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REVIEW OF AVOIDANCE REACTIONS OF TROPICAL FISH TO A SURVEY VESSEL

(Revue des réactions d'évitement des poissons tropicaux au passage d'un navire de prospection)

by

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RESUME

Les réactions des poissons pélagiques tropicaux au passage d'un navire de recherches sont décrites en fonction de l'impact qu'elles peuvent avoir sur les résultats des prospection acoustiques. Deux composantes principales sont décrites: déplacement du poisson latéralement ou en plongée, et situation dans les trois dimensions.

Une description empirique des influences des divers stimuli d'un navire sur les poissons est proposée: les trois stimuli pris en compte sont le bruit, l'éclairement d'un navire la nuit et la vision de la coque le jour, l'importance de la réaction des poissons est estimée inversement proportionnelle à la portée du stimulus.

ABSTRACT

The reactions of pelagic tropical fish to the presence of a survey vessel are listed and related to the type of stimulus emitted by the boat. They are described according to the impact they present on the result of acoustic surveys. The two main kinds of reactions are: lateral or vertical avoidance (dynamic behaviour) and instantaneous spatial position of the fish (tilt angle).

An empirical evaluation of the influence of the three principal stimuli emitted by a boat is proposed. Those stimuli are the global noise of the vessel, its lights by night, and the vision of the hull by day. The magnitude of the reaction of the fish seems inversely proportional to the range of these stimuli.

INTRODUCTION

The reactions of the pelagic tropical fishes towards the crossing of a vessel can show some very diverse aspects depending on the species, the type of stimulus, etc..., but as far as their impact on acoustic data is concerned, they present two principal components:

- the instant position of the fish: touches uniquely the tilt angle of the fish within three dimensions, at the precise moment where it crosses the axe of the acoustic beam of a sounder.

- the dynamic of the displacement: represents all the displacements of the fish within three dimensions, which can be attributed to the irruption of a survey vessel. Each of these two components which can provoke some important biases in the density evaluation will be analysed separately for day and night surveying in order to take into account their specificity. The effects will be studied at different distances from the boat. Finally the ethological components having an influence on the anatomical characteristics of the fishes (swimbladder) will not be studied here, although we know that they can play an important role in the biases that the behaviour induces in the acoustic evaluations.

DYNAMIC BEHAVIOUR

A. NOCTURNAL BEHAVIOUR

In order to simplify, we will only envisage the case of scattered fishes although schools could be observed by night too (FREON et al., 1988; WOODHEAD, 1966).

At night the behaviour is perturbed by two stimuli: noise and light of the vessel. Noise is perceptible at long distances (to the order of 10^3 m); as far as light is concerned, it can be perceived depending on the movement of the surface from some 10 to probably more than a 100 metres.

Reaction to noise

Fish are very perceptible to noise (OLSEN, 1971). This sensitiveness has several consequences.

- **at long distances**, a slow displacement can be observed, fishes have a tendancy to flee from emission points. This phenomenon observed and described in northern areas (MISUND, 1987) was confirmed by the measures of biomass around a noise source transmitting near a oil-extraction platform in tropical waters (GERLOTTO et al, 1989). We have no direct informations on this spparticular behaviour, but indirect observation on long periods. Fig 1, for instance, shows the progressive diminution of the density on a 26 hour period of insonification. We did not perform measurements by night during this experiment, but we can observe that the density remained as low in the morning than the day before: the fish con-

ping while the small ones stood in the route of the vessel.

These two observations look somehow contradictory, but it was observed also that the scattering behaviour of the fish were distinct: we observed some big night schools during the second one while almost no school were recorded in the first experiment. This could show that the environmental conditions were distinct (moon light, bioluminescence, for instance), and that this natural behaviour has to be taken into consideration.

B. DIURNAL BEHAVIOUR

In this case we are only interested in the schools of fish which essentially form the pelagic biomass.

