USE OF ACOUSTICS IN STUDIES OF FISH REACTION TO IMPOSED STIMULI

by

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ABSTRACT

The general distribution pattern of fish in a large holding pen
is described through the integrated echo intensity in six
separate cells using transducers mounted below the pen. The
reaction of fish to different stimuli, imposed in one of the
cells, is quantified by the change in frequency distribution of
the echo intensity relative to the undisturbed situation. The
experiment was part of a small-scale test of equipment to be
used for observations of the attraction-effect of fish to
oil-rig structures. The method also seems to be suitable for
general fish behaviour studies, particularly concerning
attraction and avoidance effects.

INTRODUCTION

It is a well known fact that fish are generally attracted to structures on the sea-bottom. High concentrations of fish around ship-wrecks are commercially exploited by fishermen specializing in this type of fishery. In some areas, artificial reefs are placed on the bottom to increase the fish density (ASKA 1979). Fish are also attracted to the increasing number of oil-rig structures in the North Sea, and significant fish concentrations are found inside the security-zones, where they are unexploitable by the fishing fleet.

In a pilot project to study the attraction stimuli to oil rigs, a small-scale test was made to evaluate some of the instrumentation to be used in the main project. One of the methods also seems suitable for general behaviour studies where reactions to imposed stimuli are studied.

The basic idea was to observe the mass transport of fish among six separate echo sounders when the stimuli to be tested are presented in the main lobe of one transducer. By observing the echo energy statistics for each echo sounder, the response could easily be quantified.

Since the experiment only ended in May 1985, this report will mainly present the experimental method and some of the basic results.

MATERIAL AND METHODS

The experiments were made in a sheltered bay near Uggdalseidet on the island of Tysnes, about 50 km south of Bergen. The fish, saithe (Pollachius virus), was held in a large pen, 90 m long, 10 m wide and 7 m deep, simulating a semi-natural environment. A raft, 8x12 m, with laboratory compartments, was located about 50 meters south of the pen. The small, 44-foot research vessel "Fjordfangst" was used for transportation and accommodation for the crew.

Six circular transducers with nominal beam width 22° were mounted in upward-looking positions below the pen. These were oriented by specially arranged weights and suspension lines to maintain the acoustic axes through the center of the holding pen, Fig. 1. The transducers were connected to a SIMRAD EY-M 70 kHz echo sounder and QM-II echo integrator via an automatic ping and transducer selector.

Prior to the fish measurements, the acoustic system was calibrated using a 60 mm copper sphere, and the empty-cage contributions to the echo energy were established.

After transferring about 2000 saithe of nearly uniform length, 31-33 cm, the fish distribution pattern in the pen, representing an undisturbed situation, was measured over a seven-day period.

All measurements were made relative using the relations

$$A_i = (U_i - E_i) \, C_i \tag{1}$$

$$f_i = A_i \left(\sum_{j=1}^{j=6} A_j \right)^{-1} \tag{2}$$

where

A_i = corrected and calibrated integrator value in cell no.i (mm/min)
U_i = uncalibrated integrator value in cell no.i (mm/min)
E_i = empty-cage contribution in cell no.i (mm/min)
C_i = calibration factor for transducer no.i
f_i = relative contribution to the total from cell no.i (i.e. relative fish density in cell no.i)

The basic calibration parameters for the echo sounder and integrator, together with the measured empty-cage contribution, are shown in Table 1.

A second system was used to study the overall movements and reactions of single fish, individually tagged and positioned within the holding pen, using receiving hydrophones at both ends of the pen, Fig.1. The positions of the fish were determined using a simplified version of the SINTEF pinpoint system (MOHUS and HOLAND 1983). The positions were continously logged by a computer connected to the positioning system.

Stimuli such as artificial structures with shadowing effects, artificial surface lights, UW-lights with different filters and underwater sound were imposed in one of the cells, or, when preference was tested, in two not-neighbouring cells. To study the speed of attraction or reaction force, the increase or decrease of fish density in the stimuli-cell alone was observed.

Hydrography, current speed and direction were continously logged for observation of preference or fish behaviour in relation to these parameters.

