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Study of learning capabilities of tropical clupeoids using an artificial stimulus

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Learning capabilities of a small tropical pelagic fish, the thread herring (*Opisthonema oglinum*), were studied under experimental conditions. The conditioning consisted of associating a series of three sound pulses with a stress (hoisting a horizontal rigid net from the bottom to the surface). Individual sensibility and school stability measures indicate that fish can be stress-conditioned. Furthermore, these conditioned fish, when mixed with non-conditioned fish ("naïve" fish), can lead reactions in a school. The results and their influence on fishing are discussed.

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Introduction

Schooling behaviour in fish has been advanced as a mechanism that allows the individual to reduce the risk of predation (Pitcher, 1986). According to several authors (e.g. Hollis, 1984), the function of Pavlovian conditioning is to enable the animal to optimize interaction with biologically important events. The performance of a conditioned response allows the animal to deal better with food, rivals, predators, and mates. To investigate the importance of individual learning to fishing operations, the conditioning capabilities of a coastal tropical clupeoid, thread herring (*Opisthonema oglinum*), and the effect of the stimulated reaction of these fish on naïve fishes in a mixed school were studied under experimental conditions.

Material and methods

This study was carried out in Martinique (French West Indies). The fish were caught by day in front of the laboratory with a small liftnet and were transported to two tanks (4 m diameter and 1.6 m height) under light anaesthesia and heavy oxygenation so as to limit stress. These tanks were supplied with filtered sea water by open circulation and were strictly identical in shape and colour. An underwater loudspeaker was arranged to transmit the same sound to both tanks. A sliding, rigid net was laid on the bottom of the first tank (tank with net: tank WN). The second tank had no such net or loudspeaker (tank B). Thirty-five fish were allowed to settle in each tank. A prophylactic antiseptic treatment was applied during the two first days of acclimatization.

The experiment consisted of three phases: a 4 day habituation phase, a 10 day conditioning phase and a 2 day transmission with extinction phase.

During the habituation phase, 27 sets consisting of three sound pulses of 10 s duration each, separated by 10 s intervals, were emitted. Each pulse of 500 Hz frequency increased progressively in amplitude and stopped suddenly at the maximum value. The sound sets were applied randomly during daytime.

Before the conditioning phase, we removed the 35 fish from tank B to a raceway. In tank WN, we associated the sound pulses previously described with a stress, following in this way a classical aversive conditioning procedure. The stress consisted of hoisting the net close to the surface 5 s after the last pulse and maintaining it at the surface for 10 s. This stress was applied 22 times at random times during daytime about three times daily (the conditioning phase ended when all the fish reacted to the first sound pulse). The series of sound pulses represents the neutral or conditioned stimulus (CS), and the hoisting of the net represents the absolute or unconditioned stimulus (UCS).

During the transmission and extinction phase, the conditioned fish were mixed with the naïve fish in the two tanks. The CS without the UCS was emitted 10