In the day time two stimuli prevail:

- the noise, identical to that at night

- the visual stimulus. In this case it concerns the direct vision of the hull. It is only effective at around 10 metres and certainly not above 50 m, even in clear transparent tropical waters. Therefore it acts only at weak distances, contrarily to the nocturnal illumination where the pinpoint source can be perceived at a greater distance. At the present time we do not have enough experimental results allowing for the separation of the effects of the auditive and visual stimuli, but some preliminary results on the shape of schools should indicate that the impact of the visual stimulus alone gives rather different results if they have been recorded with the boat using sails or motor.

1. Behaviour at a long distance.

The stress is of the same nature as in the night (noise at long distance). The only data on this subject that we have at our disposal is that observed under oil-extraction platforms (fig.1). We observed the same diagram of slow radiated escape at the same distance as that at night which has been described elsewhere by diverse authors for cold waters (see for instance OLSEN, 1987). In warmer areas, we can cite the work of NEPROSHIN, 1979.

2. Behaviour at short distances.

- lateral avoidance. It was observed but not measured; particularly in the surface layers, and manifests at the immediate proximity of the boat: therefore it appears to be tied to the presence of the hull in the field of vision (included in certain occasions the vision of the superstructures across the surface, which in certain cases may be visible in front of the hull). It is clear that this avoidance leads to a very high underestimation of the biomass, which in certain cases can almost totally disappear.

- vertical avoidance. We measured for the sub-surface schools observed a moderate vertical avoidance (fig. 6) that we globally evaluated at a dive of 5 m for the school included between the surface and 20 m deep (GERLOTTO and FREON, 1988). An observation on a single school overpassed three times by the sail boat (1: sails; 2: motor; 3: motor) suggested that the visual stimulus alone was responsible for a diving reaction at the very last moment (observable on the echogram), meanwhile the existence of the auditive stimulus (motor) showed an earlier reaction (FREON et al., 1990).

It is suitable to add the variations of structure induced by the ship's crossing to this global displacement. We have been able to notice in particular that a school has a tendency to compress more in it's higher parts than in it's lower parts. Figure 7 shows the difference between a "natural" structure of a surface school and a "stressed" structure.

INSTANT POSITION

A. NOCTURNAL BEHAVIOUR.

The static behaviour of the fish acts on the TS: more the position is different from the horizontal position, more the TS weakens. The evaluation of this component of the induced behaviour is indispensable for two reasons: first it determines which TS value must be applied to the data for a transformation in biomass estimations, then it gives one of the factors allowing the comparison of the data collected during day and night.

We have not carried out measurements of the angular position of the undisturbed tropical pelagic fishes. There exists two sources of information in the litterature on this position. By photographic observation (BUERKLE, 1983; AOKI and INAGAKI, 1986), and observing caged fish.

Although sometimes discrepancies are observed, it is interesting to note that most of the time the results coincide. It has been found for the fish "in situ" an average angle of 12 degrees in comparison to the horizontal which corresponds on the TS graph to a decrease of about - 6 dB in comparison to the nominal value, and the measurements in the cage gave, for example, a difference of - 5 dB between the day and night for the herring (EDWARDS and ARMSTRONG, 1989), or - 7 dB for Sardinella aurita (GERLOTTO, 1987)

Having only the data obtained by a sounder, we tried to determine the impact of noise and light on the angular position of the fish by using them alternately or together.

We assumed that the passage of a lighted vessel at normal speed of surveying represented a "maximum stress". Hypothetically we admit that the fish in a situation of maximum stress is polarized with regard to the source of the stimulus; it's position can either be horizontal, in "alert", or slanted agreeing to the model suggested by OLSEN et al. (1983). We have studied the following cases:

- special attention to the lighting conditions of the vessel by night, which must be as dark as possible;

- separate analysis of the school data and the scattered fish data;

- separation in the analysis of the results of the upper layer (i.e. < 20 m) and the lower one (> 20 m).

We intented to obtain some corrective factors, although it is impossible to consider that we can calculate a universal factor: we have seen that according to the environmental conditions the actual reaction of the fish may change. Nevertheless some rough corrective factors may be applied:

- correction of the mean depth of the schools: when a school is recorded in the upper layer (< 20 m), its mean "natural" depth is considered 5 m higher than the recorded one;

- the mean tilt angle of the fish in the upper layer is considered always horizontal.

