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Directional responces in herring to sound and noise stimuli.

by

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INTRODUCTION

Successful fishing with active fishing gears as purse seine and pelagic trawl requires exact knowledge of the behaviour of fish. The advanced modern fish-finding techniques make it possible to follow the fish and its actions,but tells very little about the motivation of the behaviour. Such knowledge has shown to be most valuable in fisheries, for example in the purse seine fisheries of the Atlanto-Scandian herring in the summer season.

A lot of practical evidence do exist among fishermen about responses in the fish by acoustic stimulation. Scaring and also avoidance responses of the fish are common reports. An active avoidance by a fish indicates an ability to detect the direction to the stimulus source. Such experiences are to some extent in clear disagreement with findings through laboratory experiments or with theoretical expected capacities of directional hearing in fish.

The existence of an "acoustical link" between the two ears and the swimbladder in clupeoids fishes is supposed to make this system useless for any directional discrimination of sound. It has been suggested that only at short ranges are the lateral organs able to localize a sound source.

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On the last year C.M. a very interesting paper about avoidance of acoustic stimuli by herring was presented by Hering. The need of further experimental investigations in order to approach the question of directional hearing in herring was felt to be necessary.

MATERIALS AND METHODS

The herring investigated was Atlanto-Scandian herring (22-25 cm). The experiment were undertaken from a floating field station in a sheltered fiord (Fjellspollen near Bergen, Norway) during last su summer (1969).

The fish was kept in a net cage (Fig.1) submerged to 4 m, and could be observed from the surface towards a light contrast bottom in the cage. To simplify the determination of the distribution of the school, the top-cover was visually divided in 8 departments by ropes.

The testing method was a systematical observation of unconditioned responses of the herring to sound and noise stimuli from underwater loud-speakers. The loud-speakers were submerged to the same depth as the fish, and could be placed in different positions in relation to the cage. An experimental set up is shown in Fig. 2a and Fig. 2b.

Different test series have been run in order to observe how responses to acoustic stimulation in herring is influenced of source distance, quality and presentation of stimulus, and especially, as will be reported in this paper, how their responses are affected by stimulation from different directions.

A block diagram of the instrumentation is given in Fig.3. The speakers could give sound pressure of 50 dB/1uBar at 1 yd in a frequency range 40-10000 Hz. The stimulus was control measured by a hydrophone hanging close over the cage. The hydrophone had built in 20dB pre-amplifier which gave it a sensitivity of -58dB/1 volt/1 uBar at 5-50000 Hz. The background noise was mostly within -35 to -30 dB/1µBar over all level.

After an adaption period of 1-2 weeks in the cage, the first rather nervous activity of the fish had slowed down to a patient anti-clock-wise schooling, and the experiment could start. The members of the school (30 fishes) stayed as a rule fairly equally distributed in the cage.

The stimuli were presented by first giving a week signal and then gradually increasing the signal strength. An electronic stepping device was programmed to increase the signal in 7 steps, each of 9dB (increase of the signal) and of half a second's duration. The stepping rate was set to one every second.

This choice of program was based on a compromise between a best possible spontaneous reaction, and a minimum observation delay on the reaction of the fish to a certain signal step.

In order to avoid "learning" by the herring, the number of trials each day were limited to 10-20.

RESULTS

The behaviour of the herring showed to be rather nervous to acoustic stimuli. A typical response was to breake up the "resting" schooling, consentrate in a cluster for a moment in one part of the cage, and then form a new dense school which very often took out in a new swimming direction.

Each response to a stimulus could typically be observed and recorded in two ways:

a) By determining the "breaking-point" i.e. observation of the point in the circular school where the fishes broke the school by turning and swimming back.
b) By determing the"rallying-place" i.e. observation of the area in the cage in which the fishes tend to consentrate during the first 1-2 sec. after a response had taken place.

The "breaking-point" could be determined to the closest 1/2 cage-division. The "rallying-place" was determined to the cage divisions in which "most" fishes (estimated as more than 25 of the 30 fishes) grouped together for a moment after the first response. If such a distribution could not be observed in an area of maximum 3 cage divisions, the response to that particular stimulus was determined as being none or indistinct (not significant).

By systematically applying these criteria on the responses to stimuli, typical distributions of the responses could be obtained. In Table 1 is presented an extraction of the observation journal from a test series with a stimulus of low frequency noise (100Hz bandw., 100 Hzc.f.)

