International Council for the exploration of the Sea

C.M. 1987/B:10
Fish Capture Commitee

POSITION PREDICTION OF HERRING SCHOOLS IN PURSE-SEINE CAPTURE SITUATIONS

by

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ABSTRACT

Sonar observations of herring schools in the North Sea and along the Norwegian Coast reveal a rather constant swimming behaviour of individual schools in purse-seine capture situations. On the basis of this a method for position prediction of herring schools is developed. The method may give the opportunity for position prediction on true-motion sonars in real capture situations.

INTRODUCTION

In the purse-seine fishery exact positioning of the gear relative to the schools is of major importance. To help in this process an increasing number of purse-seiners have installed advanced, computerized sonar equipment to localize and reveal the behaviour of schools. By connecting information from different navigation instruments and the sonar unit itself, some of these sonars can simulate a true-motion picture of the capture situation.

It is observed that the swimming behaviour varies from one herring school to another in purse-seine capture situations. Often the schools avoid the vessel horizontally because the herring senses vessel generated low frequency sound (Olsen et al. 1983).. Nevertheless the swimming behaviour of individual schools remains rather constant. This is true whether the vessel circles or eventually shoots the purse-seine around the school (Misund 1987). By use of computerized sonar equipment, it could become possible to predict the swimming behaviour of schools in purse-seine capture situations.

SWIMMING BEHAVIOUR OF HERRING SCHOOLS

The swimming behaviour of herring schools in the North Sea and along the Norwegian Coast was quantified from video recordings of the SIMRAD SM 600 sonar display on board the purse-seiners M/S "KLARING" and M/S "LIBAS" in 1984 and 1985. Twenty nine schools were observed long enough (from 6 to 25 minutes) for quantified swimming behaviour to provide a sufficient basis for position prediction. The vessel circled the schools at a horizontal distance of about 200 meters with a speed of about 5 knots.

Horizontal swimming speed was quantified on the basis of observations at 30 second intervals by the equation:

$$Vh = (Y_n/30) \quad \text{(meter/second)}$$
Y_n : swimming distance per interval

The horizontal swimming speed was averaged for the first five minutes (Vh 5min) while the vessel was circling the school, for the rest of the capture situation until eventually shooting (Vh tot), and during shooting (Vh shoot). The pattern of horizontal movement was quantified by an index of horizontal movement (IHM) by the equation:

$$\text{IHM} = \text{Straight distance between first and last school position} / \sum_{i=1}^{n} Y_i$$

Index of horizontal movement was calculated for the first five minutes (IHM 5min), and for the rest of the capture situation until eventualy shooting (IHM tot), and during shooting of the purse-seine (IHM shoot). In addition, the average heading of the school was measured for these periods. For the purpose of correlation the compass was defined from 0 to 720 degress.

On average the horizontal swimming speed remained fairly constant whether for the first five minutes or the rest of the circling (Fig. 1A), or during shooting (Fig. 1B). The pattern of horizontal movement was also about equal for each of these periods (Fig. 1C and D). In the same way average heading remained fairly constant during the capture situations (Fig. 1E and F). An overall description of the behaviour of the schools with regard to shape, size, swimming behaviour, and avoidance of vessel and purse-seine is given by Misund (1986, 1987).

Table 1 gives the results of regression analysis of the variables presented in figure 1. There were significant regressions between all compared variables. For the swimming speed and pattern of movement at least 60 % of the variation of the dependent variable (Y) was explained by the regression ($r^2 > 0.6$). For the heading at least 45 % of the variation of the dependent variable was explained by the regression ($r^2 > 0.45$).

Table 1. Regression analysis of swimming variables (a: regression coefficient, 95 %: 95 % interval of confidence, b: regression constant, p: probability; r^2: determination-coefficient, n: number of measurements).