- schools are classified according to their height and density in transparent, semi-transparent and opaques, and different correction are applied on their biomass estimation.

CONCLUSION

It can be seen that once certain rules are established, particularly the complete separation in the analysis of data between day and night, the selection of a lighting level for the boat, the separate study of the schools, etc..., the behaviour of the tropical fish does not present a major handicap to the research.

We have not studied here the quantitative behaviour of lateral avoidance of the schools, or certain natural components of the behaviour like the occupation of the surface layer inaccessible to the sounder, and those functions of the behaviour operating on the physiological characteristics of the fish, but these components evidently should be taken into account.

Finally it must not be forgotten that the natural behaviour may also interact with the stressed behaviour: at certain times of the day and certain periods of the year, the natural behaviour may be much stronger than the stressed one and the fish do not react in the usual way to a survey vessel. These relations might be studied too.

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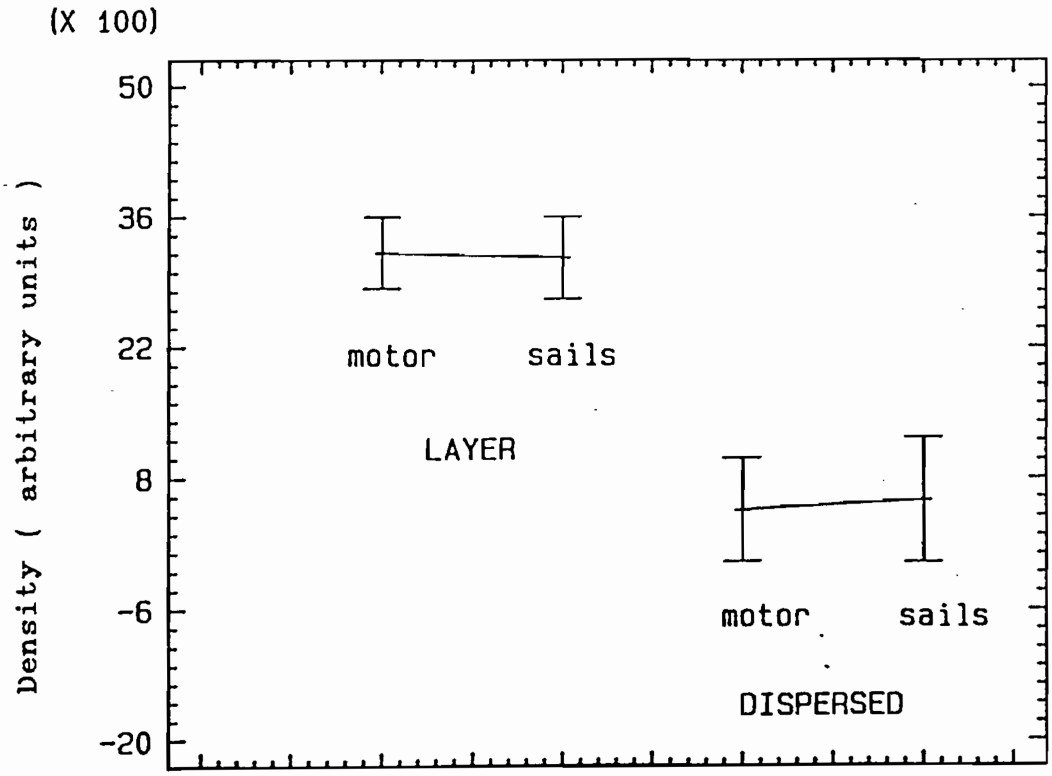

Fig. 3. 95% confidence intervals of factor mean density for sails versus motor and layer versus dispersed from FREON et al., 1990

