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Determining the entrance position of fish in trawls

by

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Abstract

The entrance position of a fish is defined as its two-dimensional position in a cross section of a trawl near the centre of the headline. Individual fish entering the trawl, detected by high-resolution scanning sonar, were positioned by digitising the co-ordinates of the echo relative to the trawl panels. Entrance probabilities for different species may be computed for grid elements on the cross section, integrating the positional information over an entire trawl haul, and studied as a function of light level, density and fish size. Examples of entrance probabilities for cod and saithe on a few selected trawl hauls are shown.

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Introduction

Standardised bottom trawl surveying is the most common method used for abundance estimation of demersal and semi-demersal fish stocks (Azarowviz, 1981; Gunderson 1993; Godø, 1994). The main objective of the survey is to obtain an indicator of abundance (Pennington and Brown, 1981) and to reveal changes in population age structure and distribution over time. It has been demonstrated that these objectives rarely are met (Godø 1994), mainly due to the selectivity of the trawl or trawl process, and variable availability of the target species within volume swept by the trawl. The selection process in a bottom trawl is complicated, and the operation may be separated in three or more definite processes, namely mesh selection, horizontal herding and vertical herding, each acting to separate the actual sample from the available density, species and

size distribution on the selected locality. Several of the selection mechanisms involved are dependent on the light level (day/night/depth), and of the combined sound stimulus from the trawling vessel, otter boards and the ground gear. Significant improvements have been made on gear standardisation, with trawl menstruating equipment to ensure stable trawl performance, towing distance and bottom contact (Engås, 1994), but still, large differences are seen in catch rates and size distributions in repeated hauls on the same location (Aglen et al. 1999). Although some of the observed differences may be explained through variable vertical availability, due to day/night difference in vertical distribution pattern of the target species, the on-location-variability can only be reduced by drastic operational changes. The one commonly recommended is only to operate the sampling by daytime. As acoustic instruments are not an integral part of a standardised bottom trawl survey, the actual, or estimates of the vertical availability are not likely to be known in most bottom trawl survey results. Experiences from the Norwegian survey for cod and haddock, where parallel estimates of fish density are made by acoustics and bottom trawl (Hylen et al. 1986), clearly show that vertical availability is not only a day/night phenomenon. Availability varies from year to year, often correlated with the age structure in the stocks, but also with the abundance of main prey organisms (Godø, 1998). If bottom trawl survey methodology in the future aims to reflect the absolute abundance of groundfish, tools for including measurements of vertical availability and a better understanding of the herding process is needed.
Echo sounders with pressure-stable split-beam transducers have already been mounted on the headline of the trawl (Michalsen et al. 1999) in order to estimate the abundance of fish unavailable above the trawl. Cabled echo sounders and scanning sonar, which are in regular commercial use for catch monitoring in pelagic trawling, have been tried on bottom trawls (Ona & Eger 1988).
If the herding process of a trawl is successful, most of the fish between the otter boards will enter the mouth area of the trawl. Preferred, ideal entrance position would be in the central part of the opening, in the forward-projected opening area of the codend, since this leads to less mesh selection in the main body of the trawl. This paper describes a refinement of an earlier suggested method (Engås & Ona, 1990), used to study the fish entrance pattern of a bottom trawl by positioning the echo of the fish during entrance, relative to the bottom and trawl panels. The accumulated distribution of entrance may be used to quantify and study the herding efficiency for different species and size groups of fish in bottom trawls. Typical deviated parameters are: (1) fraction of entrance area used, (2) mean horizontal entrance position, (3) horizontal concentration factor, (4) mean vertical entrance position and (5) vertical concentration factor.

