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The responses of cod *Gadus morhua* (L) to chemical attractants in moving water

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Introduction

Cod can detect food by chemoreception (Pipping, 1926; Brawn, 1969), and are able to locate the source of attractive chemical stimuli in experimental tanks (McKenzie, 1935; Pawson, 1976). In these conditions the fish appear to detect chemical gradients and orientate by chemoklinotaxis or chemotropotaxis. Wild cod, however, inhabit tidal areas where their search for food on the sea-bed will be most efficient if they drift or swim with the current, and turn to swim upstream when chemical stimuli emanating from food are detected. This note describes an experiment designed to test the hypothesis that cod will show a positive rheotaxis in response to chemical attractants in moving water.

Materials and methods

The fish were required to swim with the current and not to hold station with the background, heading upstream, as often occurs with an optomotor response (Harden Jones, 1963). A perspex annular tank (274 cm in external diameter with a 30 cm trough containing water to a depth of 14 cm) was used to allow the fish to swim continuously in either direction, with or against a current produced by a Stuart-Turner No. 10 centrifugal pump. This was constant at 17 cm/s in the middle of the trough, as measured by timing a float. Although the water velocity could not be varied, its apparent velocity could be altered by varying the angular velocity of an irregularly striped black and white background on each side of the transparent trough. It was hoped that a velocity would be found at which the cod did not exhibit an optomotor response, but swam downstream. The apparatus was illuminated by a ring-shaped fluorescent tube and was surrounded by a blackout. The attractant (an aqueous filtrate of 5 g macerated frozen squid *Loligo* sp. mantle in 400 ml sea water) was introduced through a transparent 5 mm bore PVC pipe by gravity feed from a beaker. This was manipulated by the observer, who sat inside the annulus and recorded events with a Telford cine camera (8 frames/s), using a large circular mirror placed above the tank.

The swimming speeds of the fish were calculated by recording the time taken to swim between markers spaced round the tank. The sea water in the tank was changed after each test and remained between 10 and 11 °C throughout the experiment. Two 20 cm cod were used singly in order to observe their reaction to the moving background, and three more were used in the tests (two trials per fish) involving the chemical attractant. These observations were made at the Department of Agriculture and Fisheries for Scotland, Marine Laboratory, Aberdeen in April 1971.

Results

Throughout the trials to find a background speed at which the cod would swim with the current, the moving background did not appear to have any effect on their movements. They seldom swam more than half-way round the tank before turning and swimming in the opposite direction, and maintained the same speed relative to the tank in either direction. After these trials, however, the fish swam almost continuously downstream when the background was stationary! The following tests were carried out

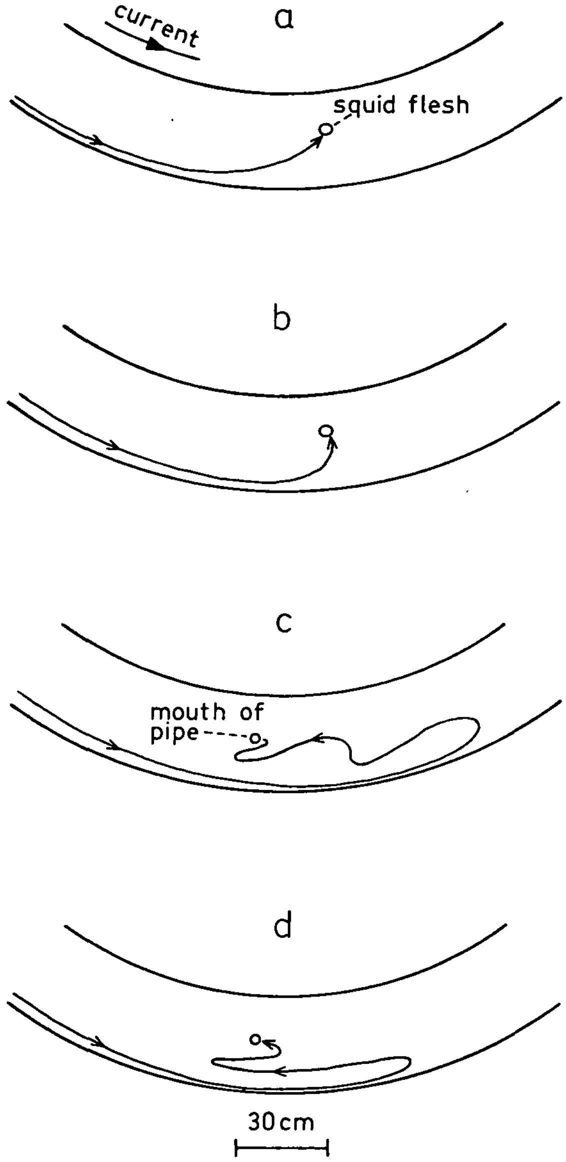

Figure 1. Tracks of 20 cm cod swimming with the current in the annular tank, when presented with a piece of squid flesh lying on the bottom (a and b), and with a colourless aqueous extract of squid flesh issuing from a pipe (c and d).

