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Density Dependent Catchability in Bottom Trawl Surveys

by

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Abstract

Fish form schools, layer or patches in which the individual fish's behaviour is not independent of its neighbours movements. On the other hand, at low densities fish may have the freedom to act as single individuals independently of what other fish are doing. Potentially, if these contrasts occur in nature, they may give rise to behavioural differences of fish in front of the trawl at high and low densities with successive effects on catchability and bottom trawl indices of stock abundance.

We explore in this paper the hypothesis that the density of fish has a significant effect on catchability of the survey trawl. Data from Norwegian and Canadian video observation recorded during trawling are studied, and related to bag trawl experiments which measured escapement underneath the survey trawls in both regions.

Introduction

Catchability is generally assumed constant between surveys, i.e. varying without trend, when estimating swept area indices from bottom trawl surveys. However, it is well recognised that this assumption is incorrect. Fish behaviour, density, maturity, light intensity, physiological condition, the environment, and trawl performance are some of the main factors that will cause catchability to vary. Such changes in catchability can create biases in the time series and reduce the precision of the abundance indices. For example Godø (1994, 1995) suggested that abundance of Barents Sea cod (*Gadus morhua*) indices would be negatively biased downward when stock density was low and positively biased upward when density was higher due to a strong link between density

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and fish behaviour in the trawl path during the fish capture process. These changes in stock density were thought to be related to variation in the distribution pattern of the stock whereby fish may occur as single individuals scattered across their habitat or concentrated in patches.

Recent studies show that fish escapement underneath the survey trawl can be quantified by attaching bag trawls underneath to capture downward escaping fish (Engås and Godø 1989, Walsh 1992, Godø and Walsh 1992; Dahm and Weinbeck 1992). We explore the hypothesis, which arose from qualitative video studies of cod, haddock and flatfish that fish behaviour in front of the trawl and hence escapement underneath the trawl are affected by variation in fish density during the catching process. We will use data from bag trawl experiments conducted in the Barents Sea and off the coast of Newfoundland and discuss the significance of these finding in terms of reliability of survey trawl indices.

Materials and Methods

The Norwegian data was collected of the northern Norway coast in 1995 (Table 1) using the standard Norwegian survey trawl: the Campelen 1800 shrimp trawl. This three bridle shrimp trawl is rigged with 40 m sweeps, 35.6 cm diameter rockhopper footgear and a 20 mm mesh size codend . For the purpose of catching escaping fish three bag trawls were mounted under the trawl as described by Engås and Godø (1989). Tow duration was in most cases 20 minutes at about 3 knots.

The Canadian data was collected off the east coast of Newfoundland in 1994 using two trawls: 1) the old standard survey trawl, the Engel 145 High Lift otter trawl rigged with three bridles 54 m sweeps, with 35.6 cm rockhopper footgear and a 29 mm codend liner; and 2) the new standard survey trawl, the Campelen 1800 shrimp trawl rigged with 40 m sweeps, 35.6 cm diameter rockhopper footgear and a 12 mm mesh liner in the codend (see McCallum and Walsh 1996 for rigging details of both gears). Similar to the Norwegian experiment three bag trawls were mounted underneath the main trawl covering 100% of the fishing area of the main trawl as illustrated in Walsh (1992). Tow duration for all experiments were standardised to 1 nm. The tow duration used a standard survey towing speed of 3.0 knots and a tow duration of 15 minutes.

Table 1 Norwegian and Canadian bag trawl experiments

COUNTRY	YEAR	MONTH	GEAR	SPECIES	NO. TOWS
Canada	1994	January	Campelen	cod plaice	23
Canada	1994	January	Engel	cod plaice	21
Norway	1995		Campelen	cod haddock	45

Analysis

From the Norwegian data, both cod and haddock (*Melanogramus aeglefinus*) were in sufficient numbers to be used in the analyses. Cod and American plaice (*Hippoglossoides platessoides*) were analysed from the Canadian experiments.

The density of fish was determined from the catch data (sum of codend and bag catches). Schooling of fish normally occur by size. The catches were therefore allocated to three size groups which constituted the density information used in the analysis. The size groups were:

Size	Cod and haddock	Flatfish
Small	0-29	0-19
Medium	30-49	20-29
Large	50+	30+

The hypothesis of density dependency of the under trawl efficiency is tested through an analysis of variance model (ANOVA). Efficiency is calculated as the trawl catch proportion of sum of trawl and bag catches. Escapement under the trawl is normally strongly fish size dependent. Therefore size together with density was used as explanatory variables and time (day or night), and species were class variables in the model. In the Norwegian experiment tows were not conducted at dawn and dusk. In the Canadian experiments day was defined as the period when the sun was above the horizon. The analysis were done by SAS Lab (SAS 1992). A power transformation was necessary to avoid violation of assumptions done in the ANOVA.

