 1962), from 1974 and 1987 (Norwegian trawlers).

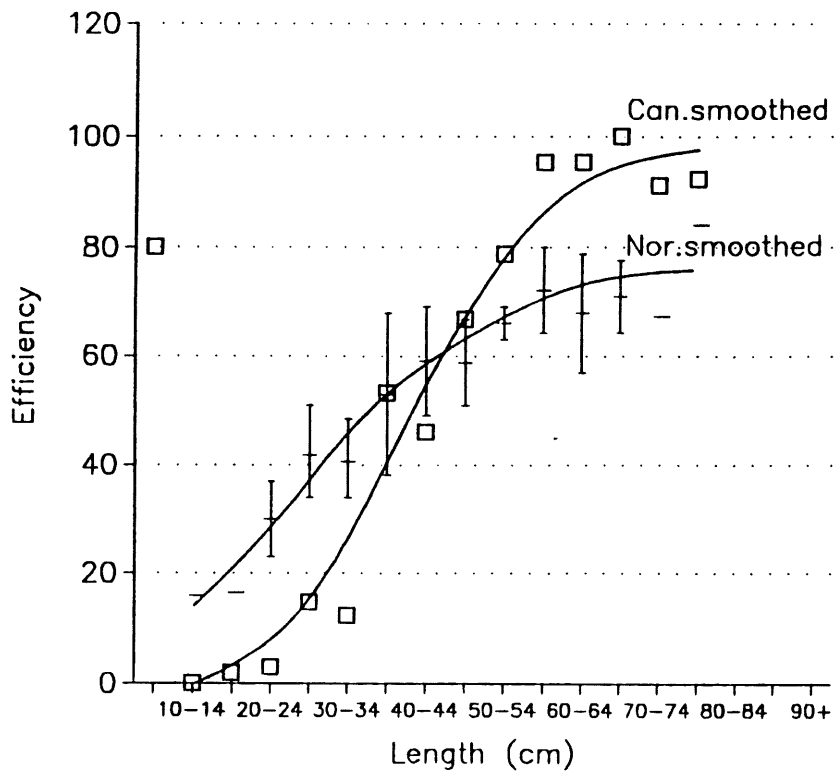


Figure 5. Escapement of cod under the fishing line of Canadian (Can.smoothed) and Norwegian (Nor.smoothed) survey trawls. From Godø and Walsh (1992).

