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AVOIDANCE REACTIONS OF ULTRASONIC TAGGED COD DURING BOTTOM TRAWLING IN SHALLOW WATER

by

Arill Engås, Aud Vold Soldal and Jan Tore Øvredal

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

Introduction

Observations made by echo sounder (Ona 1988) have shown that cod (Gadus morhua L.) may avoid an approaching survey vessel horizontally and vertically. However, there has been a lack of information on the escapement behaviour of the individual fish. This short note discribes an experiment carried out in a shallow fjord in Northern Norway, where the reactions of single cod towards a small survey vessel during bottom trawling were studied, using ultrasonic tagging technique.

Methods

Three cod (45, 52, and 52 cm) were caught by jigging in midwater at 35 to 40 m bottom depth close to the mouth of a shallow fjord, Makkaur-Sandfjord, Northern Norway. The fish were transported in tanks with circulating sea water to a net pen close to the head of the fjord, where it was stored for 3 to 8 days until the start of the experiments. Ultrasonic tags (Holand 1983) transmitting at frequencies ranging from 100 to 152 kHz, were attached to the basis of the dorsal fin during anaesthesia (Methomidate). After a recovery periode of about half an hour, the fish were released close to the head of the fjord at bottom depths of about 15 to 20 m.

The fish movements were tracked with a directional hydrophone mounted onboard a rubber boat. To make the fish position visible from the research vessel F/F "FJORDFANGST" (47", 165 HP), the rubber boat was continually manoevered to a position perpendicular above the fish. While "FJORDFANGST" was bottom trawling towards the fish at a speed of 1 m/s (2 knots), the position of the fish relative to the vessel was recorded at short time intervals, using the radar onboard "FJORDFANGST" to measure the distance to the rubber boat. The direction from the vessel to one cod tagged with a 150 kHz transmitter, was also verified using a 150 kHz sonar as receiver (Furuno CH12). The positions were plotted on a GPS video plotter (Shipmate) and the resulting fish and vessel tracks were later used to calculate distance, swimming speed and direction of the cod relative to the vessel.

Results

Examples of cod movements relative to the vessel path are shown in Figure 1. As long as the vessel was far away, the fish movements were small and random. When the distance to the vessel was about 200 m, the cod usually started to swim calmly along in front of the vessel at speeds below 1 m/s. As the vessel approached and came as close as 100 m, the crew onboard the rubber boat noticed a more restless swimming pattern, although difficult to measure and quantify, until the fish suddenly increased its swimming speed and made a rapid burst diagonally forward and out of the vessel track. This was jugded to be a clear avoidance reaction towards the approaching vessel. Figure 2 shows examples of the swimming speed of individual fish relative to its distance from the vessel. As the distance became less than approximately 100 m, the swimming speed increased to about 2 m/s.

Only some selected trawl hauls are shown in Figure 1, but the general trend described above was found in all experiments except for two: In these cases the cod performed a zig-zag swimming pattern (Fig. 3) along the vessel track line in front of the vessel, maintaining almost equal distance (about 60-70 m) to the approaching vessel as it moved forward. The start of the response was similar to the generally recorded behaviour pattern: The fish made a rapid burst diagonally forward and sideways out of the vessel track. About 50 m to the side of the track line, it suddenly turned, crossed the midline and swam diagonally forward about 50 m out to the opposite side, then turned again, etc. After about 4 turns, the rubber boat lost the acoustic signal from the fish, and the further swimming pattern is unknown.

The three cod were all released close to the head of the fjord. During the first experiment day, although the fish performed aimed avoidance reactions to the fishing vessel, the overall direction of the fish movements was outwards the fjord. After having run through a set of 5 to 6 experiments with the inidvidual fish, the vessel left for the day. When the fish were searched for the following morning, the acoustic signals from the fish were detected at the specific location outside the mouth of the fjord at about 40 m bottom depth, where the fish were jigged some days earlier (approx. 7000 m from the release point). The following days the fish were always found close to this spot whenever searched for. The same escapement behaviour pattern as observed within the shallow fjord, was found when the trawling experiments were repeated at bottom depths of 40 m.

