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Trawl avoidance as a source of error in estimates of the prevalence of *Icthyophonus hoferi* disease in Norwegian Spring spawning herring (*Clupea harengus* L.) in the feeding area

Kurt Kvalsvik* and Dankert W. Skagen**

* University of Bergen
Department of Fisheries and Marine Biology
Bergen High Technology Center
N-5020 Bergen, Norway

** Institute of Marine Research
P.O. Box 1870
N-5024 Bergen - Nordnes, Norway

Summary

Results are presented from a survey in the Norwegian Sea in the summer 1993, where the abundance and distribution of herring was investigated, using a high resolution sonar and pelagic trawling at the surface. An index of avoidance was constructed by comparing the catch to be expected from the sonar registrations of the number of schools and the amount of scattered registrations, with the actual catch in each haul. This index was negatively correlated to the frequency of diseased herring in the catch. This indicates that diseased herring is less capable of avoiding the trawl. Application of this result for estimating the true disease prevalence is discussed.

Introduction

The fungus *Icthyophonus hoferi* causes a disease in herring with high mortality, which is likely to contribute substantially to the natural mortality of herring (Sindermann, 1956; McVicar, 1982; Anon, 1991).

One important problem in estimating the impact of this disease on the stock is that the disease rate in samples varies substantially both between fishing gears and between catches.

It has long bees suspected that diseased herring may be overrepresentated in catches, in particular those taken with trawl, and that one reason may be that diseased herring is less mobile than healthy herring, and does not participate in normal schooling behaviour (Hjeltnes & Skagen, 1992). Thus, in the overwintering area it has been found that the percentage diseased herring outside large concentrations was higher than inside such concentrations (Holst, 1995 submitted).

During pelagic trawling, a substantial part of the herring is able to avoid the trawl. A possible measure of avoidance is the discrepancy between what is actually caught and what would be expected to be caught, as indicated by acoustic registrations during the catch operation. The present study was undertaken to explore this possibility in the situation where the herring is feeding near the surface, and to relate this measure of avoidance to the fraction of diseased herring in the catch.

Material and methods

Data were collected during a survey with R/V "G.O.Sars" in the Norwegian Sea in the summer 1993. At the time, herring was abundant from the continental shelf edge westward to approximately 10°E. The survey covered this area north to 71°30N. In addition the area between 66°N and 71°30N was covered westwards to between 0° and 7°W. In this area, only a few herring were caught in each haul.

Trawling in the surface layer was performed with a medium sized pelagic trawl (Åkratrål) equipped with two large buoys at the tip of each wing (Valdemarsen & Misund, 1994). The warp length was 300-350 m, and the opening of the trawl was approximately 500 m behind the vessel. The towing speed was 3 - 4 knots and the haul duration usually 30 min. The trawl stations using this technique is shown in figure 1. Stations marked with brackets were excluded from the analysis, either because essential data were missing or because mackerel was abundant in the catches.

Using data from trawl sondes, the horisontal opening of the trawl was estimated. Using this, together with the towed distance, the actual number of herring caught was transformed to number caught per square nautical mile swept area (CPN). This number together with the percentage of diseased herring at each station is shown i figure 2.

Sonar registrations were done with a Simrad SA-950 sonar. This is a high frequency, high resolution sonar (95kHz, with 32 adjacent beams of 1.7° each, covering a sector of 45°). During trawling, the sonar was heading forwards with a downward tilt of 6°. The signal was recorded on paper (Totland & Misund, 1993).

The number of schools visible on the sonar recordings were counted for each haul, and scools were classified as large, medium sized or small according to the colour and width. A tracing was only accepted as a school if it could be followed for at least 150 m, excluding the 50-100 meters closest ahead of the wessel. The number of schools were transformed to numbers per square nautical mile. In addition, the amount of small scattered echoes (SC) was recorded on a subjective scale from 0 (no echoes) to 4 (abundant echoes).

Echosounder registrations were obtained with a Simrad EK-500 echosounder. The echoes were classified and integrated using the Bergen Echo Integrator system (Knudsen, 1990). The data used in the present study are the registrations classified as due to herring in the upper 50 meters over the distance where the trawl was fishing. The data were transformed to number of herring per square nautical mile using a target strength of 20 log L - 71.9 (Foote, 1987).