Material and methods

The trawl experiments were performed in March 1991 north of North Cape in the Nysleppen area at depth of 270 – 310 m from the research vessel "Johan Hjort". The standard Norwegian bottom sampling trawl, the Campelen 1800, with rockhopper ground gear (Engås & Godø 1989) was used during the trials. The normal vertical opening and wingspread of this trawl, as measured by the Scanmar sensors are 4.0 – 4.5 m and 17.5 – 18.5 m, respectively. The tow duration was about 30 minutes (Table 1), as measured from registered touchdown (Scanmar) of the ground gear to starting time of retrieval. Towing speed was standard 1.5 m/s (3 knots). The catch, Table 1. was worked up according to the procedured for bottom trawl surveys at IMR. A 330 kHz Simrad FS

3300 trawl surveillance sonar was mounted on the inside of the trawl, fastened to the central part of headline, and connected to a 2000 m net-sonde cable. A full specification of the sonar is found in Ona & Eger (1987). The sonar mechanically scanned the mouth area of the trawl with a single, circular transducer with 2.7 degrees opening angle. This ensured a visualisation of the echoes in the opening through a slice of 180 x 2.7 degrees in each scan (Fig. 1), transverse to the towing direction, about 3.5 meters in front of the central part of the ground gear. The vertical opening of the trawl during these experiments could be slightly changed by adjusting the tension of the cable to the sonar head.
The sonar data was stored on high quality videotapes for later analysis. From replays of the data, the detected single fish was positioned by digitising the position relative to a co-ordinate system. This had its x-axis along the bottom, and y-axis vertically at the bottom, toughing the left echo of the trawl panel, with origin at the crossing point between the axis (Fig. 1). The accumulated distribution of fish was described through summarising the number of detected targets in a grid with a resolution of 32 units along the x-axis (about 0.6 m) and 12 units along the vertical axis (about 0.4 m), and later contoured.

On the gridded data measurements of area concentration factor was measured as the area occupied by 80% of the fish, and further, mean horizontal position with standard deviation and mean vertical position was estimated. Computations were done at cell resolution level, and later converted to absolute units, meters, and adjusted for average cell size in x and y directions.

Results

The main results from the analysis is shown in Fig. 2, where the distribution of the accumulated detection's are indicated as density contours within the area of the trawl mouth. It is clearly seen that the herding of the fish have been effective, even under more or less complete darkness. Light level at 270 – 300 m depth was estimated from US Navy Illumination Charts (Anon 1952) to be less than 10^{-6} Lux during night time in March. Bioluminescence may have been created by larger zooplankton, but was not investigated here. As seen from the entrance positions and also from the computations of horizontal and vertical concentration factors, Table 2, these fishes utilise a small fraction of the trawl opening. The catch data show that all stations contained a mixture of large cod and saithe, mixed with smaller haddock. While the two first hauls contained a blend of the three species, the latter station only contained 2% haddock, 63% saithe and 35% cod. The average size of the cod and saithe were about 50 cm, and for haddock about 20 cm. The herding process of the otterboards and bridles must have been effective as the main portion of the fish is entering the trawl mouth in the centre of the trawl opening. The bulk of the fish, as represented by 80 % of the detected targets (F_{80}), used 18 to 22 % of the trawl opening. A slight horizontal shift in the distribution is seen in trawl haul 185, with the mass centre at 1.36 m to starboard, relative to the centre line of the trawl. The measures of horizontal concentration, the standard deviation of position, relative to the centre line, indicate that 67% of the fish is found within ± 2.58 to ± 3.31 meters of the mass centre for these particular trawl catches. In the vertical direction, more than 99% of the fish is detected in the lower half of the trawl opening, with a mass centre less than one metre above the bottom. The vertical concentration is large, as indicated by the low standard deviation, and the distribution is skewed towards the bottom. Exact vertical distributions may easily be reconstructed from the cellular data.

Table 1. Data on catch from the three trawl stations taken at the Nysleppen experimental area: 71 18'N 26 15'E, where the scanning sonar was used to determine the position of fish during entrance. N, number of fish, W-weight (kg), <L> mean length (cm).