Results and Discussion

Fish behaviour

Based upon examination of several video recordings of fish in the mouth of the trawl we offer a qualitative description of fish behaviour for round fish and flatfish as follows:

Cod/haddock

We classified three predominant density related behaviours that was seen independently in both the Norwegian and Canadian experiments and was also evident in other video recordings from other monitoring events (see Fig. 1).

Loners :When 1 or 2 medium to large size cod are present in the recordings they were seen close to the front of the footgear and exhibited a characteristic kick and glide swimming motion behaviour across the trawl mouth. These fish tend to stay very close to the bottom and their turn-over rate is high. During these movements the cod are actively searching for gaps in footgear rigging or bottom contact to escape.

<u>Schoolers :</u>When 5 or more fish are present together in the recordings they form a school and exhibit uniformed behaviour as they swim orientated to the tow direction. They attempt to maintain greater distances between themselves and the footgear and exhibit very little frightened behaviour. Generally when one fish turns to enter the trawl several of the others will follow. The fish are approximately 0.5 to 1 m off bottom and their turnover and escapement rates are lower in comparison with the loners.

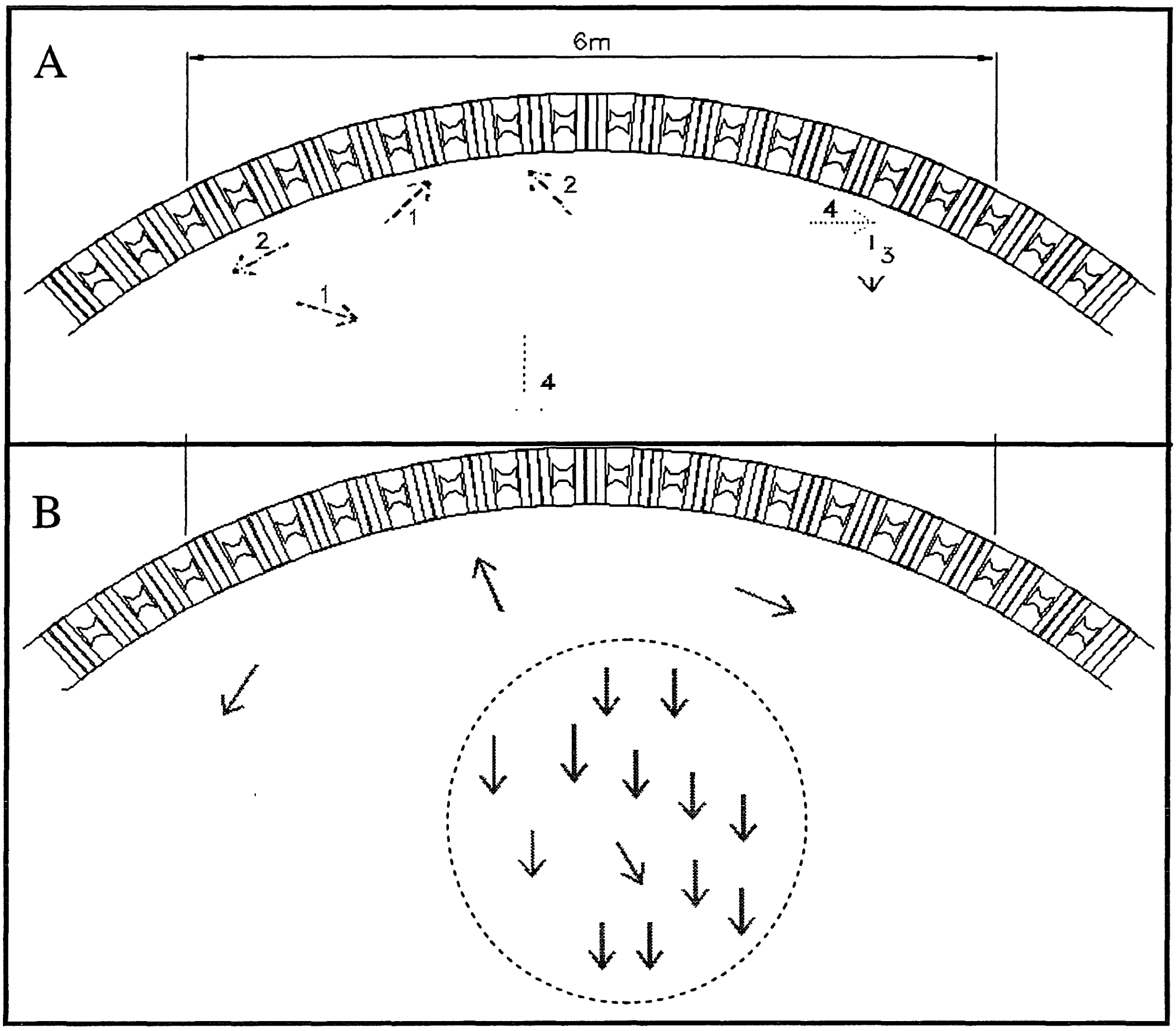

Figure 1. Schematic presentation of distribution and behaviour in front of the ground gear of loners (A) from different situations (1-4), and loners-schoolers (B, schoolers are encircled).

<u>Loners-schoolers</u>: At times loners and schoolers will appear in the video recordings together. In this case the loners do not join the schooling group but stay behind it and act independently in the manner described above. The charateristic crossing behaviour of the loners seems to be interupted in this situation.

Flatfish

Flatfish (doesn't include the halibuts) appear to react independently with various components of the footgear, i.e. are non-schoolers. Individual flatfish stay very close to bottom in front of the footgear and movements are generally laterally upon close approach of the footgear. After repeated encounters with footgear flatfish will either slow down their swimming (or stop) and allow the gear to pass over them or take advantages of gaps in the gear to escape under the footgear.

In front of the footgear, the flounder's ability to manoeuvre becomes critical and appears to be a function of density of fish in the trawl mouth. As density increases, flatfish will tend to move a little higher off bottom and when tired will burst upward and turn into the net. Flatfishes arriving in the mouth area also encounter other flatfishes routed for the first time off the bottom by the footgear. Since behaviour reaction to a trawl component is generally in a lateral direction and not forward as in roundfish, swimming is often disrupted to prevent collisions with these other fish routed from bottom. When this happens, the fish lift off bottom, turn or flip backwards into the net and the probability of escape under the footgear is lowered.