In large catches, a random sample of 100 herring was examined for *I. hoferi* disease. In catches of less than 100 herring, all were examined. The criterium for the diagnosis was the occurence of macroscopially visible characteristic lesion either in the skin, the heart or both (Hjeltnes & Skagen, 1992). The fraction diseased is shown for each trawl-station in figure 2.

Statistical analysis and results

The analysis was done separately for within and outside the area where herring was abundant, i.e. to the east and west of 10°E (areas B and A respectively). The sonar data were combined into a common index representing the expected catch, by using a general linear model with the number of different sized schools and the amount of scattered echoes as explanatory variables. The scatter was treated as a categorial variable. The result are shown in table 1 and in figure 3.

This model explains about three quarters of the variance in the catches in area A. In area B only a small fraction of the variance in the catches was explained by this model. The predicted catches from the model for each station was taken as an index of abundance from the sonardata, and termed sonar index.

The additional predictive power of including the echosounder abundance estimate was wery small, increasing R^2 from 0.734 to 0.735 for area A. In area B, herring was identified by the echosounder in only one out of 31 hauls.

For area A, a catch index was constructed to give a measure of the relation between estimated and actual catch. It was computed as:

$$\text{Catch index} = \frac{\text{Actual catch}}{(\text{Sonar index} + \text{Actual catch})}$$

This index has the range from 0 - 1, with the value 0.5 if the expected catch (Sonar index) equals the actual one. The advantage of this index over the simple fraction is that it does not give extreme values if the denominator term is small. A small catch index can be interpreted as a larger than average degree of avoidance, the catch being smaller than expected.

A general linear model was used to study possible explanatory variables for the fraction diseased (FD) in each catch area in area A, assuming that the number diseased given the number investigated is binomially distributed, and using a logistic link function. Trial runs were made both with catch index and with the ratio between actual catch and sonar index as explanatory variables. The catch index performed best of these two, as judged by the log likelihood. The parameter estimates for this model are given in table 2, and the regression curve is shown in figure 4.

Discussion

This study was undertaken to explore the possibility of explaing some of the variance in the rate of disease in trawl catches by variations in avoidance. It relates in particular to herring feeding close to the surface in the summer (i.e. in area A). In this situations, echosounder measurements of the abundance of herring were of limited value. The results here indicate that counting schools and scattered echoes as they appear on the sonar during trawling may lead to a useful relative measure of abundance. The discrepancy between this measure and the actual catch may serve as a measure of avoidance. The finding that the fraction of diseased herring in the catch was related to this measure of avoidance indicates that diseased herring may be overrepresentated when the actual catch is small compared to the amount of herring in the area.

These results are not sufficient to estimate the disease prevalence in the population. However, if a ratio between the sonar index and the true abundance of herring can be established, the fraction diseased predicted by the model at the corresponding level of the catch index can be taken as an estimate of the overall prevalence. For example, the highest catch index in the present material (0.87) would imply an infection rate of 1.8%.

In area B, only small numbers of herring were caught, and most of them were diseased. Acoustic registrations were very sparse in this area, and the acoustic data were not useful as predictors of the actual catch. Therefore, further analysis of the connection between disease rate and avoidance was not attempted here. Whether this is herring that has been left behind, or it has been more or less passively carried to this area is not clear.

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Tables and figures

Table 1. Results from multiple regression (area A). CPN is explained by sonar data.

Statistica multiple regression	**Dependent variable: CPN** **R = 0,856716 R^2 = 0,733962 Adj. R^2 = 0,600943** **F(7, 14) = 5.5177 p< 0,00330** **Standard error: 10220.**		
N=31	**β-values**	**St. error β**	**p-level**
Average	-481,41	339,83	0,1785
Small	12,04	66,68	0,8593
SC0	157,22	10220,15	0,9879
SC1	12509,40	3925,44	0,0066
SC2	2811,79	4270,38	0,5209
SC3	17631,50	6968,04	0,0240
SC4	27560,98	10947,17	0,0246

Table 2. Parameter estimates in logistic regression. log p/1-p = $b_0 + b_1$*Catch index.