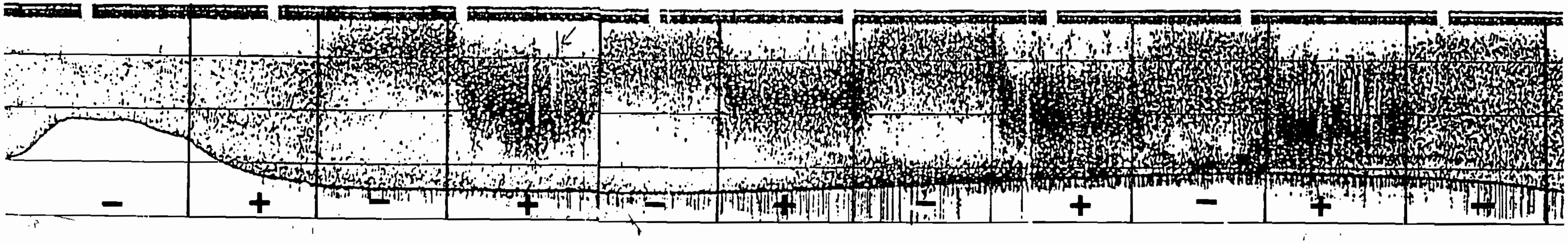

Fig. 4. Observed diving reactions of fish with a lighted boat
(from LEVENEZ et al, 1987).
+ light on - light off

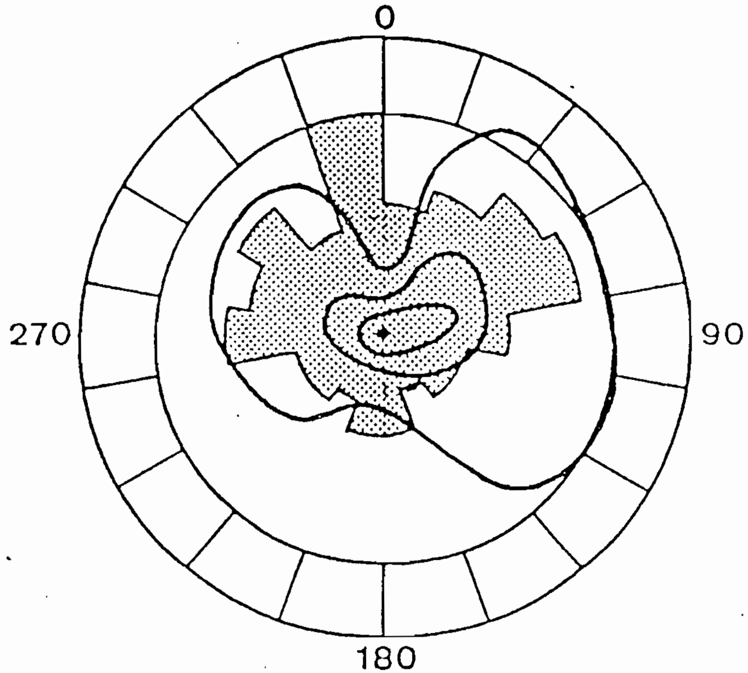

Fig. 5. Relation between vessel noise and school avoidance
(from GERLOTTO and FREON, 1988)
sound pressure lines (from URICK, 1975)
proportions of escaping schools
by 20° sectors (from MISUND, 1987)