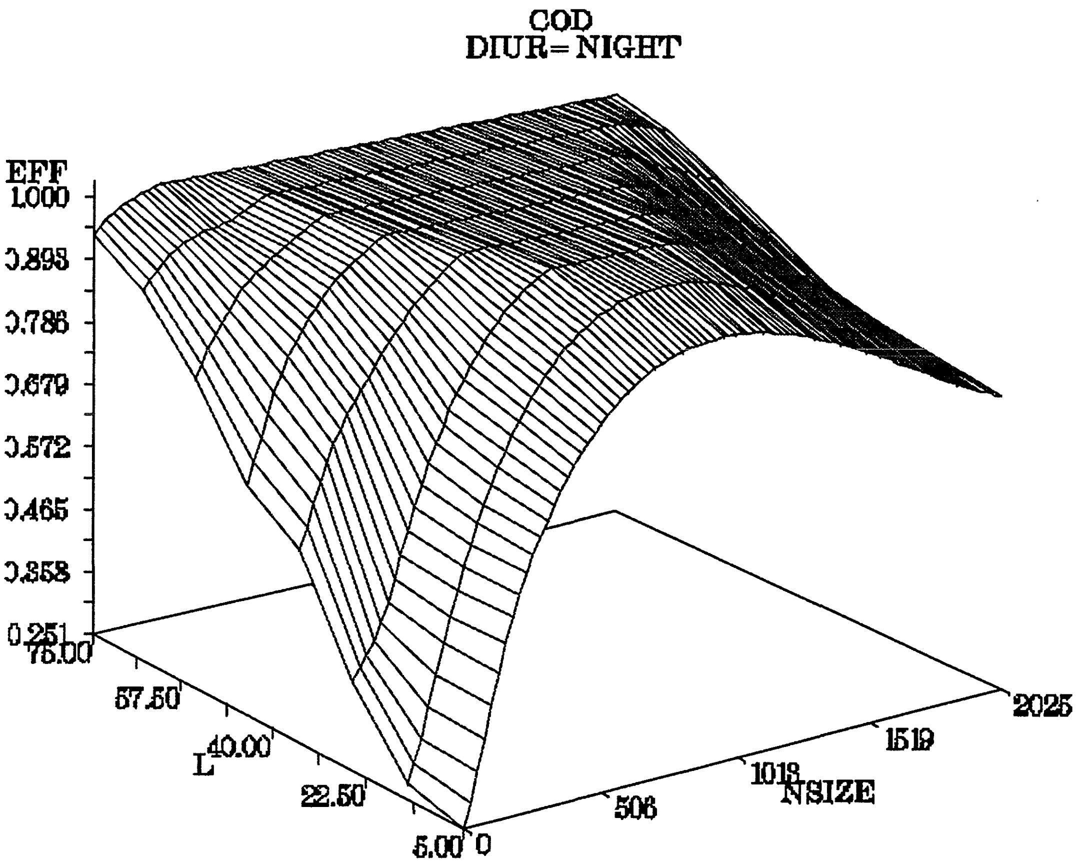

Figure 2. Length (L) and density (NSIZE) dependency of efficiency on cod as observed in the Canadian experiment. Efficiency = codend catch/sum of catch in codend and bags.

Trawl experiments

The statistical analysis show that trawl efficiency is a function of length and density in both the Canadian and the Norwegian data (Tables 1 and 2). The length effect is not surprising since Engås and Godø (1989) and Walsh (1992) showed that trawl efficiency was size dependent in gadoids and flatfish. Time of day and species effects are significant in Norwegian data but not Canadian data. Diel difference in escapement of cod may differ across geographical regions and within a region. Walsh (1991) showed that escapement was significantly higher at night in flatfish but not cod.

Figure 2 shows an example of variation of efficiency related to density and length. The density dependency is in many cases difficult to separate from other factors of