Variable	**Parameter estimate**	**Standard error**	**Wald Chi-Square**	**Pr > Chi-Square**
Intercept	0,4646	0,2471	3,4882	0,0618
Catch index	-5,1173	0,5352	9,4312	0,0001

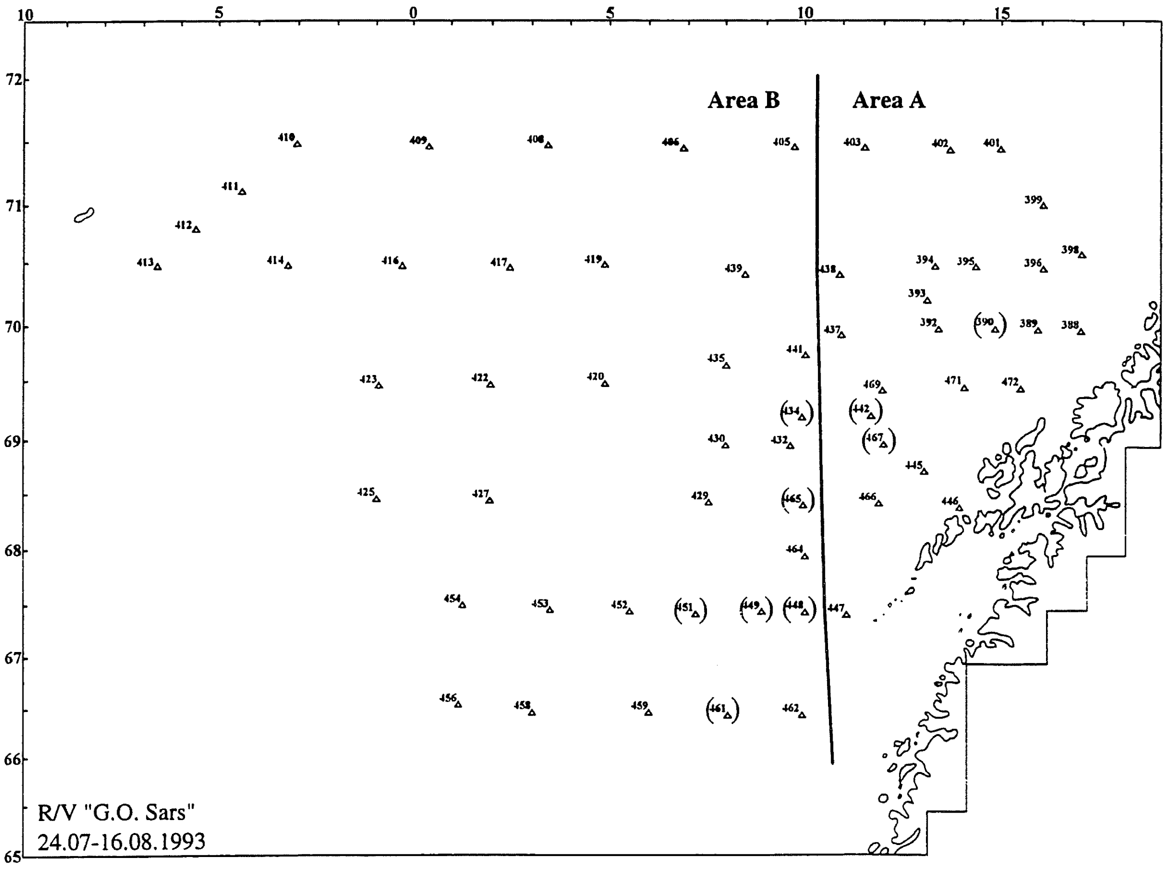

Figure 1. Pelagic trawl stations. Stations marked with ( ) are excluded from the analysis.