Discussion

The three ultrasonic tagged cod in these experiments all showed the same avoidance behaviour towards the approaching trawling research vessel. They avoided the vessel path by a change in swimming direction and an increase in swimming speed. While the vessel was more than about 100 m apart from the fish, it was cruising calmly along in front of the vessel with no signs of panic at speeds below 1 m/s, which is the maximum cruising speed of a 50 cm cod at 5°C. However, there was a conspicuous change in fish reaction as the distance was reduced. The fish probably then sensed the approaching vessel as an impending threat and mobilized the energy of the white muscles to perform a rapid burst horizontally away from the vessel track. The speed, direction and swimming distance was adequate to prevent the fish from being caught by the gear.

The escapement track was similar to that predicted for fish reacting visually to an approacing object (Wardle 1986). However, the visible range of a fish in clear water does not exceed about 40 m (Guthrie 1986), and it is therefore reason to believe that sound is the determinant in triggering the avoidance reactions. No measurements of the sound level of the vessel noise were carried out, and it is therefore not possible to relate the escapement stimulus to a given sound level. As the direction of the escapement route was nearly always unambiguous out of the vessel path, the fish did not only seem to react at a certain noise level, but also seemed to be able to predict the bearing of the vessel as it approached. The swimming behaviour of the cod in response to the vessel may be described as an "effect of pursuit" (Misund 1986), where the pursued individual avoids in the same direction as the pursuer until a fast sideways reaction is elicited at short range.

It is documented that the noise field of a ship may have a shape similar to a butterfly (Urick 1976), with two lobes protruding forward along the vessel sides (Fig. 4). In the two cases when the cod were performing a zig-zag swimming pattern in front of the vessel, they may have been trapped between the two main lobes of the noise field. As it made the first escapement burst diagonally forward in front of the ship, it may have sensed an increasing noise level as it got in touch with one lobe. It then turned around, made a diagonal burst towards the path of the vessel where the noise intensity was lower until it met the noise field of the other lobe. Then it turned again and repeated this reaction sequence until it by chance escaped the area influenced by the noise field. A similar avoidance reaction pattern has earlier been reported for herring schools (Aglen and Misund 1990).

The experiments were carried out in shallow water, 15 to 40 meter bottom depth. The acoustic tags did not give any information about the swimming depth of the fish, and it is not known whether the fish in addition to a horizontal avoidance also made a vertical response. However, at these small bottom depths, there is little room for large vertical escapement, and the only possible way for the fish to escape the approaching vessel is horizontally. The trawl experiments were carried out with an open codend. However, the recorded swimming patterns showed that the fish were successful in avoiding the approaching vessel and gear in every trawl haul studied. Parallel to the behaviour experiments, several trawl hauls were performed in order to study the species and size distribution of fish in the area. Only cod less than 30 cm were caught by the trawl. Although larger cod may be absent from the shallow fjord, the poor catch success may also be due to the fact that cod above 30 cm generally are able to avoid the fishing gear at these water depths and towing speed (1m/s). Trawl catches will thus not give representative information on the length distribution of cod, and probably neither for other species, in shallow areas like this.