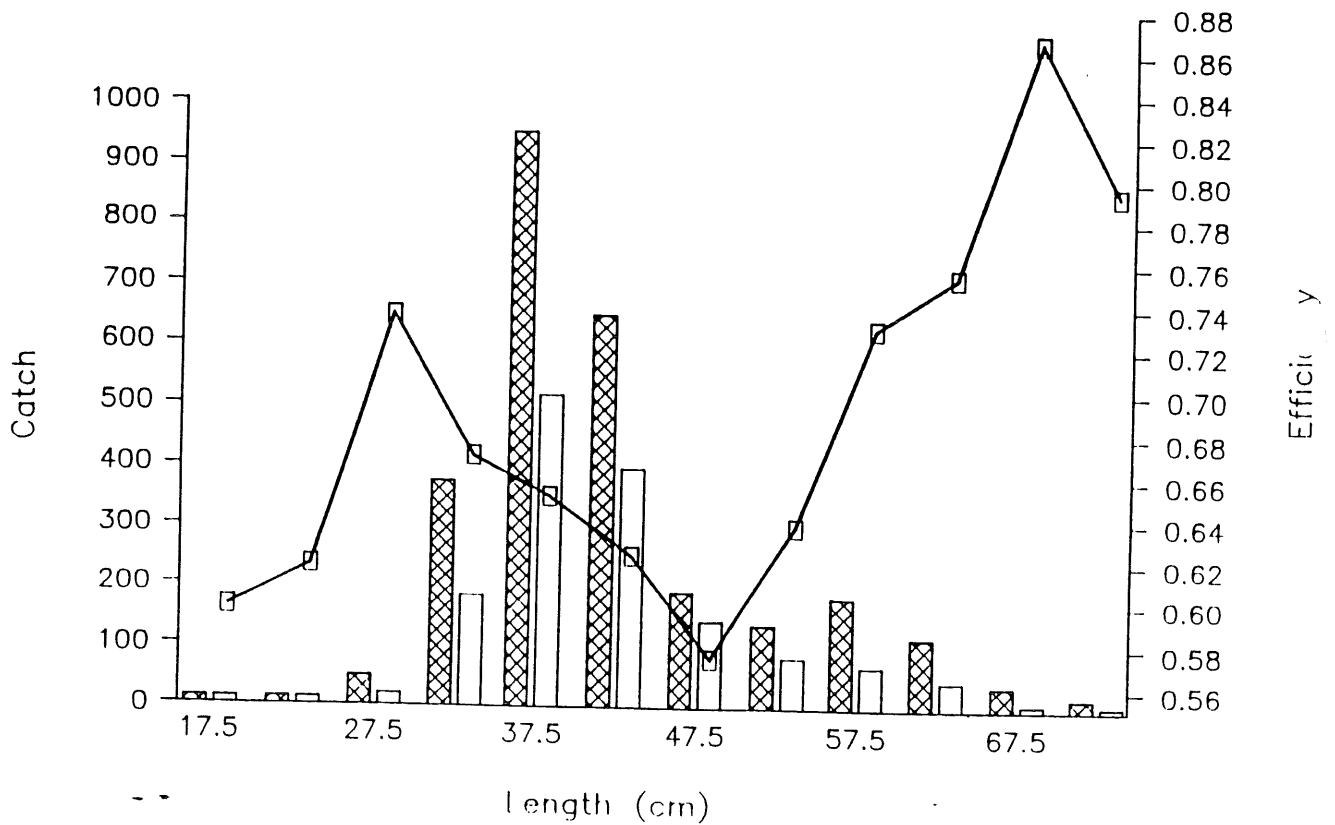


Figure 6. Social effects on escapement of cod under the fishing line of a trawl. Hatched bars are catch in numbers, open bars are numbers of escapes under the trawl. Fish belonging to the dominant size group (25-45 cm) form and react as a school and thereby escapement is reduced compared to larger and smaller individuals.