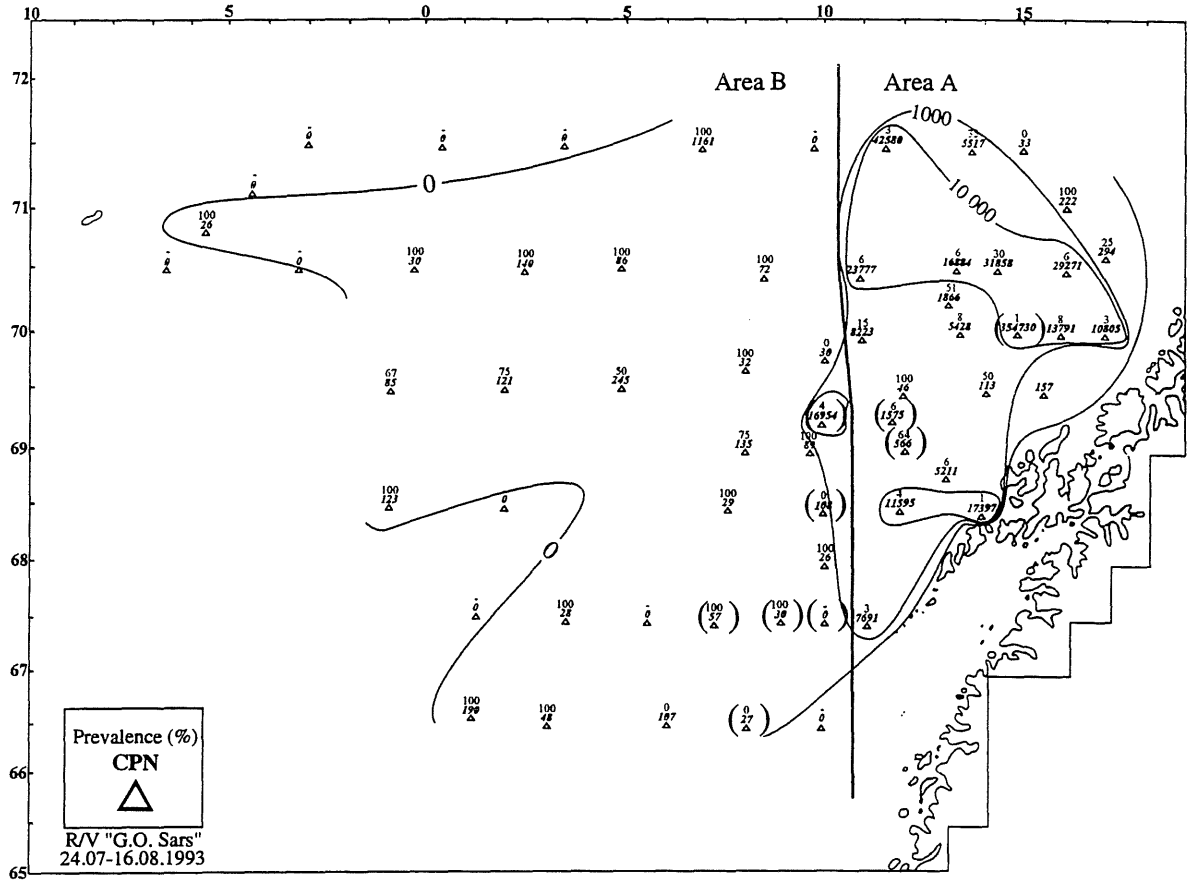

Figure 2. Distribution of catches (CPN) and percentage of diseased herring in each catch. Stations marked with ( ) are excluded from the analysis.