RESULTS

General distribution pattern

A total of about 500 series of measurements of fish distribution pattern in the pen were made in the experiment. A typical series, with two-minutes integration on each transducer, is shown in Fig. 2 from the raw material.

Several types of behavioural modes were observed in the undis-
turbed situation with no artificial stimuli in the pen. Under
the typical bright daylight condition, the fish was evenly
distributed near the bottom of the pen, or schooling slowly
back and forth in the deeper part of the pen. In the evening,
heavy feeding activity was observed during most of the experi-
mental period, with the fish evenly distributed horisontally
near the surface. The fish also showed a certain preference to
the cell most exposed to the tidal current in the fjord.

The natural variability of distributions within the pen is seen
from the frequency of fish densities in each cell, Fig. 3. The
central part of each distribution reflects a stable, nearly
ideal distribution pattern, while the tails, where up to 85 %
of the fish is located within one cell, are a result of school-
ing activity, more rarely seen in the pen.

A general description of the undisturbed situation is shown in
Fig. 4. The diagram represents the distribution of fish in the
pen over a 3-week period. The stippled line indicates the
ideal distribution pattern with equal amounts of fish in each
cell. Using this distribution as a model in a Chi-square test,
the observed distribution pattern is not significantly differ-
ent from the ideal (p>0.25). A certain preference for the cell
most exposed to the weak tidal current in the fjord is seen.
The cell located in the inner part of the bay is consequently
less exposed to the current, and the fish density is also
slightly lower.

The individually tagged saithe seemed to prefer the central
part of the pen, almost totally avoiding the inner part of the
bay, cell no. VI, Fig. 5.

Response to stimuli

The stimuli to be tested was presented in one of the four
central cells, usually no. III or V, or in both when preference
was tested. To quantify the reaction, a series of measurements
before and after the stimuli-measurements were made. A typical
example of the attraction to white underwater light, 1000 W, is
shown in Fig. 6. More than 70% of the fish is attracted to the
light-cell, and strong feeding activity on naturally occurring
organisms was observed. The distribution pattern prior to the
stimuli, and after, is nearly ideal. The attraction to the
same light mounted above the surface was also strong but not
comparable to UW-light, Fig. 7. The attraction range also
seems to be significantly reduced.

Table 1. Basic parameters from calibration of the acoustic
system.

CHANNEL	Calibration[1] factor	Empty-cage[2] contribution (mm/min)
I	0.96	14
II	1.18	23
III	0.95	11
IV	0.91	12
V	1.20	11
VI	0.88	10

1) Estimated from 10-minutes integration on a 60 mm copper
sphere, centered on acoustic axes of the transducer in a
calibration-rig.

2) About 5% of a typical fish density value.

When testing preference, cell no. III and V were used simulta-
nously, and preference to either of the stimuli-sources was
then observed as a gradual increase in echo-energy in one of
the cells, with a comparable reduction in the other. A signi-
ficant increase of the fish density to comparable levels in the
two cells was normally observed during the first minutes in
such a test. Before reaching a stable distribution pattern,
however, a certain portion of the fish in one of the cells
would move to the preferred cell. Fig. 8 shows a stable
pattern 30 minutes after introducing a blue 500 W underwater
lamp in cell no. III and a red 500 W UW-lamp in cell no. V.

Speed of reaction

The reaction speed could be studied by observing the change in
echo energy in the stimulus cell per unit time. An example of
the attraction to a low-frequency, 160 Hz, pulsed underwater
sound source is seen in Fig. 9. There is a very rapid increase
in fish density within the cell during the first two minutes
after the sound signal is started, but as no additional stimu-
lus was given, no further interest is observed. The fish
density decreases gradually.

Similar observations were made with several stimuli, the
exception being that of the light stimuli, where an increased
fish density was maintained within the cell over long periods.
The naturally occurring food organisms available, perhaps also
attracted to the illuminated cell, made this more a conditioned
reflex.

DISCUSSION

The experiment clearly shows the potential of the acoustic method in studies of fish reaction to imposed stimuli. The relatively strong stimuli in this investigation were used more to demonstrate and evaluate the multi-element integration method than to investigate attraction to stimuli already covered in the literature, as in PROTASOV (1970).