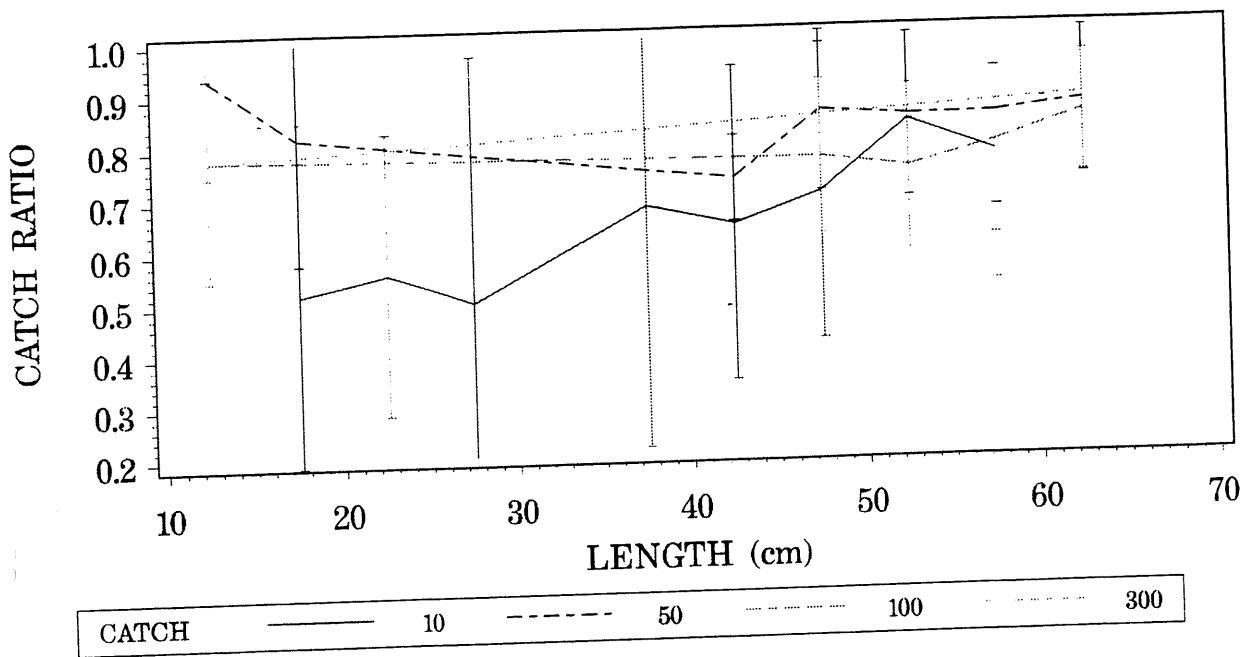


Figure 7. Catching efficiency at various catch levels during escapement studies with small bags under a Norwegian sampling trawl equipped with rockhopper ground gear.

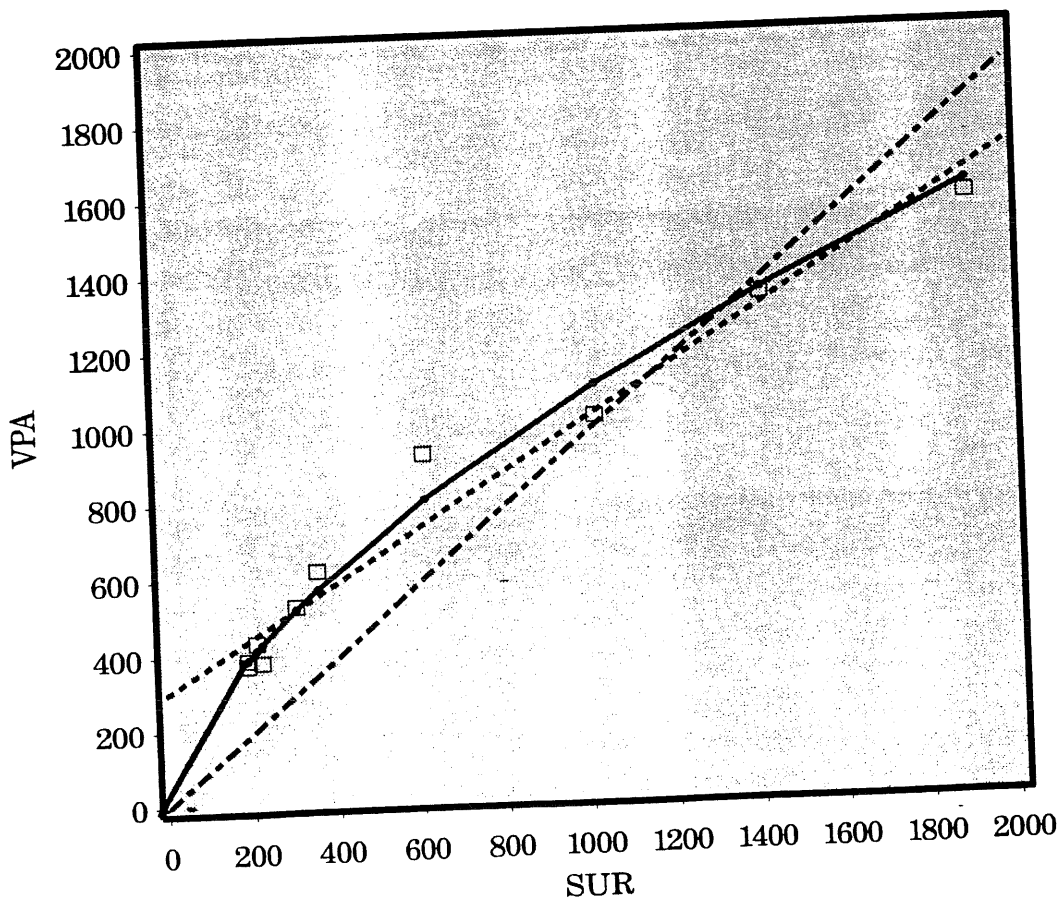


Figure 8. Relationships between survey and VPA abundance estimates of cod. Hatched lines are linear regressions with and without intercept. Continues line is based on a log - log regression (from Godø 1994).