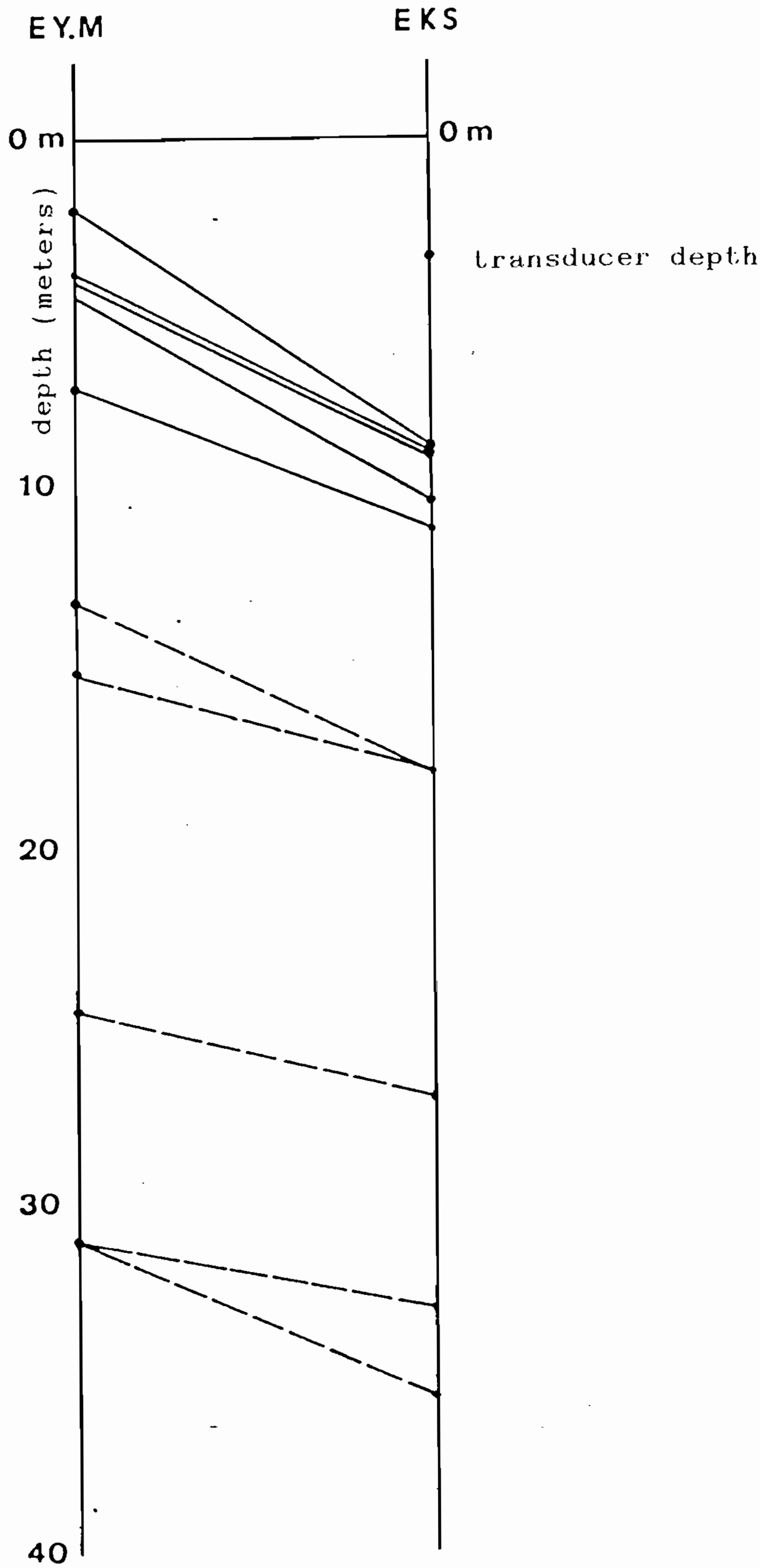

Fig. 6. Evolution of the depth of the tops (————) and bottoms (----) of schools observed successively under unstressed conditions (EYM) and stressed conditions (EKS)