The strength of the method lies in the possibility of quantifying the reaction to a stimulus directly. Using the additional information in series like Fig. 9, it should also be possible to quantify the reaction strength. Further analysis of the data will include a simplified model for mass transport of fish into or out of the stimuli area, discribed through equations of the form:

$$-\frac{dN}{dt} = \beta (N_t - N_0) e^{-\alpha t} \tag{3}$$

where N_t = total number of fish in the pen
         N_0 = Number of fish within the stimuli-cell before stimuli
         α, β = - rate parameters

This will hopefully describe the transport rate of fish into the stimuli cell. The rate parameters will then constitute estimates of reaction strength to the stimuli. For more diffusive stimuli, like bait or chemicals simulating bait, the reaction distance should also be included.

The promising results from the pilot project have inspired plans for a more sophisticated system where the echo energy statistics can be monitored in realtime.

CONCLUSIONS

The acoustic method can be used to quantify the fish reaction to presented stimuli.

The method can be used both in semi-natural environments and in the larger sea-scale.

The attraction effects of stimuli based on light and sound have been demonstrated using this technique. The attraction force may be further quantified from the data.

Significant differences in long-term fish distribution pattern of undisturbed fish involving all fish and individually tagged fish is seen. This may indicate that the process of tagging, or the tag itself, introduce a behavioural difference.

