SONAR OBSERVATIONS OF SCHOOLING MACKEREL
DURING PURSE SEINING

by

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Abstract

The swimming behaviour and horizontal dimensions of mackerel
schools have been quantified by use of a multibeam, true
motion sonar during purse seining in the Northern North Sea,
August 1986. The horizontal dimensions of the schools were
quite variable, but on average the schools were elliptical
shaped, about 1.8 times longer than wide. The average school
area was proportional to the biomass of the schools. The
horizontal swimming speed was on average about 3.5
bodylengths/s, but there were great variations in swimming
behaviour among the schools. The schools performed strong
avoidance of the vessel, and schools escaped capture in about
37 % of the purse seine sets.

Introduction

Modern purse seining is based on sophisticated acoustic equipment to locate schools and guide shooting of the purse seine. A computerized, multibeam sonar like the Simrad SM 600 can simulate the motions of both vessel and school, and provides the opportunity to quantify the swimming behaviour and horizontal dimensions of schools (Bodholt 1982).

Fish schools usually appear as rather compact units with individuals in synchronized and polarized motion (Pitcher 1983), but the dimensions and shape of schools can be quite variable (Squire 1978). To quantify the size and swimming behaviour of mackerel schools, a method by use of the Simrad SM 600 was applied during commercial purse seining.

The swimming behaviour of the schools was compared to a model of fish avoidance of vessel generated sound (Olsen et. al. 1983). The swim-bladder less mackerel is probably relatively insensitive to sound pressure (Hawkins 1986), but can probably detect the particle motion component of low frequency sound which stimulates the otholith receptors in the inner ear directly (P. Enger, University of Oslo, pers. comm.). Vessel generated sound has its acoustic energy maximum for frequencies below 100 Hz (Gjestland 1968).

As the mackerel has outstanding swimming abilities (Blaxter 1969), it was reasonable to expect the same level of avoidance of both vessel and purse seine as herring performed in similar situations (Misund 1987a).

Materials and Methods

The mackerel schools was observed during purse seining by M/S "Libas" (1348 GRT) on Aktivneset outside western Norway and Vikingbanken in the Northern North Sea, August 1986. The

vessel was circling the schools with a speed between 4 to 10
knots, and the distance vessel-to-school varied between 90 to
340 m. The sonar picture of the Simrad SM 600 was recorded by
a JVC video camera. The recordings were displayed on a 22
inch JVC monitor, and analyzed according to a method
described by Misund (1987a). The horizontal dimensions of the
projected school area were measured, and the positions of
vessel and school marked on transparencies at intervals of 30
s (Fig. 1). The horizontal movement of the school, its radial
direction of movement relative to the vessel, horizontal
distance, and direction of bearing vessel-to-school were
measured in each interval.

Only sonar recordings of distinct schools observed in day-
light were considered in the analyzis. The fishing was
conducted by a traditional North Sea purse seine, about 634 m
long and 154 m depth. The biomass of catches was estimated on
the basis of the volume occupied in the fish holds, and about
100 specimens were length measured to the nearest 0.5 cm. The
sea surface temperatures on the actual fishing grounds varied
between 11.8 to 13.5 C^o.

RESULTS

The average length of the mackerel was 34.2 and 36.2 cm on
Aktivneset and Vikingbanken respectively, but both length
distributions were bimodal and within the same range interval
(Fig. 2). Therefore no separation is made between the record-
ings on the two fishing grounds in the following analysis.

On average, the school area of 15 observed schools amounted
about 2000 m^2, with a crosswise extent 1.8 times longer than
the lengthwise extent (Tabel 1). This indication of an ellip-
tic shape are supported by a strong rank correlation between
the measurements of the horizontal dimensions.

There was a linear relationship between the average school
area (A) and the corresponding biomass (B) of whole schools

caught (Fig. 3) expressed by:

$$A = 27.9\ B + 323 \qquad\qquad (r = 0.96,\ p < 0.05)$$

As apparent from Fig. 3 there was a relative large variation in the horizontal dimensions of the measured schools.