Date (Time)	Depth (m)	Station no.	COD N/W/<L>	HADDOCK N/W/<L>	SAITHE N/W/<L>
10.03.91 (0050-0110)	310	184	280/126 (57.5)	336/37 (17.8)	112/170 (52.4)
10.03.91 (0306-0336)	310	185	317/523 (53.1)	128/21.6 (21.7)	418/623 (52.0)
10.03.91 0458-0528	275	186	1794/2154 (48.4)	102/41 (26.2)	3208/5136 (52.7)

Table 2. Computed fraction of trawl opening used, F_{80}, and horizontal and vertical mean entrance position with their standard deviations. Computations were made at cell resolution, and later converted to meters.

Station no.	F_{80}	<X>	SD(X)	<Y>	SD(Y)
184	0.18	-0.03	3.15	0.77	0.56
185	0.16	1.36	2.58	1.01	0.73
186	0.22	-0.01	3.31	0.98	0.76

Discussion

The results show that modern acoustic equipment can be used to study the entrance pattern in bottom trawls, and to measure indices of trawl efficiency. From the concentrated entrance pattern during nighttime, we may conclude high herding efficiency for cod and saithe, but the sound and hydrodynamic stimuli of the otter boards and bridles seems also to efficiently herd small haddock. They must have been herded and concentrated vertically long before entrance, since the reaction distance and time available for the fish to react and move is too small for this pattern to be established in the mouth area alone. Since the sonar head is mounted on the headline of the bottom trawl, the vertical section is 3 – 4 meters in front of the central part of the groundgear, it is not likely that significant numbers have been detected several times, by forward swimming and reappearance. It is usual, at least for daytime catches, that larger fish turns and swims with the trawl direction until exhausted, but extensive forward swimming relative to the trawl groundgear, when operating at 3.0 knots, is not observed on video investigations.

The extremely tight vertical distribution of the fish indicate that there must be a downward escape response during the herding both for cod and saithe, either due to the vertical component of the vessel noise, or due to a adapted behavioural response for these fishes. The small haddock may have been responsible for most of the vertical extension in the hauls 184 and 185, as haddock is known not to concentrate vertically (Engås, 1994), or rather to use the upper half of the trawl.
As the paper mainly is made to present a methodology-approach to improved understanding of trawl catch efficiency the observations will not be thoroughly discussed with respect to light level, stimuli and observed differences between trawl hauls. The presentation is mainly made in order to stimulate a discussion on several assumptions made in bottom trawl survey methodology, bearing implications also for other methods, as acoustic surveys.

These are:
Assumption no. 1. All species in the water column in front of a bottom trawl is fished with the same efficiency. (That is: The catch of a bottom trawl gives a representative picture of the mixture).
Assumption no. 2. For one species, each size group is fished with equal efficiency. (That is: the catch of a bottom trawl gives a representative picture of the true size distribution.)

Assumption no. 3. For all densities, and mixtures of densities, a bottom trawl has the same efficiency. (That is: linear response).

The validity of several of these assumptions have been thoroughly investigated by comparative investigations, improvements of groundgear contact and through visual investigations, mainly concentrated on the size selectivity.(see Engås 1994 and Godø 1994), but obtaining real efficiency measures seems to be more difficult.

How the fish enters the mouth area of the trawl is a good indication of how the fish respond to herding, both horizontally and vertically. The acoustic method may deliver data on this, and large differences are qualitatively observed between important species like cod, haddock, redfish (Sebastes sp.) blue whiting and hake. The general tendencies seen are that the slow swimmers like redfish and hake are not efficiently herded in either direction, and larger fish are more efficiently herded than small fish.
If entering position are carefully studied using scanning sonar on selected size groups of each species, a number of hard fact can be estimated to help establishing trawl efficiency factors for species and size groups. Using the same or similar equipment for studying the arrival time for individuals during the haul may also be used to study the effects of density on catch efficiency. In the investigations shown, measures of nearest neighbour distance may be computed, as the sonar detections indicate that there is a definite minimum distance held during entrance. This may be more important to a stressed individual during herding and “diffuse” positioning than in other situations. The “need for space” during stress may be the key to understanding also the effect of density dependent catch efficiency.
Future analysis should allow for a detailed analysis of the raw data captured by the acoustic system shown. Although the target strength is extremely sensitive to orientation of the entering fish, the analysis may then include size-specific position. With ultra-high frequencies, 2 MHz, it has been shown that even shrimp and larger zooplankton may be similarly positioned, but only within a limited range, about 4 meters.