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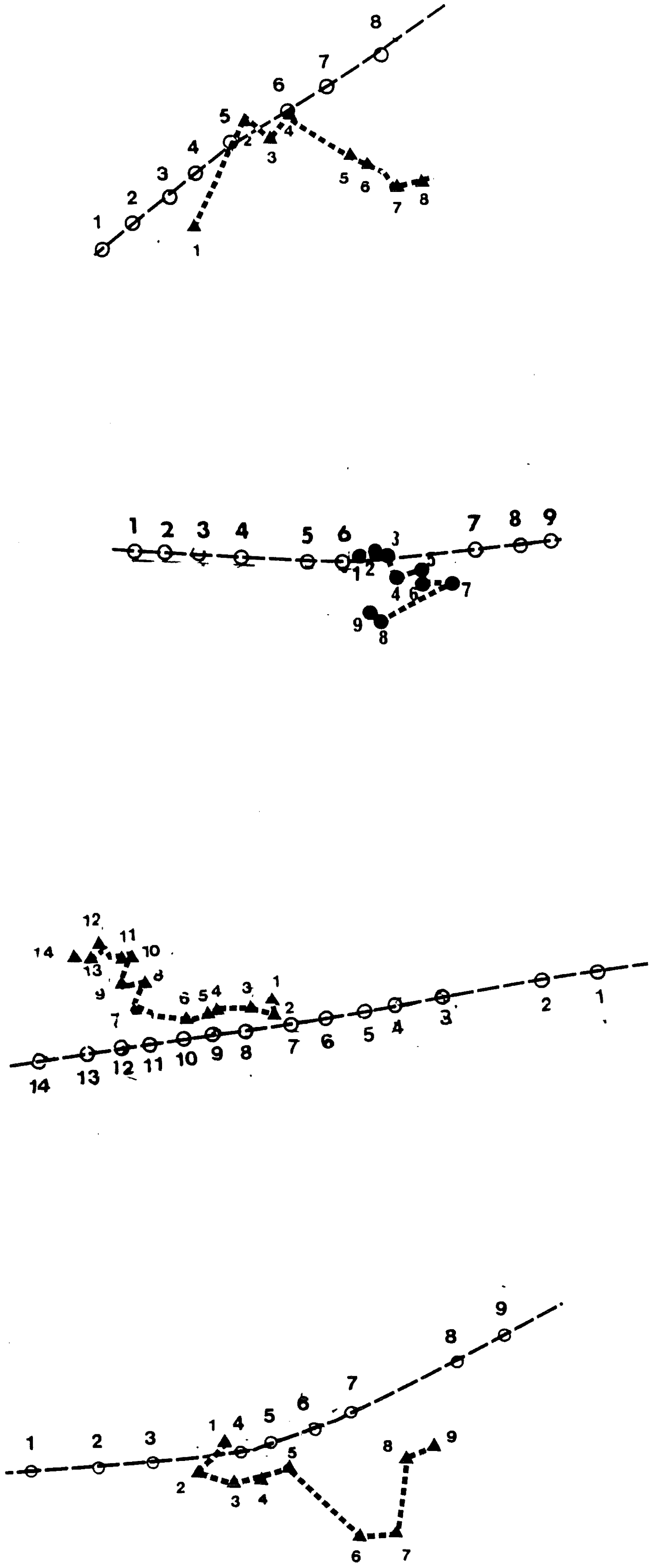