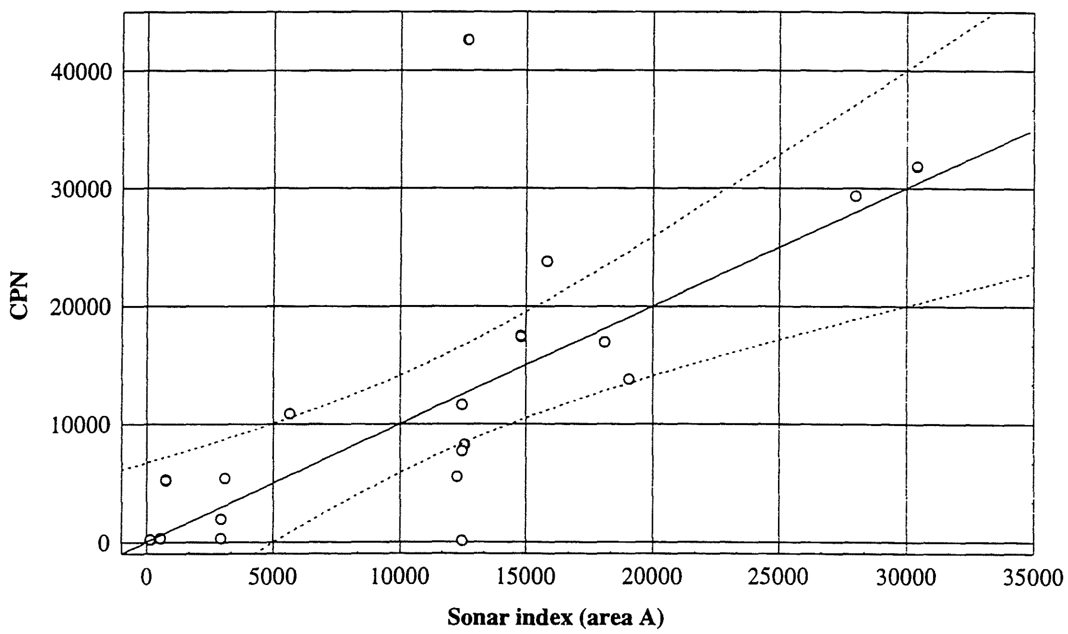

Figure 3. Sonardata were combined into a common index by using multiple regresion (area A). The line shows the expected catch (sonar index) with 95% confidence limits.

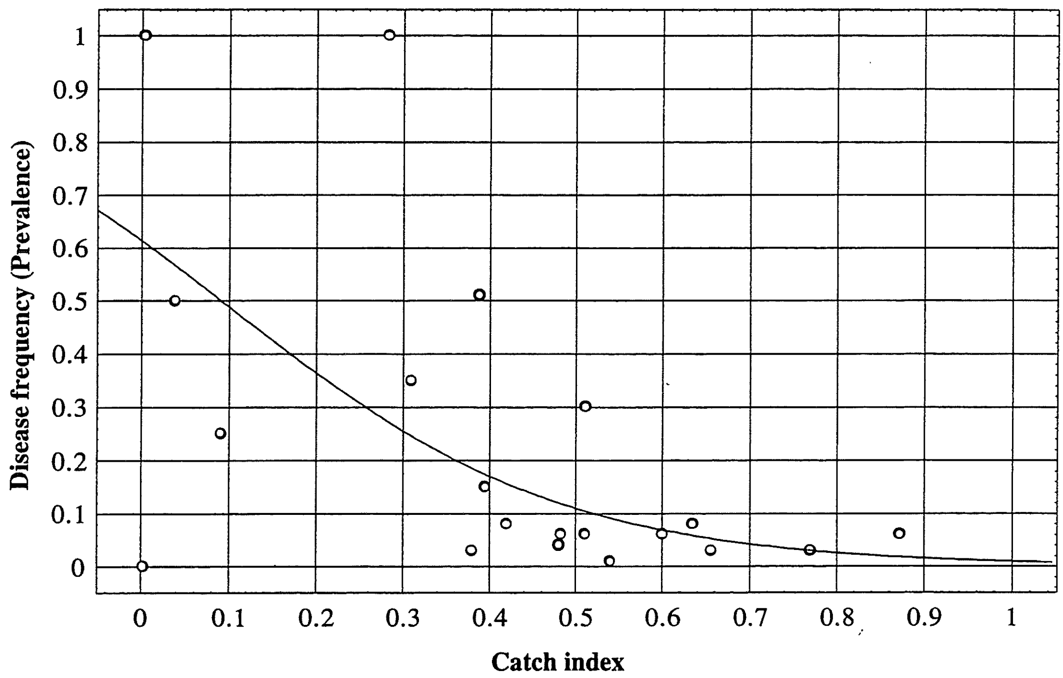

Figure 4. Regression curve from logistic regression, with catch index as explanatory variable.