With the sound sources diametrically placed, the differences in "breaking-point" and "rallying-place" are most clearly demonstrated. A change in the direction to one of the loudspeakers by moving it 45° (Fig.3,B pos 2) also shows a significant change in "br.p." and "r.pl." in accordance with the changed stimuli direction.

A typical response to an acoustic stimulus that caused reaction, was then to turn away from the sound source and swim against area of less stimuli intensity. For some of the fishes this involved just a slight change in swimming direction, but for others who was "met" by a stimulus in front, or less than 45 -60° in front, the response was a complete turn.

Because of the way of stepping up the signal
only a rough estimate of the signal strength causing a scaring response was possible. Very often, however, the response was rather spontanious on a certain signal step and the level of this signal step could be measured. As an average the signal must rise to more than 30 dB above the level of the background noise before a reaction occured. Without taking into acount any possible delay between response and observation, this gave a signal strength of about 0 dB/1 uBar before the stimuli changed the behaviour of the school.

A significant directional response has been obtained in a frequency band from 20 Hz up to at least 6000 Hz. A response on puretone signals up to 10000 could be demonstrated, but it could not be determined as directional or not.

The influence of an increased sound source distance on the directional response has not been fully investigated. A directional response has been obtained on a source distance of 15 m. There are, however, some indications of that the response itself is less pronounced at increased source distances, compared to a constat sound pressure level of a stimulus.

DISCUSSION

The limitation of the obtained results is primarily due to the restricted space of movement of the herring. The observed responses tell little about natural responses to acoustic stimuli. They can only give indications of the herrings capabilities of a changed behaviour on a certain acoustic stimulus.

The observed change in behaviour caused by a 45° change in the direction of the stimuli, indicates that the directional discrimination of acoustic stimuli in a school of herring is at least 45°, probably better.

Even if the behaviour of the herring in the net cage seemed quite normal, the life in captivity might have an influence on the pronounced scaring effect of different acoustic stimuli. Experiences from practical fishing indicate that other biological factors also are important. The roughly estimated "response-thresholds" can only be looked upon as representative in that perticular biological situation.

The acoustic stimuli were measured and are expressed in sound pressure. Biologically this is thought to be correct for most of the applied stimuli. Only for the very low frequency stimuli (roughly below 100Hz) when the sound sources under the applied conditions might generate other mechanical stimuli than sound to the fishes (f.ex. particle displacements), stimulus strength expressed in sound pressure could be uncorrect or even meaningless.

The conclusion to be drawn from this could be that herring do have an ordinary directional hearing.

SUMMARY

1. Field experiments have been carried out in order to investigate directional responses in herring to various acoustic stimuli.

2. Directional responses on stimuli generated from a sound source 5.5 m from the fish, has been obtained in a frequency range 20-6000Hz. A directional discrimination better than 45° of acoustic signals has been demonstrated.

3. The obtained results seem to have given some evidence of a general directional hearing in herring.

REFERENCE

Hering, G. 1968. Avoidance of acoustic stimuli by herring. C.M. 1968/H:18, Pelagic Fish (Northern) Committee.