importance. When data are run in the ANOVA model density always comes out as a significant factor, sometimes alone and other times in interaction terms with other factors. Observed and modelled efficiencies for the Norwegian experiment are compared in Figure 3.

Using flatfish and roundfish in the same analysis as done in the Canadian experiments may confound the results. All studies of fish behaviour in the catching process show that these two group of fishes behave differently (see behaviour part above) and in retrospect these groups should have been treated separately. However, it appears from the video studies that the interaction between individual within the groups is in both cases modifying the behaviour as density increase. Further, this change in behaviour, although for different reasons, reduces the number of escapes under the trawl.

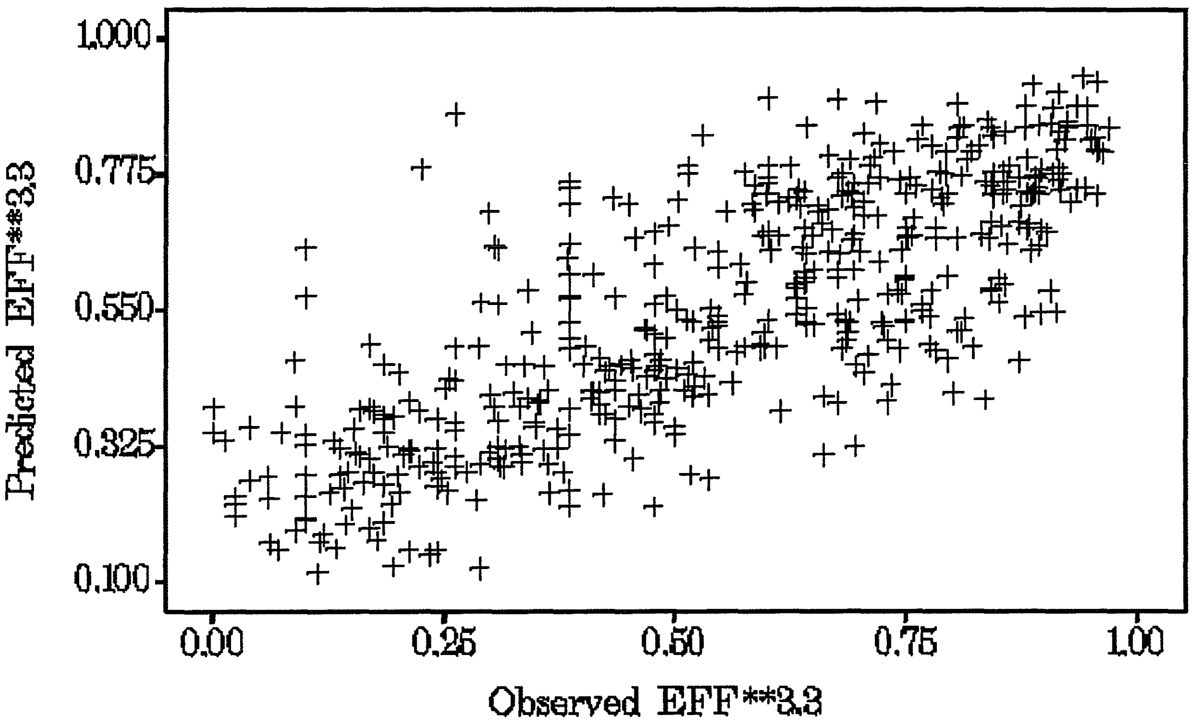

Figure 3. Observed - predicted plot based on the final ANOVA model for the Norwegian experiment.