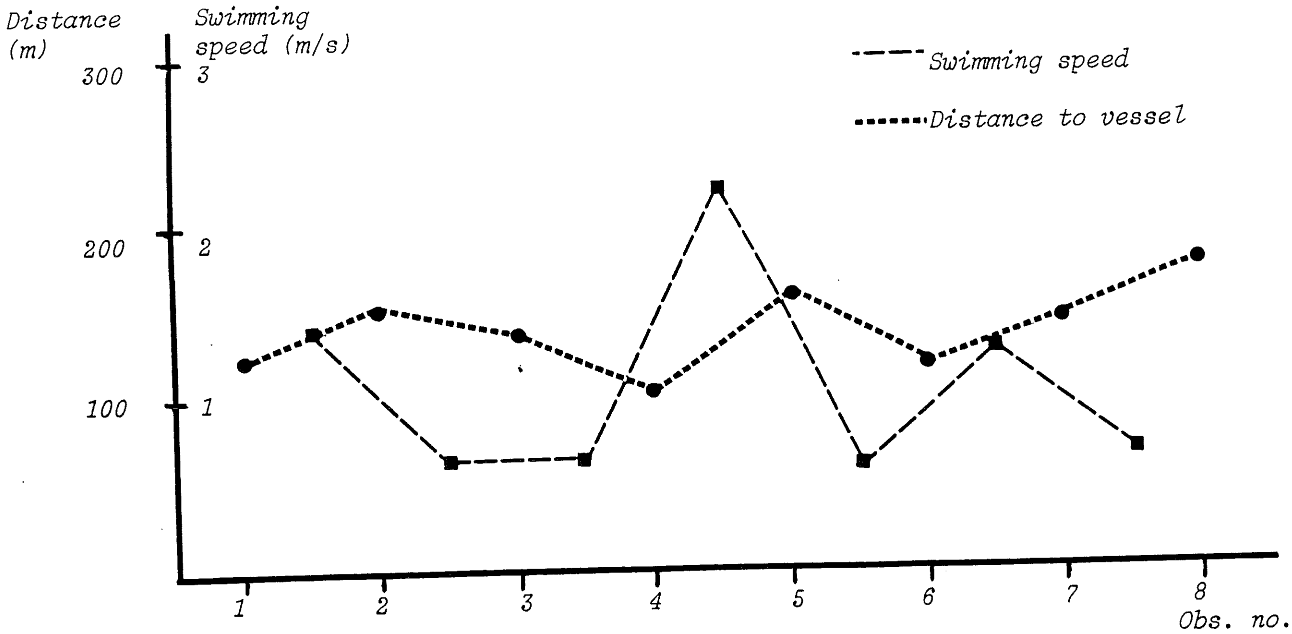
a)

b)

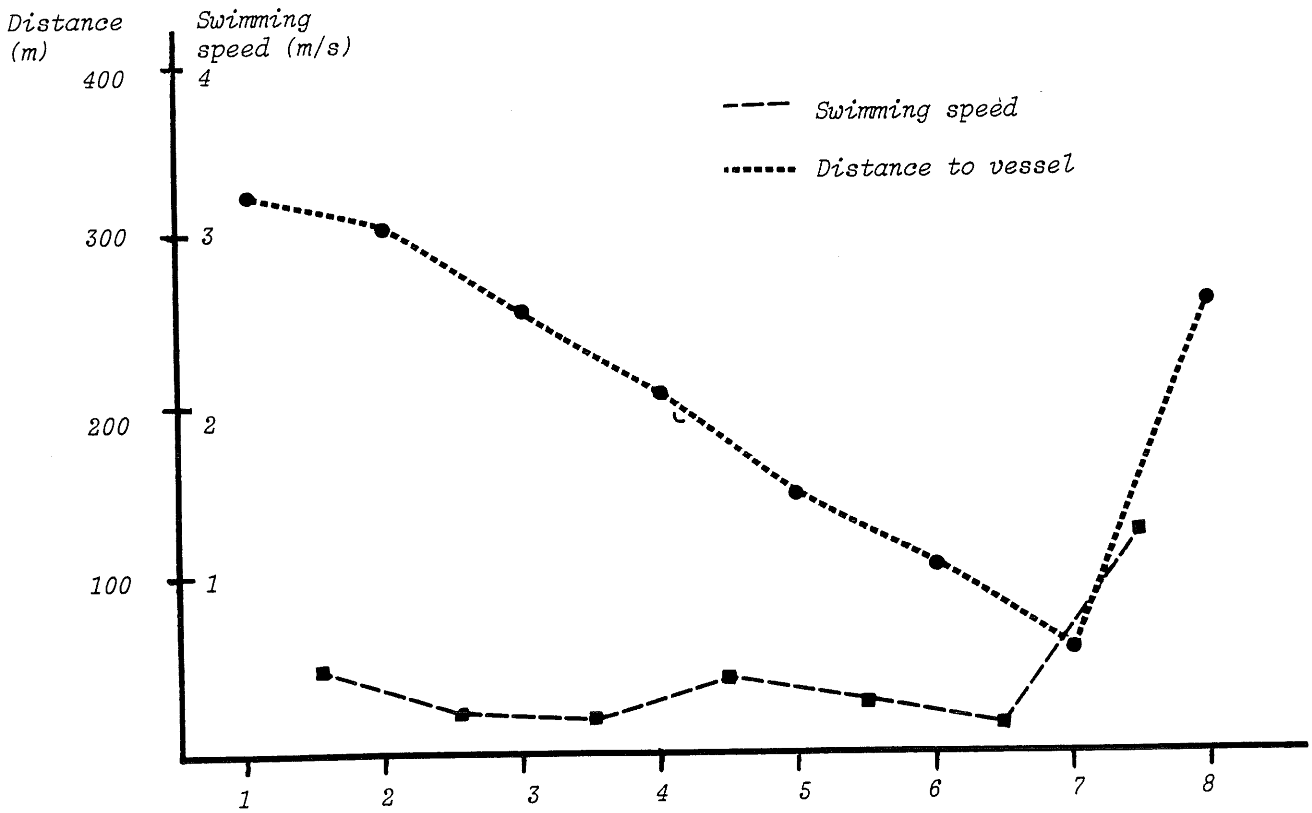
c)