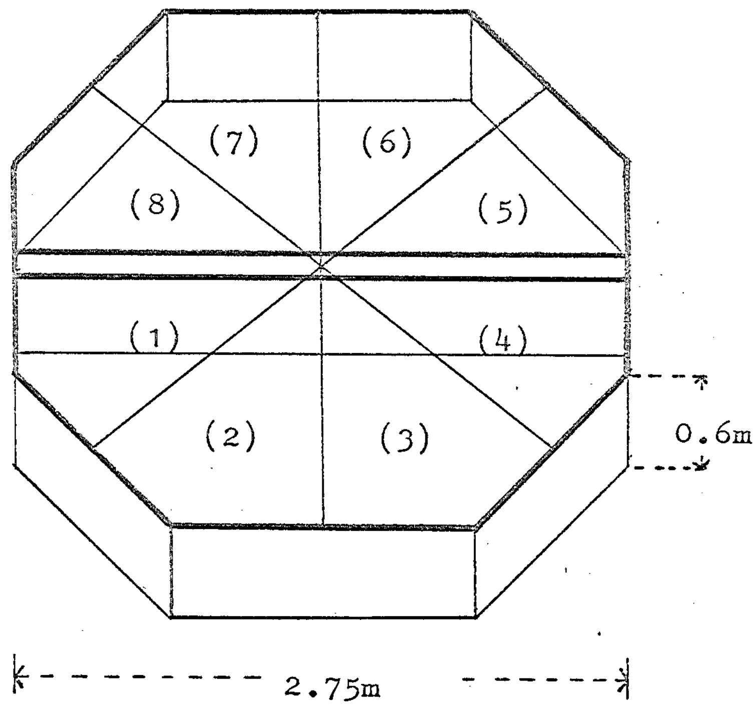


Fig. 1 FISH CAGE

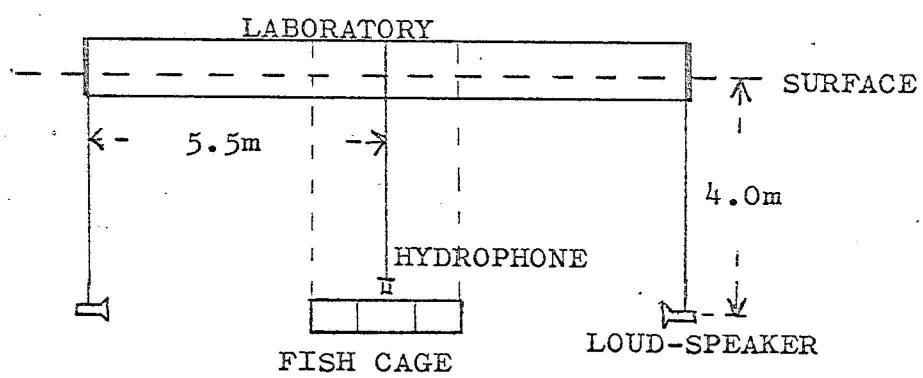


Fig. 2a EXPERIMENTAL SET UP

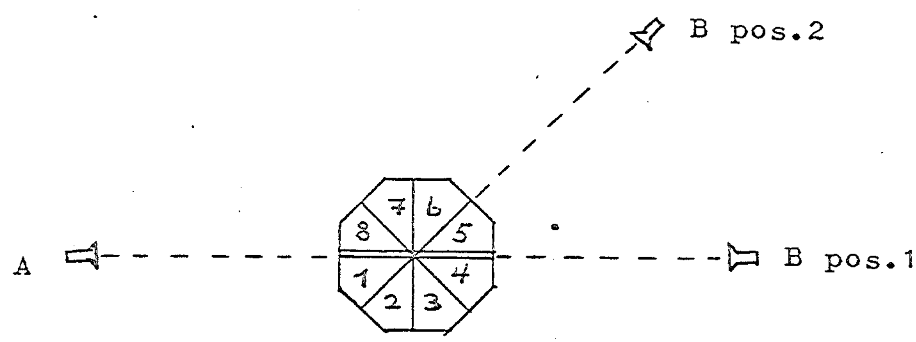


Fig. 2b POSITIONS OF THE LOUD-SPEAKERS

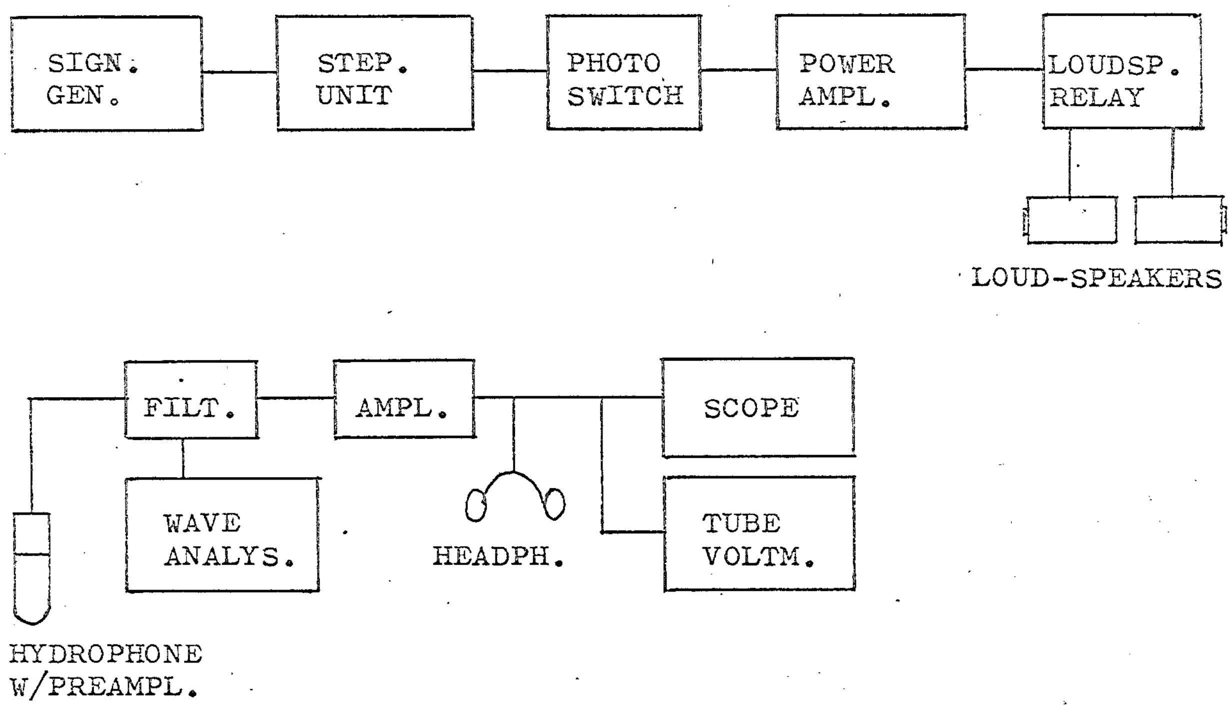


FIG. 3 BLOCKDIAGRAM OF INSTRUMENTATION

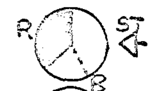
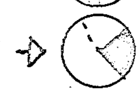
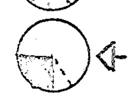
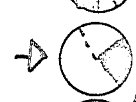
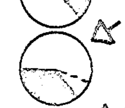
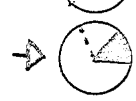
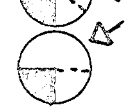
TRANSMITTING:

SIGNAL GEN.:	SINE/RANDOM GEN. TYPE 1024, B.& K.
STEP. UNIT :	SPES. MADE
POWER AMPL.:	10W HIGH-QUAL. AMPL. , MULLARD
LOUD-SPEAK.:	J 9 SOUND PROJECTORS 20W, DYNA-EMP., INC.

MEASURING:

HYDROPHONE :	DEEP SEA HYDROPH. MOD.1100, NUS CORP.