Acknowledgement

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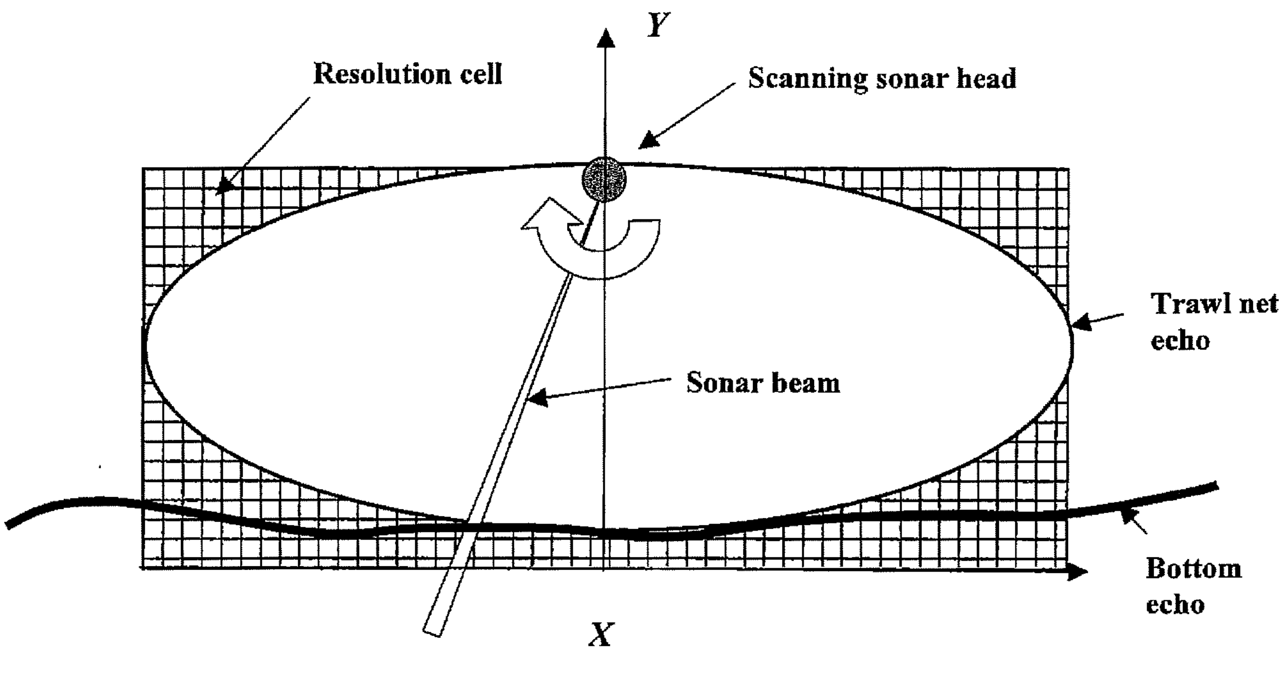
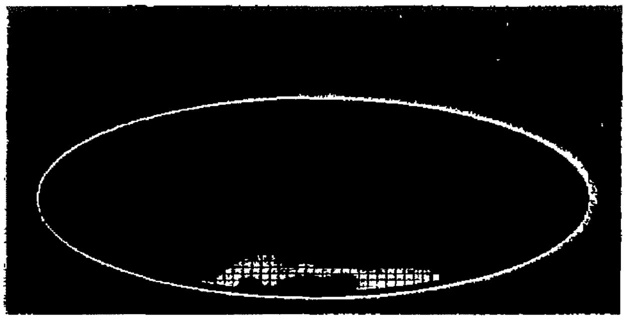


Fig. 1 Coordinate system , (X,Y, cell resolution), for positioning fish entering the trawl mouth of a bottom trawl.