REFERENCES

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PROTASOV,U.R. 1970. Vision and near orientation of fishes. Translated from Russian, Israel Program for Scientific translations, John Wiley and Sons, Jerusalem 1970, 175 pp.
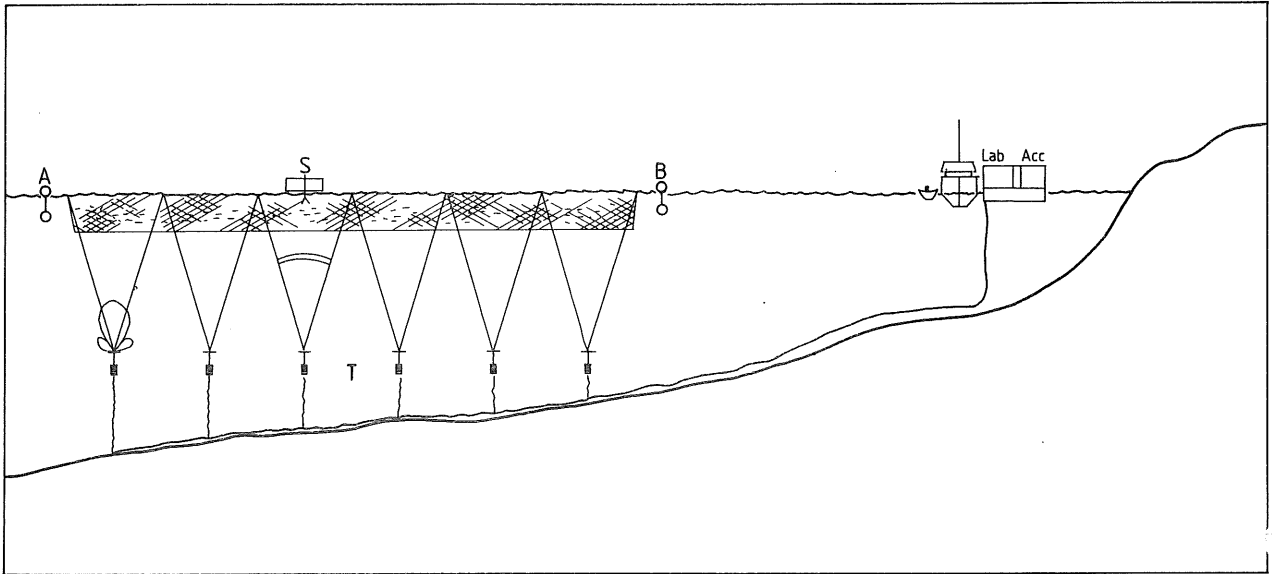
Fig.1. Experimental site with holding pen, transducers (T), stimuli platform (S) and hydrophones for acoustical positioning of tagged fish (A,B).
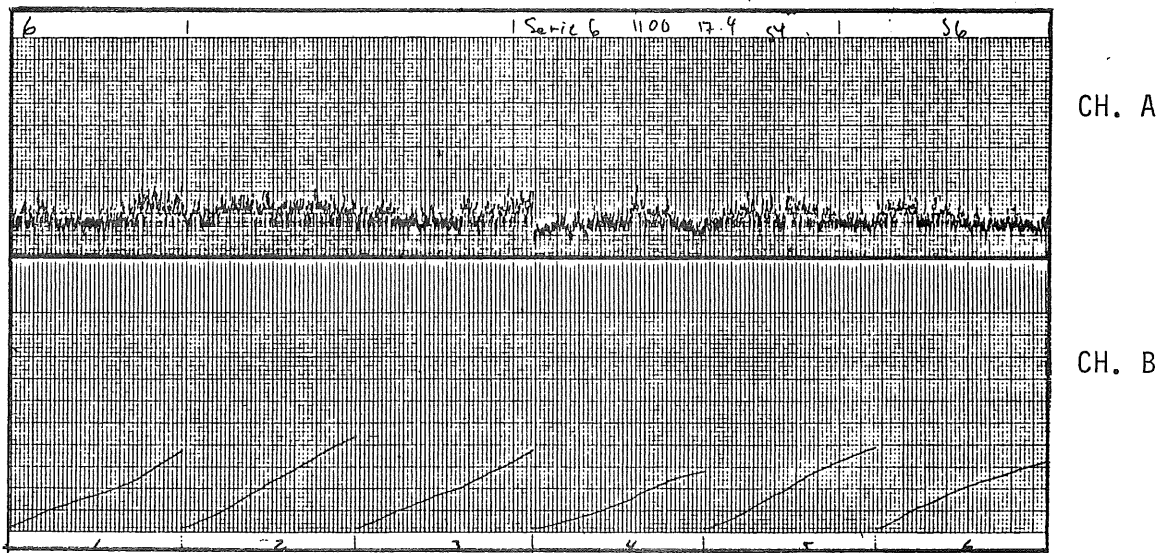
Fig.2. Example from the raw material where the distribution pattern of fish is nearly ideal.
CHANNEL A: Echo energy in each ping
CHANNEL B: Integrated echo energy for two minutes in each cell.
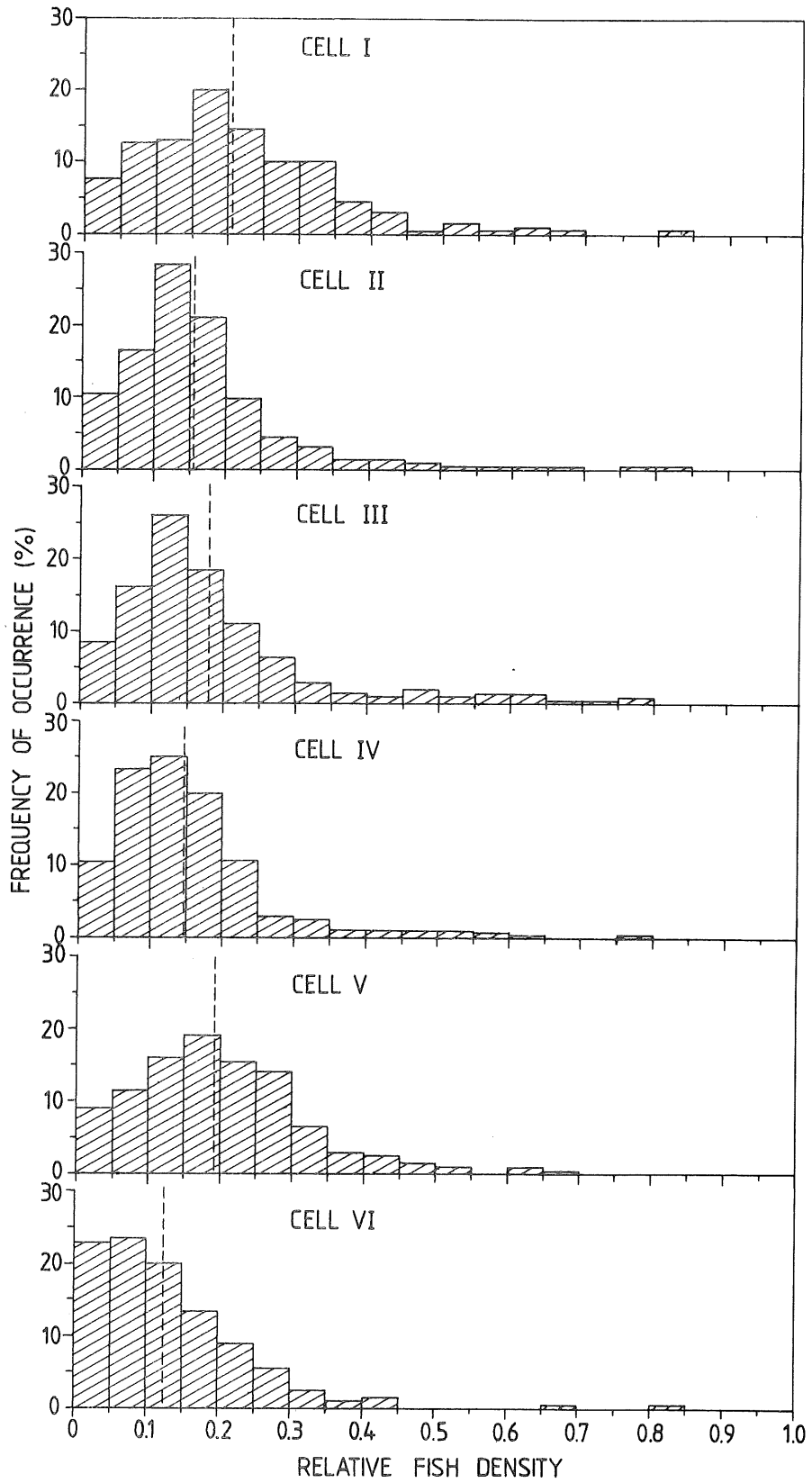
Fig.3. Observed fish densities in each cell over a three-
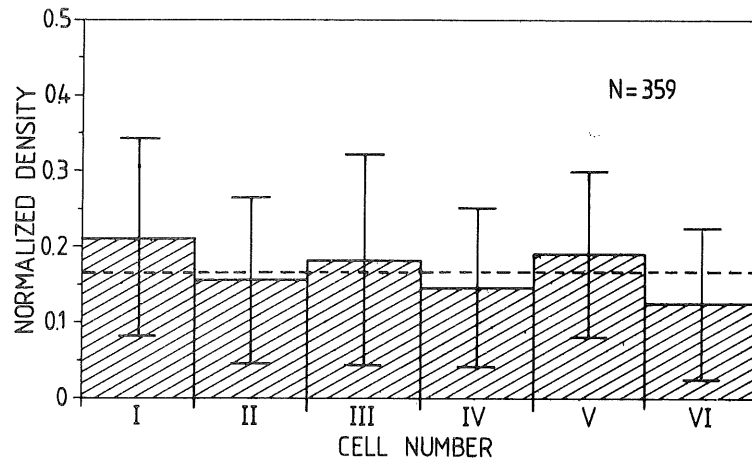week period,representing 359 measurement series on un-
disturbed fish