WAVE ANALYS.:	RADIOM. TYPE FRA 26, RADIOM. COPENH.
FILTER :	HIGH-PASS RC-FILTER 12 dB/OCT.
AMPL. :	DC-AMPL. 40 dB
SCOPE. :	TYPE 321A, TEKTRONIC INC.
TUBE VOLTM.:	ELECTR. VOLTM. 2409 , B.& K.

Table 1. Observations on responses of herring to noise stimuli (100 Hz bandwidth, 100 Hz centerfrequency).

Trial no.	Loud-sp. transmit.	Breaking-points	Rallying-places	Sign.ang. in front	Response illustr.
1	B	3	7,8,1	$67\frac{1}{2}^o$	
2	B	3/4	8,1,2	45^o	
3	A	7	4,5	$67\frac{1}{2}^o$	
4	B	3	8,1	$67\frac{1}{2}^o$	
5	B	3	1,2	$67\frac{1}{2}^o$	
6	B	3	1,2	$67\frac{1}{2}^o$	
7	A	7	4,5	$67\frac{1}{2}^o$	
8	B pos. 2	4	1,2,3	$67\frac{1}{2}^o$	
9	B pos. 2	4	1,2	$67\frac{1}{2}^o$	
10	B	3/4	7,8,1	45^o	
11	A	7	5	$67\frac{1}{2}^o$	
12	B	3	1,2	$67\frac{1}{2}^o$	
13	B	3/4	1,2	45^o	
14	B pos. 2	4/5	1,2	45^o	
15	A	7	4,5	$67\frac{1}{2}^o$	
16	B pos. 2	4/5	1,2,3	45^o