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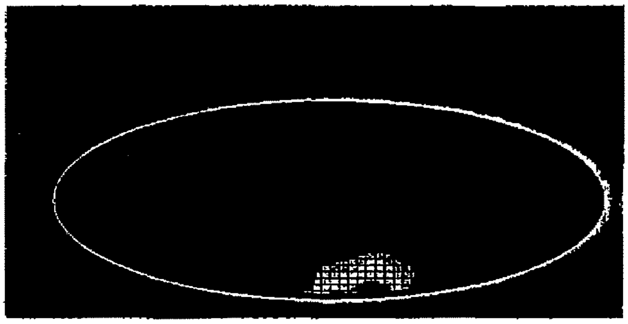

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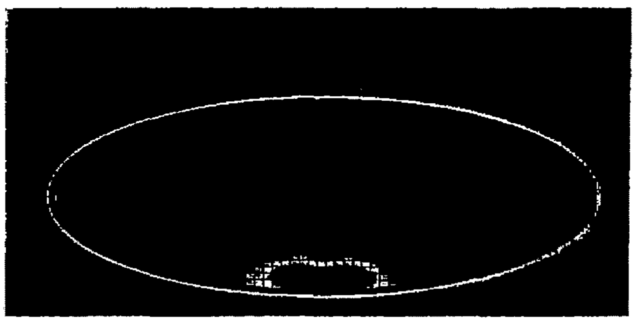

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Fig. 2. Fish entrance distribution pattern in three bottom trawl hauls. Positioned echoes are 197, 152 and 742 in the trawl hauls no. 184, 185 and 186 respectively. Catch data are given in Table 1.