Variables	a	95 %	b	p	r^2	n
Vh tot vs. Vh 5min	0.71	+/-0.23	0.20	0.00	0.60	29
Vh shoot vs. Vh tot	0.99	+/-0.31	-0.01	0.00	0.94	18
IHM tot vs. IHM 5min	0.91	+/-0.15	0.04	0.00	0.85	28
IHM shoot vs. IHM tot	0.71	+/-0.31	0.16	0.00	0.60	18
Heading tot vs. Heading 5min	0.62	+/-0.27	101.39	0.00	0.47	28
Heading shoot vs. Heading tot	0.69	+/-0.31	103.55	0.00	0.59	18

METHOD FOR POSITION PREDICTION

The method is based upon estimates of average horizontal swimming speed (Vh), index of horizontal movement (IHM) and average heading. For position prediction during circling or shooting the regression equations between the swimming speed variables, index of horizontal movement variables, and heading variables are used.

Position prediction during circling:

Input variables: Vh 5min, IHM 5min, Heading 5min, time (t)

Predicted distance = (Vh tot*t*IHM tot)
=((0.71*Vh 5min + 0.20)*t*(0.91*IHM 5min + 0.04)) (meters)

Predicted heading = (0.62*Heading 5min + 101.39) (degrees)

Distance limits of 95 % confidence:
= ((0.48*Vh 5min + 0.20)*t*(0.76*HFI 5min + 0.04),
(0.94*Vh 5min + 0.20)*t*(1.06*HFI 5min + 0.04)) (meters)

Heading limits of 95 % confidence:

= (0.35*Heading 5min + 101.39, 0.89*Heading 5min + 101.39) (degrees)

Position prediction during shooting:

Input variables: Vh tot, IHM tot, Heading tot, time (t)

Predicted distance = (Vh shoot*t*IHM shoot)

= ((0.99*Vh tot - 0.01)*t*(0.71*IHM tot + 0.16)) (meters)

Predicted heading = (0.69*Heading tot + 103.55) (degrees)

Distance limits of 95 % confidence:

= ((0.68*Vh tot - 0.01)*t*(0.40*IHM tot + 0.16),
(1.30*Vh tot - 0.01)*t*(1.02*IHM tot + 0.16)) (meters)

Heading interval of 95 % confidence:

= (0.38*Heading tot + 103.55, 1.00*Heading tot + 103.55) (degrees)

EXAMPLE OF POSITION PREDICTION

Fig. 2 and 3 shows examples of position prediction of herring schools which quantified swimming behaviour provided parts of the basis for the prediction method.

In Fig. 2 point 21 (after 10 minutes) is predicted on the basis of swimming behaviour quantified during the first 5 minutes (points 1 to 11). The precision of the predicted points are within 100 meter from the actual, but the confidence interval is rather wide. This interval will widen with time and position prediction for more than 5 minutes ahead will probably be associated with too great uncertainty to be of practical interest.

Point 58 at the end of shooting is predicted on the basis of quantified swimming behaviour from point 1 to 50 (24.5 minutes). The associated confidence interval is rather wide, but the length of the outward sector border is about the same as the length of the purse-seine. In the actual example the school escaped between the bunt and the vessel, and a better positioning of the gear might have been obtained by shooting the purse-seine along a track similar to the outward sector border, or even with the school more encircled.

The school in Fig. 3 made an unexpected turn to port during shooting, and escaped out of the purse-seine. The prediction is done at point 17 (before start shooting), and could have help in a more favourable positioning of the purse-seine in this particular situation.

DISCUSSION

The swimming behaviour varies from one herring school to another but remains rather constant for the individual school in purse-seine capture situations. Regression equations between average swimming speed, index of horizontal movement and headings can be used to predict the position of herring schools. For position prediction the interval of confidence widens with time, and the confidence area becomes relatively large 5 minutes ahead. In herring purse-seining, however, longer prediction intervals are rarely of practical interest since the shooting time usually varies between 4 and 5 minutes. The regression equations are obtained from quantified swimming behaviour of relatively few schools, and more basic school observations will probably improve the method.