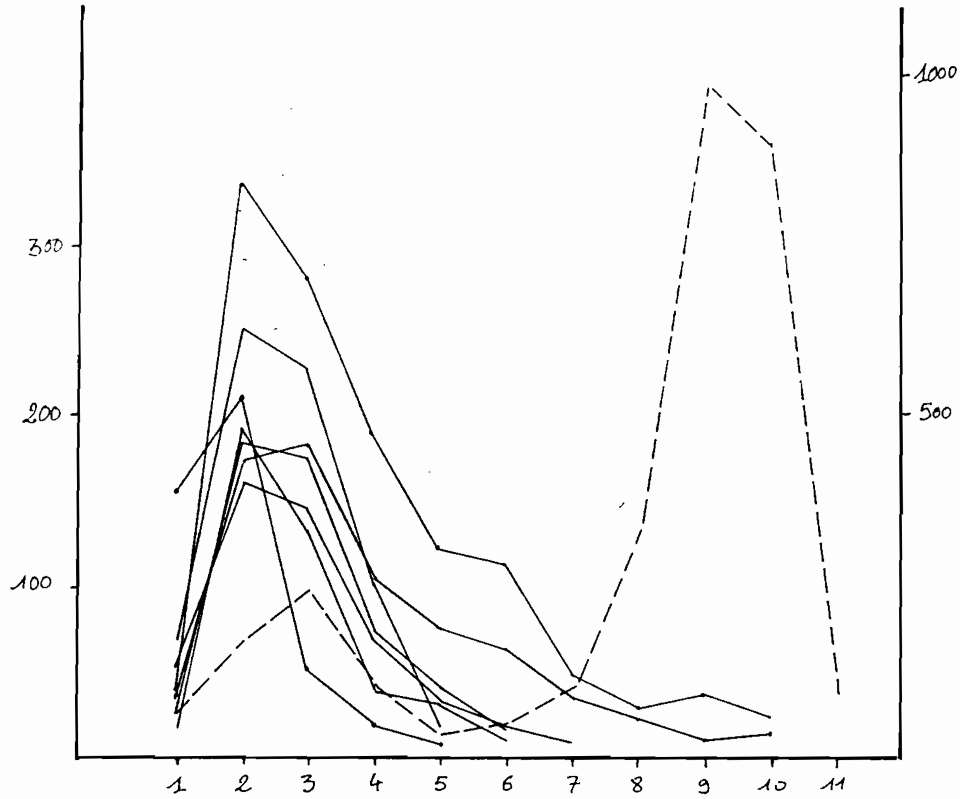

Fig. 7. Mean relative density per 1 m layer of "stressed schools" (———) and "unstressed schools" (- - -) from GERLOTTO and FREON, 1988

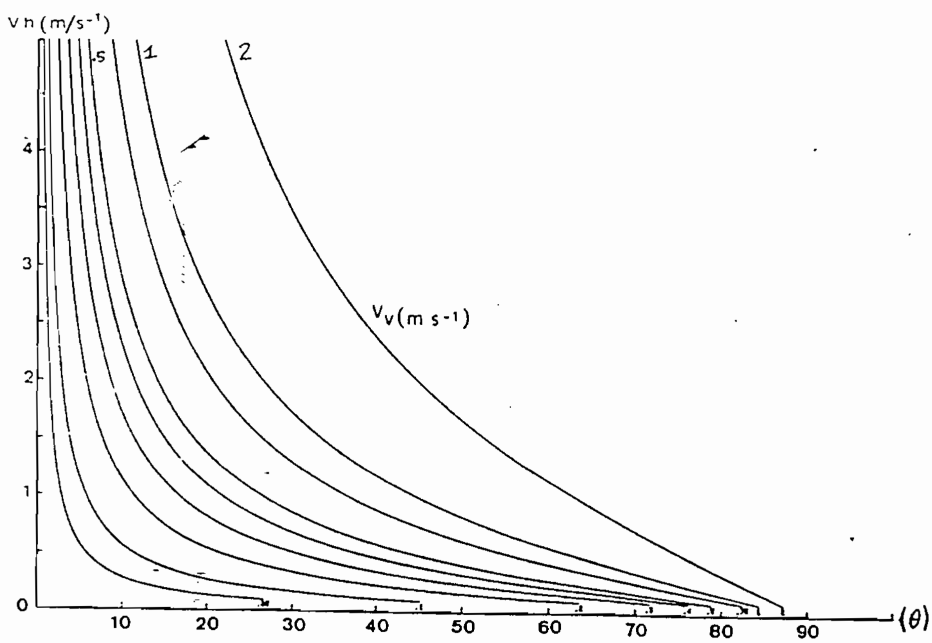

Fig. 8. Relation between fish tilt angle (Θ), horizontal flight speed (V_h), and vertical flight speed (V_v)