Table 1. Horizontal dimensions and swimming behaviour of the schools (V_h: horizontal swimming speed, V_{rh}: radial horizontal swimming speed, X: average, SD: standard deviation, r_s: Spearmans rank correlation coeff., p: level of significance, N: no. of measurements, LW: lengthwise extent, CW: crosswise extent).

			X	SD	r_s	p	N
School area		(m^2)	1946.2	1960.8	–	–	158
School shape		(LW:CW)	1.8:1	–	0.49	<0.01	158
V_h		(m/s)	1.22	0.81	–	–	158
V_{rh}		(m/s)	0.58	0.71	–	–	158
V_h	vs horiz. distance		–	–	0.20	<0.01	158
V_{rh}	vs horiz. distance		–	–	0.30	<0.01	158
V_h	vs dir. of bearing		–	–	-0.16	<0.01	158
V_{rh}	vs dir. of bearing		–	–	-0.49	<0.01	158

In average the 15 schools were swimming in a depth of about 25 m, with a horizontal speed of 1.2 m/s or about 3.5 bodylengths/s (Table 1). Maximum recorded swimming speed was 3.9 m/s or about 11 bodylengths/s.

Usually the schools avoided the circling vessel (Fig. 4 A), and radial horizontal swimming speed was in average 0.6 m/s away from the vessel (Table 1). Significant, positiv rank correlations between the swimming parameters and horizontal distance vessel-to-school (Table 1), indicates greatest horizontal avoidance at some distance from the vessel. The horizontal avoidance decreased with increasing direction of

bearing vessel-to-school as indicated by negative rank corre-
lations between the swimming parameters and direction of
bearing vessel-to-school (Table 1). This was especially appa-
rent for the connection between radial horizontal swimming
speed and direction of bearing vessel-to-school (Fig. 5).

19 successful purse seine sets with catches from 1 to about
140 tons were obtained. In 11 trials the schools escaped
capture. 5 fast swimming schools avoided beeing encircled
during shooting of the seine (Fig. 4 B), while 6 schools
escaped under the vessel from 7 to 9 minutes after start
pursing. 4 other trials were conducted on recordings which
appeared to be juvenile blue whiting or medusae.

DISCUSSION

The bimodal length distributions show that mackerel of a
relative wide range in length may organize a single school
even if schooling mackerel choose neighbours of similar size
(Pitcher, Magurran & Edwards 1985). Average horizontal
dimensions, shape, and the relation between school area and
biomass of the observed schools are rather similar to schools
of North Sea herring (Misund 1987a). This indicates that
mackerel organize schools similar to herring. In addition to
the 15 analyzed schools, noumerous other schools too small to
be of interest for purse seining were recorded on both
fishing grounds.

In average, the 35 cm long mackerel was swimming about 0.4
m/s or 1 bodylength/s faster than 27 cm long North Sea
herring in similar situations (Misund 1987a). Maximum
swimming speed was slightly above what is observed in front
of trawls (Blaxter & Dickson 1959), or 10 bodylengths/s as
predicted from the muscle contraction time (Wardle 1975).

Apparently, the mackerel detected vessel generated sounds as
the schools avoided the vessel with a radial speed about 0.3
m/s faster than 27 cm long schooling herring (Misund 1987a).

According to the Olsen model (Olsen et. al. 1983), the avoidance is triggered by an instaneous increase in the pressure gradients of the sound emitted by an approaching vessel. Detection of sound pressure seems possible only for fish with a swim-bladder (Hawkins 1986), and the avoidance of the mackerel was probably triggered by sensing of increasing strength of the particle motion component of the low frequency sounds. As the vessel generated sound is directional with a peak normal to the side of the vessel (Urick 1975), the mackerel seemed to be avoiding as it experienced increasing sound gradients (direction of bearing < 90°), but ceased avoidance as the gradients decreases (direction of bearing > 90°). Contrary to the Olsen model, the avoidance appeared to be strongest at greater distance from the vessel, indicating that the most avoiding schools kept greatest distance to the vessel.