Fig.4. Observed mean distribution pattern in the
holding pen over a three-week period. Standard
deviation, together with the ideal pattern, is
shown.
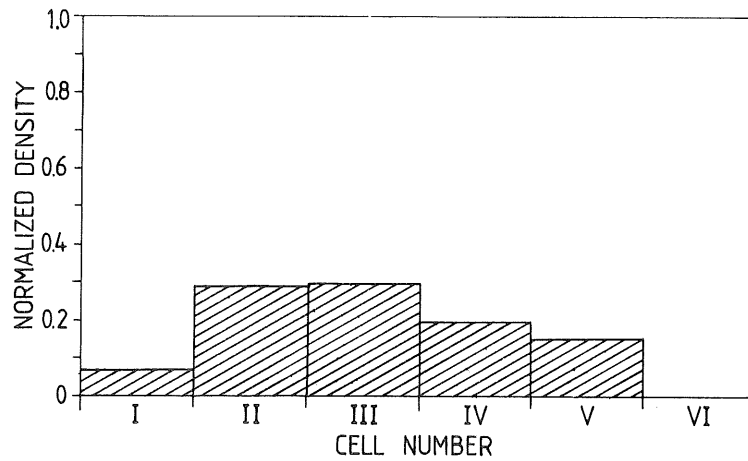
Fig.5. Distribution pattern of the individually
tagged fish from the positioning system over the
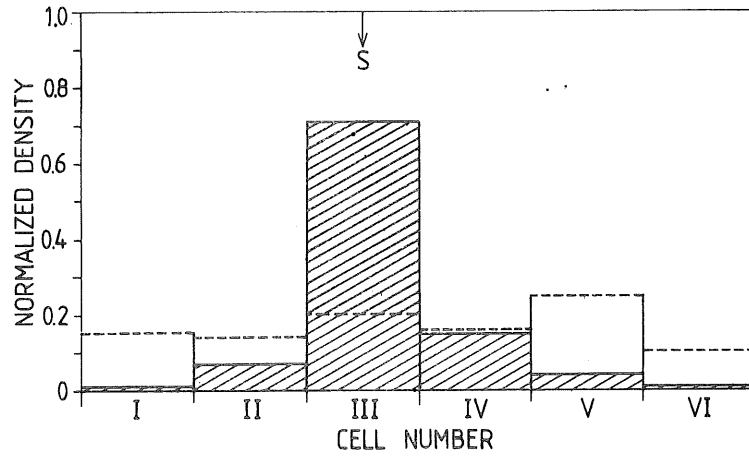same three-week period.