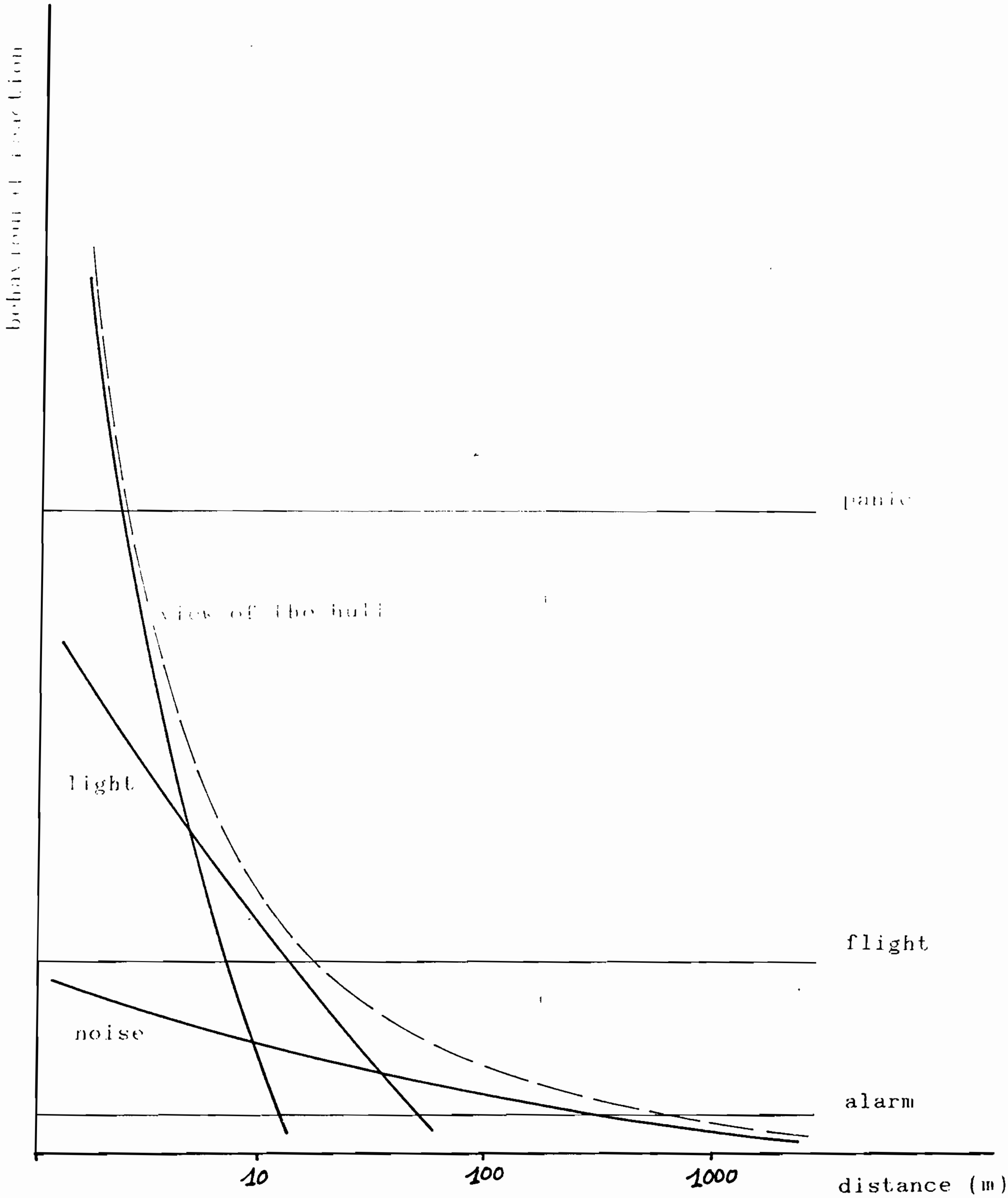

Fig. 9 Schematic synthesis of the reactions of fish to various stimuli according to their ranges