This method can probably be implemented as a software addition to true-motion sonars and gives the opportunity for position prediction in real capture situations. It may be a helpful tool for purse-seiners in tactical planning of the shooting operation. With regard to other schooling species like mackerel, a prediction tool may be especially helpful. The poor acoustic properties of mackerel may result in detection failure if it is swimming at unfavourable aspect angles (Mitson 1983). In addition mackerel schools close to the surface in summer, and the schools are often acoustically camouflaged by the propeller wake in purse-seine capture situations (Misund, unpublished).

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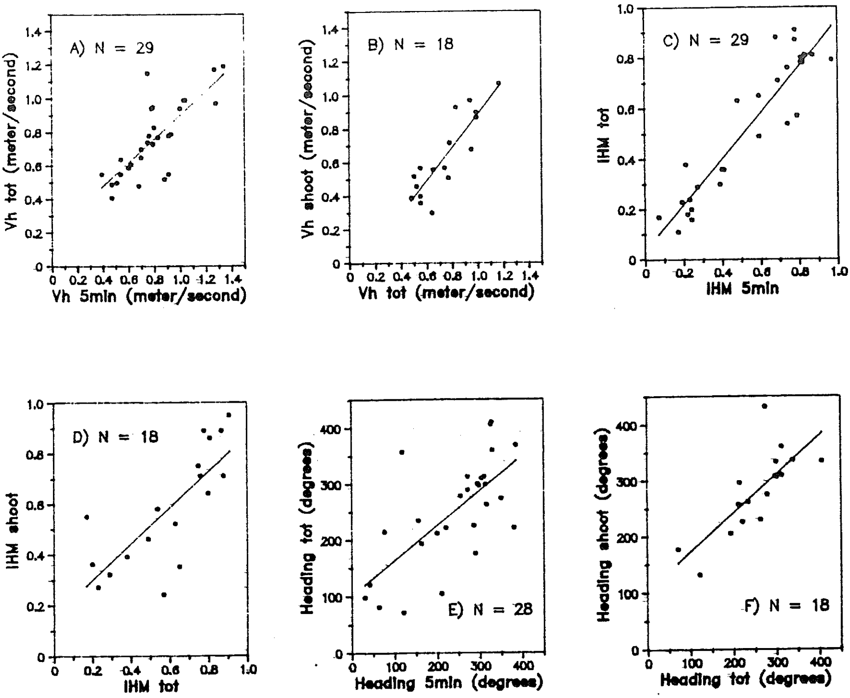

<u>Fig. 1.</u> Plots of swimming variables at different time and operating intervals, A) and B) Average horizontal swimming speed (Vh), C) and D) Index of horizontal movement (IHM), E) and F) Average heading. Note that the dependent axis is predicted for the next period from what has occured in the last period as shown on the horizontal axis.