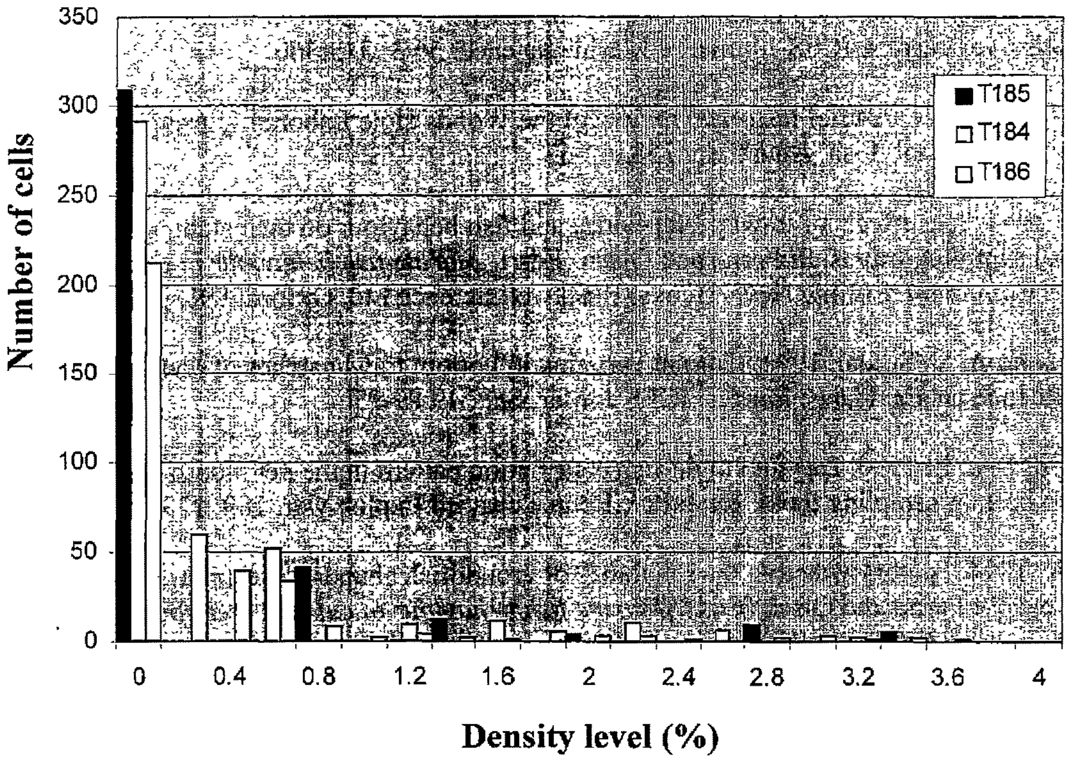

Fig. 3. Frequency of density levels in the cross sectional area of the mouth of three bottom trawl hauls. Total numbers of cells are 384. Note that most of the cells have no detection for all trawl hauls.

References

Anon 1952. Natural Illumination Charts. Dept. of the Navy Bureau of ships, Washington 25, D.C., Rep. No. 374-1, September 1952.

Anon 1998. Methods for Fishery Resources Assessment. Status and Potentials of Marine Resource and Environmental Monitoring. Report for the Norwegian Research Council, 1998, ISBN 82-12-01208-5

Aglen,A., A.Engås, I.Huse, K.Michalsen and B.K.Stensholt 1999. How vertical fish distribution may affect survey results. ICES Journal of Marine Science. 56/3: 345:360.

Azarowitz, T.R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series. Can. Spec. Publ. Fish. Aquat. Sci., 58, 62-67.

Engås, A. 1994. The effects of trawl performance and fish behaviour on the catching efficiency of demersal sampling trawls. In:Fernø and Olsen (Eds.): *Marine fish behaviour in capture and abundance estimation.* Fishing News Books, Blackwell Science Ltd, Oxford, UK, p 45 - 65.

Engås, A., and A. V. Soldal. 1992. Diurnal variation in bottom trawl catches of cod and haddock and its influence on abundance indices. ICES J. Mar. Sci., 49:89-95.

Engås, A. & Ona, E. 1990. Day and night fish distribution pattern in the net mouth area of the Norwegian bottom sampling trawl. Rapp.P.-v.Reun.Const.int.Explor.Mer, 189, 123 - 127.

Godø, O.R. 1994. Factors affecting the reliability of groundfish abundance estimates from bottom trawl surveys. In:Fernø and Olsen (Eds.): *Marine fish behaviour in capture and abundance estimation.* Fishing News Books, Blackwell Science Ltd, Oxford, UK, p 166 – 195.

Godø, O.R. 1998. Survey catchability of Northeast Arctic cod and haddock related to varying abundance of capelin. Note to the ICES Arctic Fisheries Working Group. Ad. Hoc. Assessment of Northeast Arctic Cod in April 1998.

Gunderson, D.R. 1993. *Survey of Fishery Resources.* John Wiley & Sons, New York.

Hylen, A., Nakken, O. & Sunnanå, K. 1986. The use of acoustic and bottom trawl surveys in the assessment of North-East Arctic cod and haddock stocks. In: A Workshop on Comparative Biology, Assessment and Management of Gadoids from the North Pacific and Atlantic Oceans, Seattle, Washington, June 1985. (Ed. M. Alton), pp. 473-498.

Michalsen, K, A.Aglen, D.Somerton, I.Svellingen and J.T.Øvredal 1999. Quantifying the amount of fish unavailable to bottom trawl by use of an upward looking transducer. ICES CM 1999/J:8.

Ona, E. & Eger, K. 1988. Fish behaviour and trawl geometry observed with a scanning net-sonde sonar. Proc. of the World Symposium on fishing gear and fishing vessel design, St. John's, Newfoundland, 1988: 412-416.

Ona,E . & Knutsen, T. 1992. Detection and counting of individual free-swimming krill using a 2MHz scanning sonar. ICES CM 1992/L:18,1-8.

Pennington M. & Brown, B.E., 1982. Abundance estimates based on stratified random trawl syrveys. Can. Spec. Publ. Aquat. Sci., 58, 149- 153.