Fig.6. Observed reaction to white UW-light (1000 W)
in cell no.III. Mean distribution pattern before
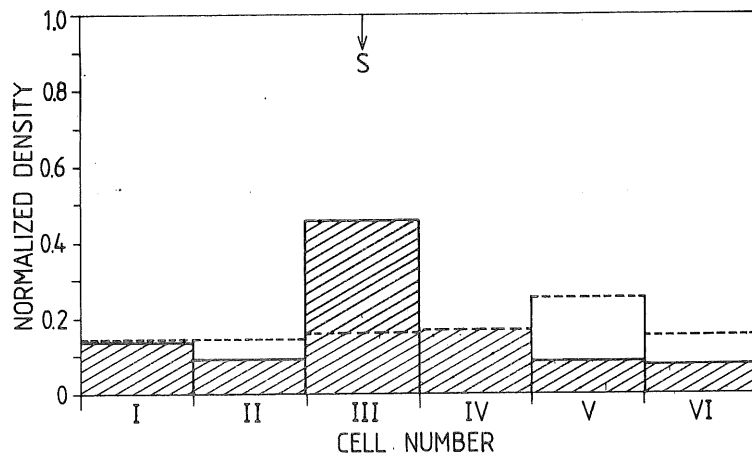and after the stimulus is shown by the stippled lines.

Fig.7. Reaction to white surface light (1000 W) in
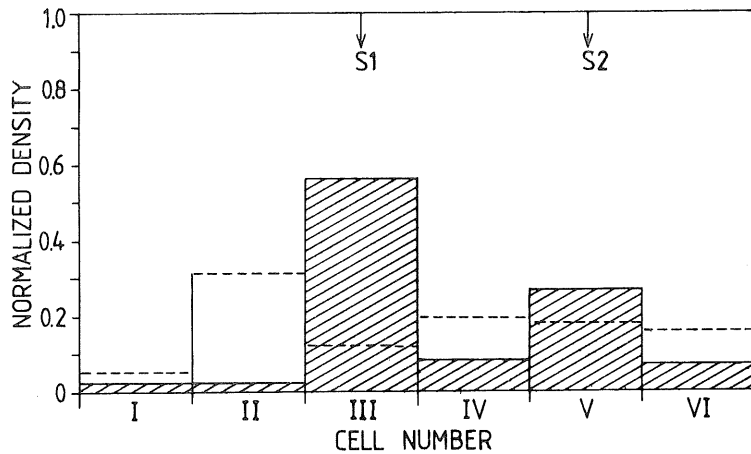cell no.III.