d)

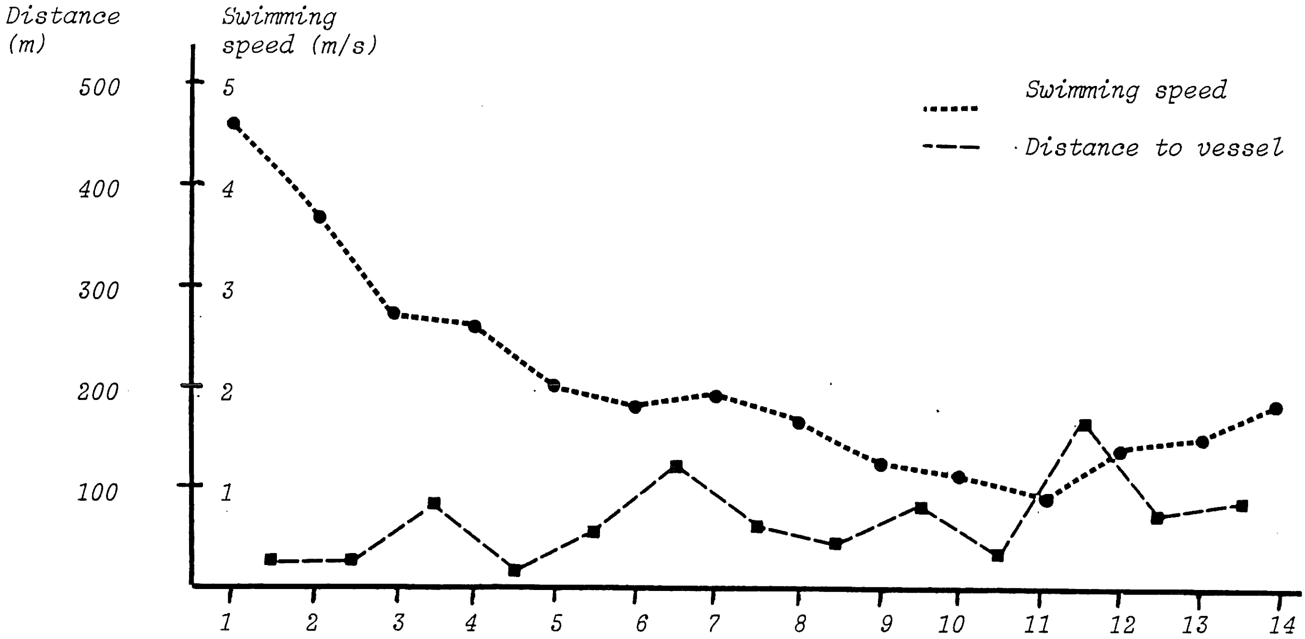
Figure 1. Examples of cod movements relative to the vessel track during four individual trawl hauls. The dots with corresponding numbers indicate the position of the vessel (open dots), and the cod (solid) at one measuring point. The vessel speed was 1 m/s. Scale 1:10000.