The swimming behaviour varied among the schools, but the single school seemed to maintain the same pattern of movement. Probably this may be used to predict the positions of mackerel schools during purse seining by the same method as for herring schools (Misund 1987b).

The capture success (no. of sets with catch) was about 63 %, which is on the same level as during herring purse seining in the North Sea (Misund 1987). 20 % of the schools escaped under the vessel from 7 to 9 minutes after start pursing. As in herring purse seining (Misund op. cit.), this is a critical phase where some schools seems to be guided out of the seine as a consequence of the pursing operation. Another 17 % of the schools avoided beeing encircled during the shooting of the seine. To raise the capture success during fishing on fast swimming and avoiding mackerel schools, an increase in the length of the traditional North Sea seines would probably be an advantage.

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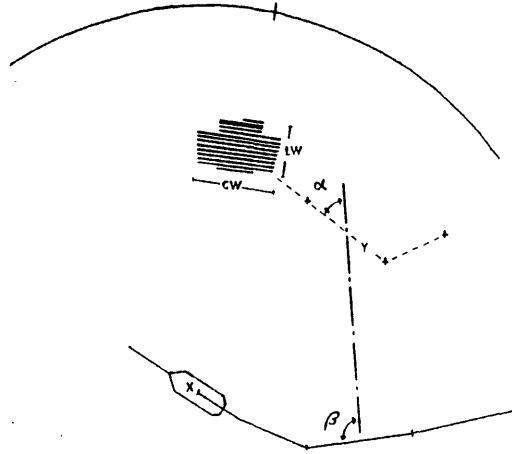   225:725-727.

Fig. 1. Analysis of the sonar display (CW: crosswise extension, LW: lengthwise extension, x: vessel position, Y: movement of school in a time interval, α: radial swimming direction, β: direction of bearing vessel-to-school.
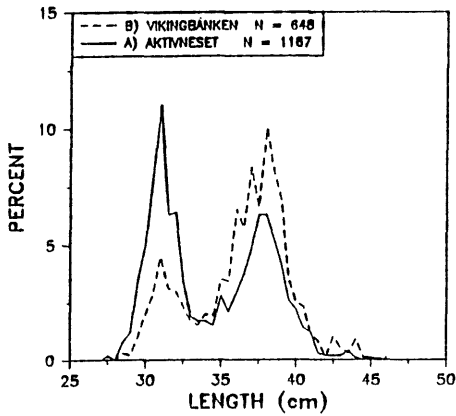

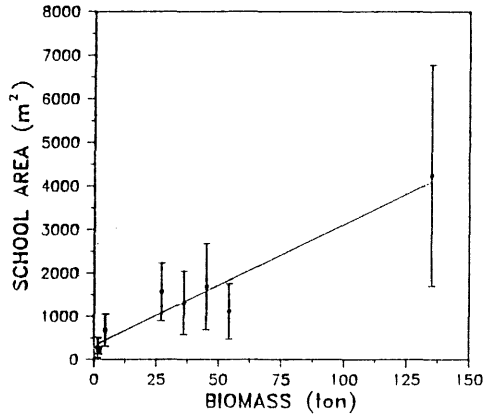**Fig. 2.** Length distributions of mackerel caught at Aktivneset (A) and Vikingbanken (B).