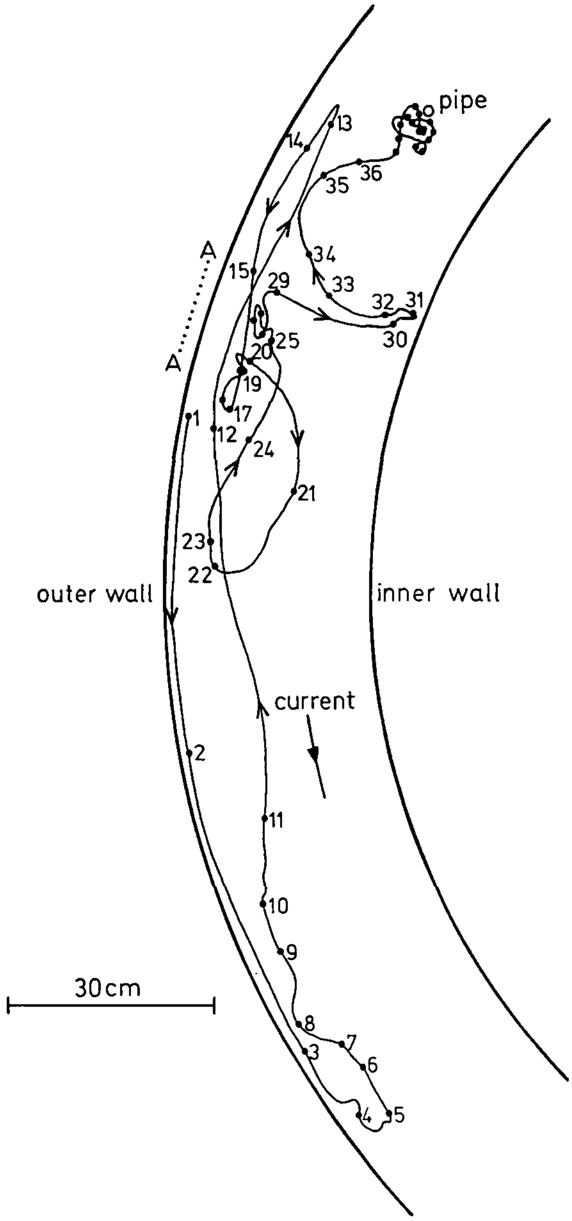

Figure 2. The filmed response of a cod to an extract of squid in moving water. Dots indicate positions of the fish's snout at 1 s intervals. Description in the text.

when the fish appeared to be settled and swimming steadily with the current.

When the pipe was present without a discharge of squid extract, it was always disregarded. However, if a piece of squid flesh was put on the tank bottom in place of the introduction pipe, to which it was visually similar, the fish appeared to see it whilst still upstream, and moved towards the centre of the trough to take the squid without going downstream of it. Figures 1 a and b, show the tracks (drawn by eye) of fish moving to take a piece of squid off the tank bottom. This indicates that in the course of the experiment the cod did not learn to visually associate the pipe with food.

The squid extract was introduced just behind and upstream of a fish, when it had swum undisturbed with the current four or five times round the tank. The flow of attracant was continuous for one minute. On passing the pipe during its next circuit the fish entered the chemical "corridor" between 50 and 200 cm below the introduction point, turned to face into the current, and then swam back towards the pipe, searching from side to side and occasionally darting forwards. If the pipe was passed the fish turned again and swam or drifted with the current until it re-entered the attractive area. The mouth of the pipe was usually located within 40 s of the fish first detecting the attractant, and was nudged and mouthed. Figures 1 c and d, show the tracks of two fish making this response.

A typical response of the cod to squid extract in moving water was filmed. This was examined frame by frame using a Specto Motion Picture Analyser and the fish's track plotted. This is shown in Figure 2, where the position of the cod's snout at intervals of 1 s after it passed the mouth of the introduction pipe are marked. After it had swum at 30 cm/s through the water to approximately 160 cm downstream of the pipe's mouth, the cod turned through 180° and swam slowly upstream (4–11 s), turning its head from side to side through an angle of about 20°. It then accelerated and swam near the outside wall of the trough at approximately 85 cm/s through the water for 1·5 s. When level with the mouth of the pipe the cod turned through 90° to face the outer wall of the through and drifted with the current for approximately 50 cm. The fish then turned to face upstream again (17 s) and after drifting for a further 40 cm it swam slowly upstream to area A ..... A. Here it lingered near the outside wall for 5 s, crossed to the inside wall (31 s), turned through 90° and returned to the outer wall above A ..... A. Still heading upstream the fish then swam towards the centre of the trough 25 cm above the point where it last crossed, and then to the introduction pipe's mouth. The cod stayed in the vicinity for at least 20 s, always heading upstream (±15°) and moving around the attractant source.

Discussion

The role of chemical attractants in food location by fish has usually been explained as a gradient effect, the recipient orientating by chemotaxis or chemokinesis to the stimulus source (Parker, 1914; Kleerekoper, 1967; and others). However, there is increasing evidence that the chemical stimulus may have an activating, and not necessarily a directional, effect, especially at a distance from its source. The above observations support the hypothesis that cod swimming with the current will turn and swim upstream on detecting an attractive chemical stimulus. This behaviour appeared to be a positive rheotaxis elicited by a chemical stimulus, and the subsequent rapid swimming against the current was probably an orthokinetic component superimposed on the rheotaxis. When the filmed fish swam upstream of A ..... A it presumably left the attractant "corridor", and it was observed to stop swimming and to drift with the current until it again encountered the chemical stimulus. In the region A ..... A the chemical gradients were probably sufficiently steep to allow a chemotaxis, and the cod soon localised the source of the attractant.

Similar observations of chemical stimuli which act as a sign stimulus releasing a rheotactic response in fish have been described for eels (Creutzberg, 1961), sharks (Hodgson and Mathewson, 1971) and salmonids (discussed in Harden Jones, 1968, pp 259–270). There is some evidence (Pawson; Harden Jones, unpublished data) that wild gadoids move with the current over the sea bed, and this mechanism offers search and energy advantages, particularly in strongly tidal areas and where visual food location is restricted.

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