Fig.8. Example of reaction when preference to filtered
light was tested. S1 - blue UW-light, S2 - red UW light,
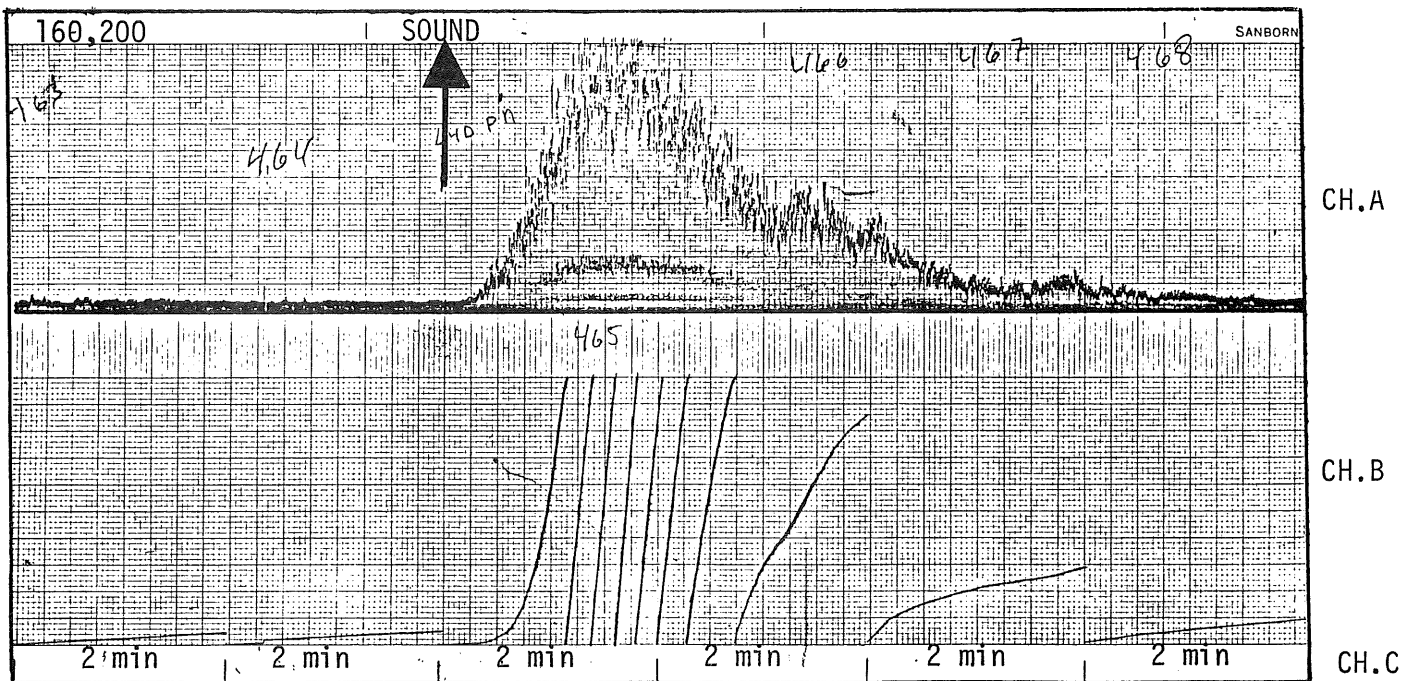both 500 W.

Fig.9. Example of the attraction to a pulsed underwater sound stimulus
(160 Hz, 200 ms), observed using only the transducer watching the
stimulus cell. Time scale is 2 min. between the vertical bars in CH. C.
Sound source activation is indicated by the arrow.