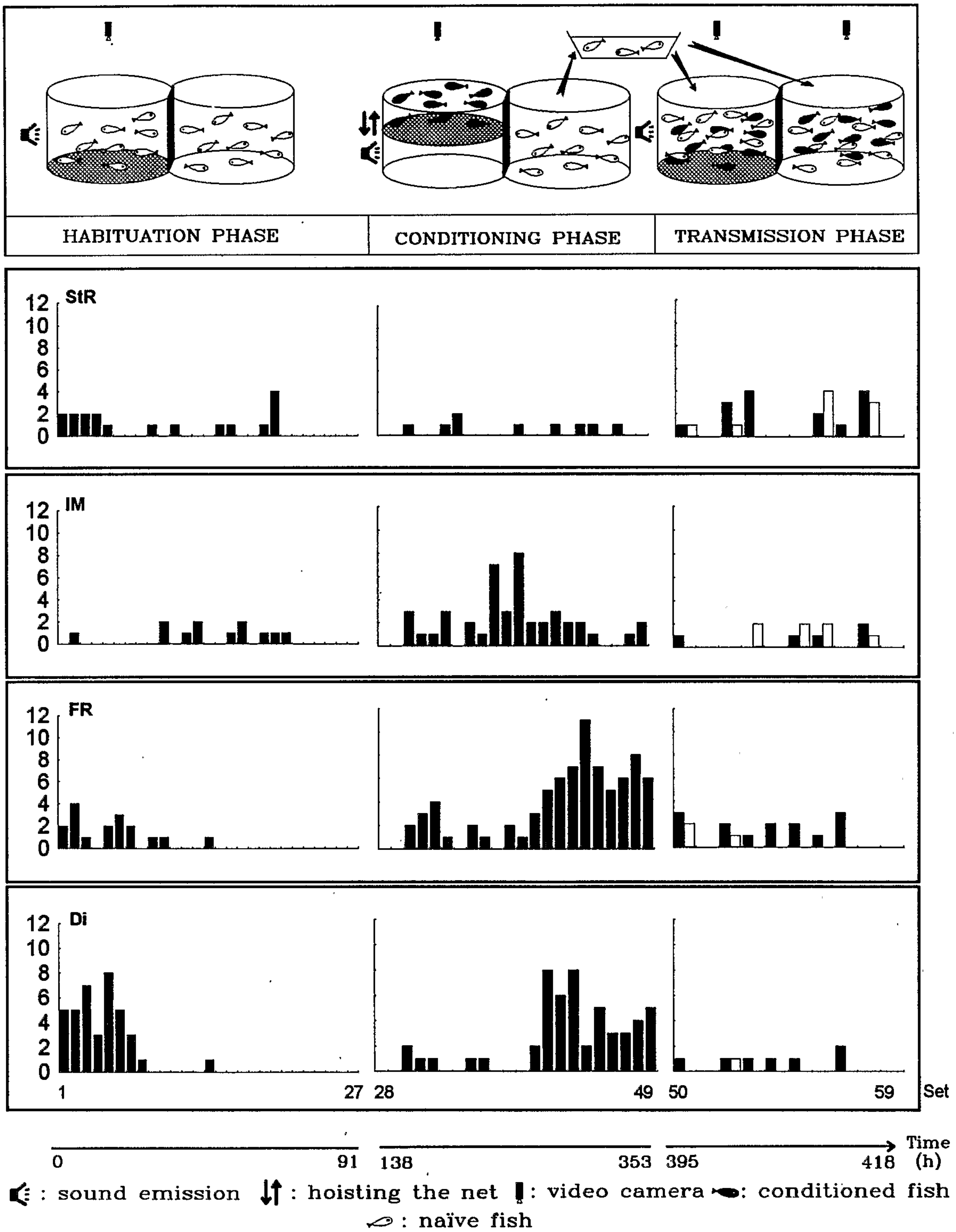

Figure 1. Three phases of the experiment (upper part) and results (lower part) expressed as frequency histograms of reactions to the conditioned stimuli in the tank with net (black bars) and in the other tank (white bars): startle response (StR), imperfect mill (IM), flight reaction (FR), dislocation (Di). Set refers to sets of three sound pulses (see text).

times. The reactions of the two mixed schools of conditioned and naïve fish, present in the same proportion in each tank (18/18 in tank WN; 17/17 in tank B), were compared.

During these three phases, each test was recorded on videotape. The fish in the tanks were swimming slowly in a circle, forming a typical mill structure (which is known as a good index of stability and quiet behaviour of a school) which they maintained as long as they were not disturbed. The reactions of the school were measured through four behavioural criteria which are, in order of increasing excitation: (1) startle response (StR), which affects one fish and does not lead to reactions of the others; (2) imperfect mill (IM), a contraction of the mill structure with a disruption of the regular swimming; (3) flight reaction (FR), which could be with fast regrouping, or dispersion; and (4) dislocation (Di), characterized by fast and erratic swimming that disorganized the school.

Results

As no mortality and no unexpected behaviour occurred during the experiment, we considered the fish to be correctly adapted to captivity. During the habituation phase, the strong responses (Di, FR) decreased in intensity and vanished rapidly after the first six sets (Fig. 1, left), which means that the sound pulses no longer elicited any fish reaction.

During the conditioning phase, the fish started to react after the third set of CS, and the reaction was well established after a dozen sets. A progressive change in behavioural response from StR to Di occurred (Fig. 1, middle). Nevertheless the conditioned reactions never became as strong as the panic observed during the hoisting of the net.

During the transmission phase, limited reactions of the mixed school in tank B were noted: after 3 series of sound pulses, some StR and IM appeared but stronger reactions were never displayed except one Di and three FR during the three first sets. By contrast, in tank WN we observed FR and Di at the beginning of the stimuli sequence. These reactions declined quickly and became individual StR in the end. We did not observe progressive extinction from Di to StR. No responses were noted after the 9th set (Fig. 1, right).

Discussion

These results show that conditioning of "primitive" fish such as clupeoids is possible. Several authors have shown that avoidance by fish or other animals of aversive conditions or predators could be reinforced by learning (Gleitman and Rozin, 1971). Conditioning by an attractive UCS such as food is well known in aquaculture (e.g. Suboski and Templeton, 1989). Concerning the conditioning process, the increasing responses from StR to Di can be explained by individual differences in ability to learn (Pyanov, 1993) and/or by mimicry or a social facilitation process (Helfman and Schultz, 1984).

Concerning the transmission phase, the strongest reactions (FR and Di) were displayed in tank WN. As they concern the whole school they give evidence for conditioned fish leading the "naïve" ones. In the case of IM and StR behaviours, we assume that they were performed by conditioned fish which disturbed to some extent the "naïve" fish but did not lead them. These reactions occurred essentially in tank B. These differences between the two tanks could result from participation of the net used as the aversion stimulus still being present lying on the bottom of the tank WN. Catching sight of the net should be associated with hoisting, and therefore a part of the UCS was maintained in tank WN during the extinction phase. This result shows that a conditioned response cannot be dissociated from the context in which it is expressed (Jenkins, 1984).

In order to relate the results to *in situ* fishing conditions, we have to compare the number of necessary CS repetitions with the number of successful escapes and survivals of fish from a gear. This last point has only recently been documented (see other contributions to this volume) but it does not seem unrealistic to expect that some fish could have the opportunity to learn. If not, fish will probably die before learning, except if a stronger stress could reduce the learning time ("one-trial learning").

We have shown that naïve fish could respond appropriately to the reactions of the trained fish despite knowing nothing of their particular learned experience. Opportunities for experienced fish leading the inexperienced probably exist in natural conditions (fishing grounds), and owing to the low degree of fidelity of individuals to a school (Helfman, 1984), these kinds of mixed schools should exist. Therefore, catchability in heavily exploited stocks could be lower than that in unexploited stocks.

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