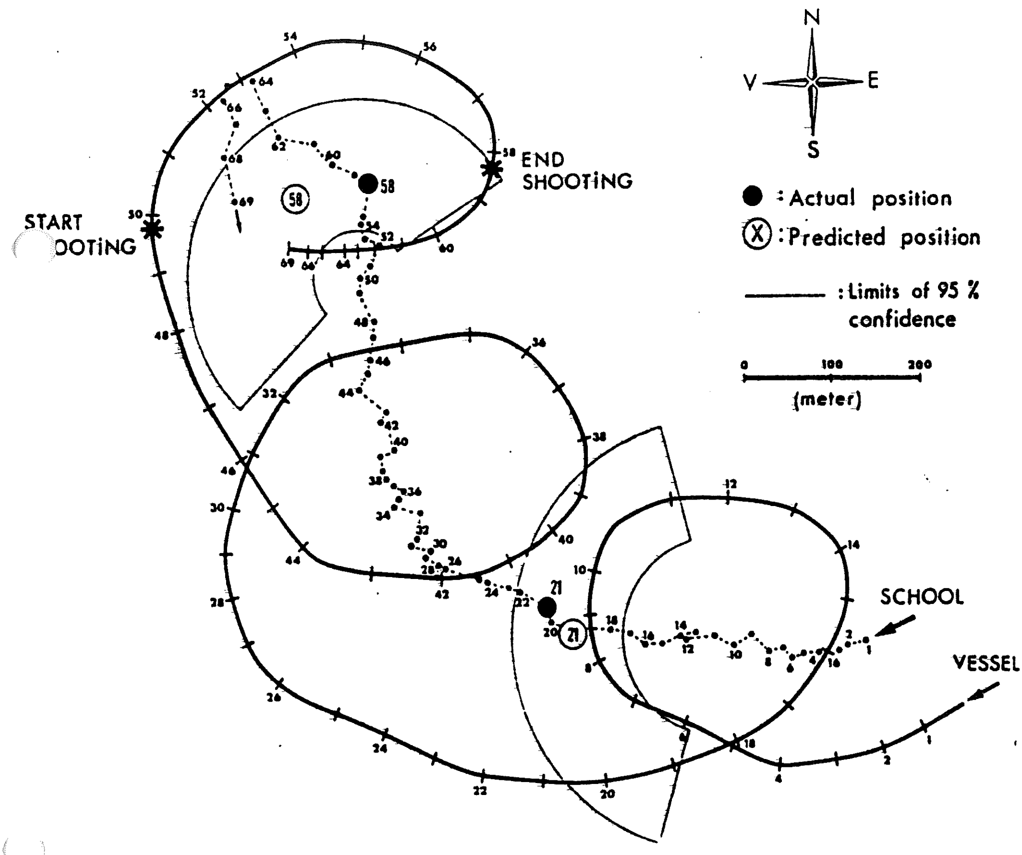

Fig. 2. Position prediction of a herring school in a purse-seine capture situation (positions at 30 second intervals).

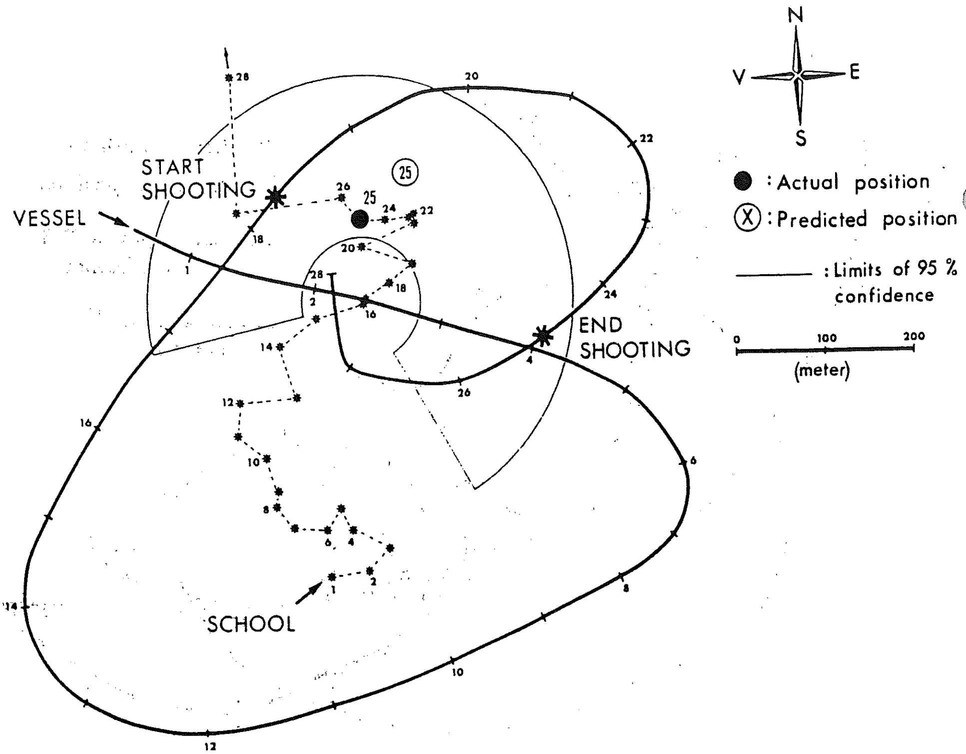

Fig. 3. Position prediction of a herring school in a purse-seine capture situation (positions at 30 second intervals).