Distance (m)
Swimming speed (m/s)
300
3
200
2
100
1
Swimming speed
Distance to vessel
1
2
3
4
5
6
7
8
Obs. no.

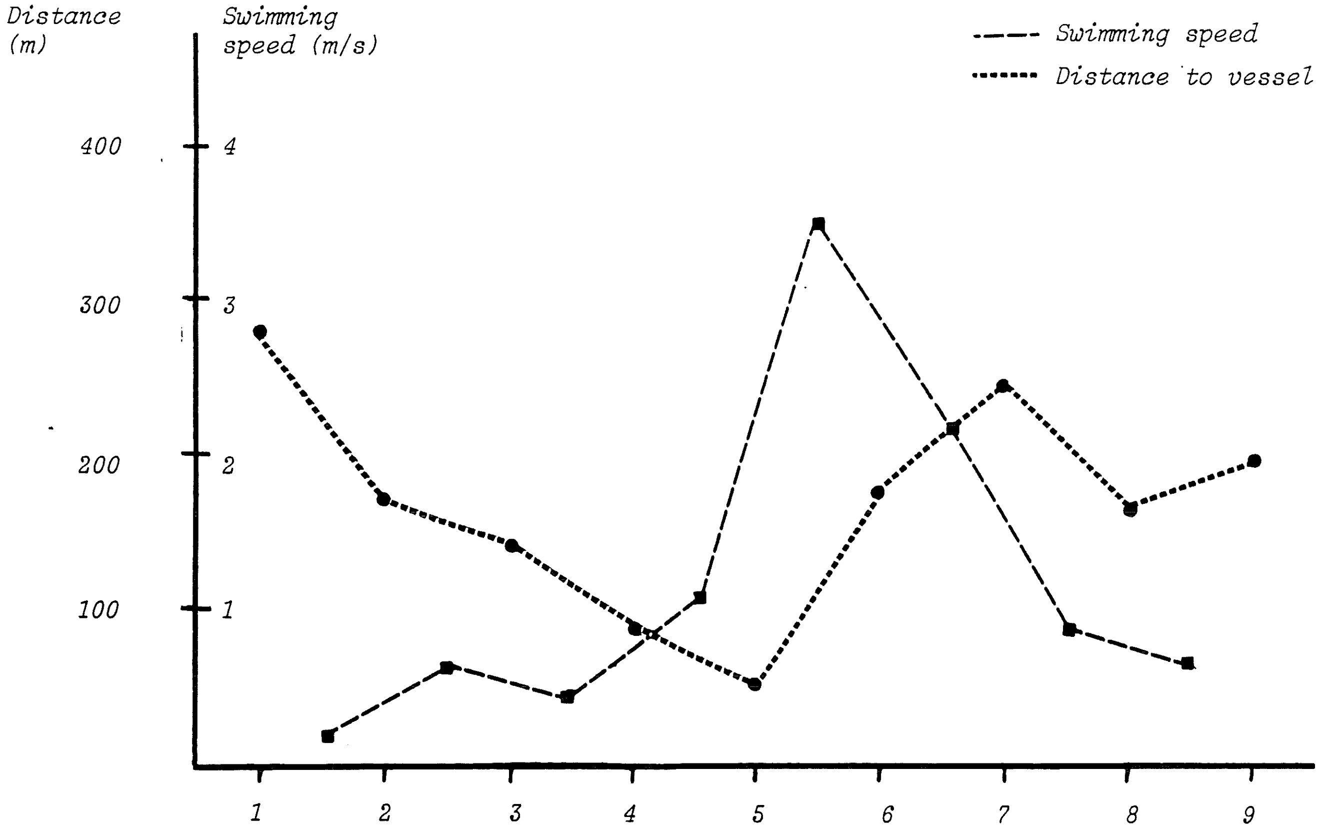
2a)