Fig. 3. Biomass of captured schools related to corresponding school area (vertical bars: st. dev.).
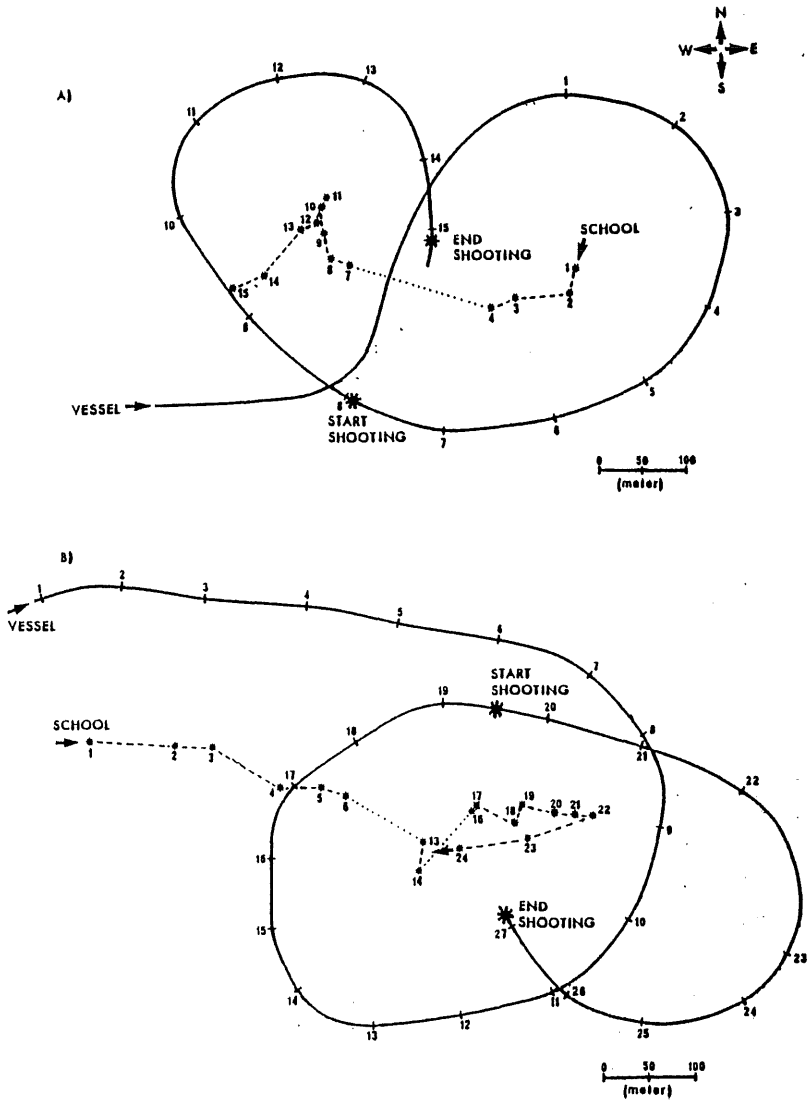
Fig. 4. Typical situations of horizontal movement of mackerel schools in purse seine capture situations. A) School of 40 ton mackerel avoiding the circling vessel both prior to and during shooting of the seine. B) Fast swimming school of mackerel avoiding encircling during shooting. Dotted lines indicates no sonar recordings of the schools.
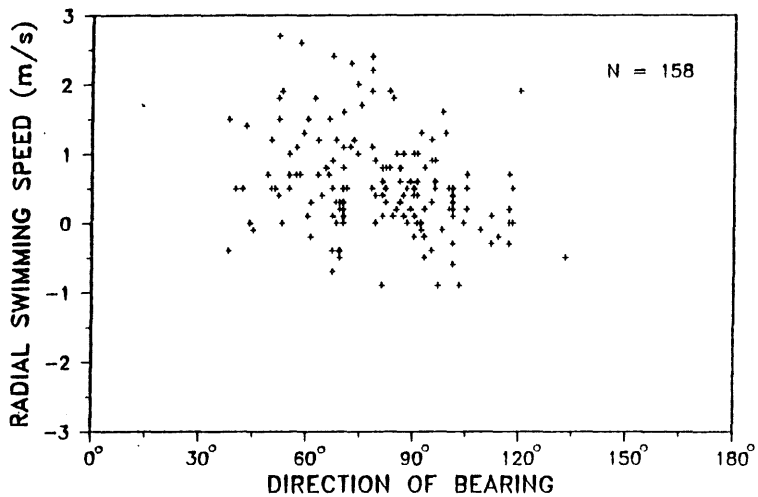
Fig. 5. Radial swimming speed related to direction of bearing vessel-to-school.