We recognise that there are some limitations in this present approach for analysing the density effect on survey trawl efficiency. Firstly, we are restricted to investigating the effect of fish density on escape rates in the trawl opening, i.e. the area covered by the trawl bags and cannot comment on the area between the wings and trawl doors. Secondly, using catch as the applied density measure may not necessarily be the best one. In theory, the same catch can be obtained from a standard haul when the study area is occupied by evenly distributed individuals at a low density compared to when hitting the only patch of fish in the area containing the same number of individuals. The physical configuration of fish prior to arrival of the vessel, i.e. under undisturbed conditions, is unknown. Video observations of the trawl mouth from experimental situations, like those presented here, indicate, however, that fish normally appear in the area in front of the footgear at varying rates. At increasing density, the fish seems to appear in front of the trawl in form of an increasing number patches. We, therefore think that it is a fair assumption to use catch as a reasonable proxy for density. Further, in the type of exploratory model used here, with several important variables entered, the output results were expected to vary substantially.

Table 1. Results from the ANOVA model run on the Norwegian data. More details are given in. Response: $EFF^{3.2}$. For the over all model $R^2 = 0.62$.

Source	DF	SS	MS	F	Pr > F
Species	1	1.426	1.426	55.97	0.0000
Length	1	0.745	0.745	29.23	0.0000
Length*Species	1	0.331	0.331	13.01	0.0003
Length*Density	1	0.320	0.320	12.56	0.0004
TIME	1	0.108	0.108	4.251	0.0398
Density	1	0.103	0.103	4.054	0.0447
Species*TIME	1	0.0665	0.0665	2.612	0.1068
Density*Species	1	0.0519	0.0519	2.039	0.1540
Density*TIME	1	0.0177	0.0177	0.694	0.4053
Length*TIME	1	0.0052	0.0052	0.203	0.6525

We strongly want to emphasise that the premises for this paper was an investigative exercise to elucidate the problem. Nevertheless, we are encouraged that similar experiments from two geographical areas gave similar supporting results.

Surveys are supposed to give precise information on abundance and composition of stocks. If our hypothesis is valid, surveys might underestimate stocks when low and overestimate when high. For example, between 1983 and 1991, the average catch per tow of cod off the Northeast coast of Newfoundland ranged from 80 to 205 fish per tow, from 1993 to 1996 it has dropped to around 2 cod per tow. In this critical situation, if our hypothesis is correct then our understanding and ability to evaluate stock development is potentially low. Recent discussion and simulations in the ICES Arctic Fisheries WG on the application of different catchability profiles in the tuning of the VPA of Northeast Arctic cod have underlined the need for better understanding of which factors are important in contributing to variation in catchability (ICES Arctic Fisheries Working Group, August 1997).

Conclusions

This paper supports the initial hypothesis of density dependence effect on catchability. We recognise the limitations of the data but believe we have demonstrated that there is a possible connection between density and catchability. We recommend that further studies which improve our understanding of natural and trawl induced behaviour along with studies of the interaction behaviour in demersal species are strongly needed to test this hypothesis.

Table 2. Results from the ANOVA model run on the Canadian data. Response: EFF^2 . For the over all model $R^2 = 0.33$.

Source	DF	SS	MS	F	Pr > F
Density	1	0.492	0.492	9.912	0.0021
Length*Species	1	0.456	0.456	9.176	0.0031
Length	1	0.333	0.333	6.702	0.0109
Density*Species	1	0.317	0.317	6.384	0.0129
Time	1	0.193	0.193	3.892	0.0510
Time*Species	1	0.152	0.152	3.067	0.0827
Species	1	0.0974	0.0974	1.962	0.1641
Length*Time	1	0.0562	0.0562	1.133	0.2896
Density*Time	1	0.0374	0.0374	0.753	0.3873
Length*Density	1	0.0057	0.0057	0.114	0.7358

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