Distance (m)
Swimming speed (m/s)
400
4
300
3
200
2
100
1
Swimming speed
Distance to vessel
1
2
3
4
5
6
7
8

2b)



2c)



2d)

Figure 2. *Examples of measured swimming speed of ultrasonic tagged cod relative to the distance between the fish and the trawling vessel. The figures a) to d) show individual trawl hauls, corresponding to those of Figure 1.*

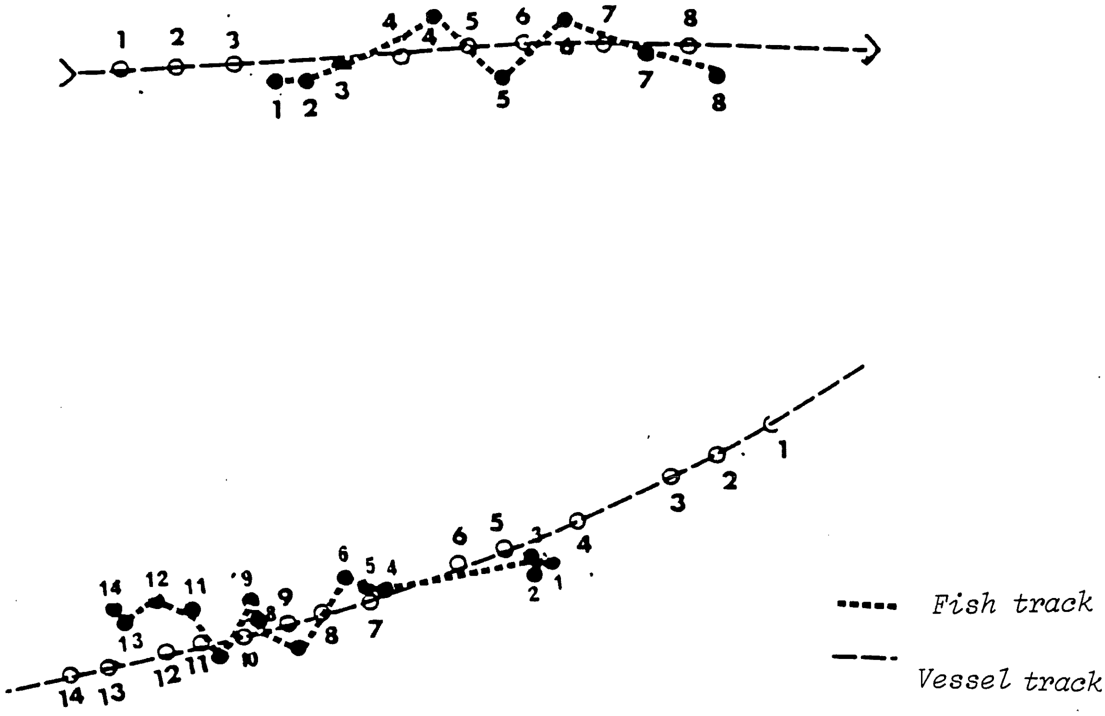


Figure 3. *The swimming tracks of two cod showing a zig-zag type of movement in front of the approaching vessel. Scale 1:10000.*

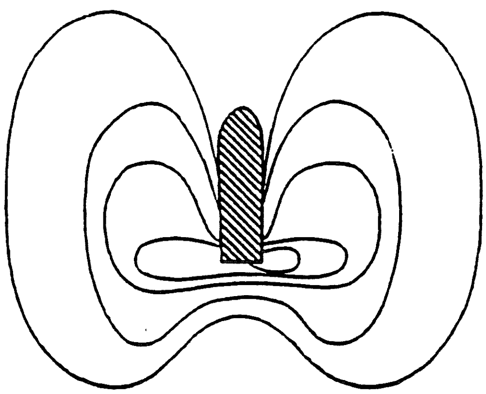


Figure 4. *Outline of the noise field around a vessel, showing its "butterfly" shape with two lobes protruding in front of the vessel (Urick 1967).*