

CHEMICAL RECOGNITION OF THE MOTHER BY THE YOUNG OF THE CICHLID FISH, *Cichlasoma citrinellum*

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Abstract—When placed in a Y-maze, the 1–10-day-old free-swimming fry of the Midas cichlid can chemically distinguish between their mother and plain water and between another mother and plain water. They do not distinguish between the two mothers offered together or between their father and plain water. Predation pressures make these responses adaptive.

Key Words—communication, fish, cichlid, *Cichlasoma citrinellum*, pheromone, maternal, development, predation, chemoreception, fry.

INTRODUCTION

Cichlid fish demonstrate efficient, persistent, parental care toward their brood, which may consist of 5 to 10,000 fry, depending on the species (Brichard, 1975; Fryer and Iles, 1972). Vision is one of the primary senses by which parents (Noble and Curtis, 1939; Myrberg, 1975) and fry (Kuenzer, 1968; Hay, 1976; Russock and Schein, 1974) recognize each other, but it is not the only one. Using chemical cues, parents can recognize their fry (Kühme, 1963; Myrberg, 1975; McKaye and Barlow, 1976) and each other (Caprona, 1974), and fry can recognize other fry (Kühme, 1963). However, efforts to show that fry can chemically recognize their parents have, until now, been unsuccessful (Cole and Ward, 1970). This paper presents the first evidence that cichlid fry can use chemical cues alone to respond to one of their parents.

METHODS AND MATERIALS

Normally colored Midas cichlids (*Cichlasoma citrinellum*) were obtained from stocks bred from adults collected in Lake Masaya, Nicaragua. Seven males were paired with slightly smaller females (standard length: males 146–171 mm, females 134–165 mm, all 3–5 years old) and bred in 240 liter aquaria (27–28°C, 12-h photoperiod). The eggs of each pair produced about 1500 nonswimming wrigglers (prolarvae) which, in about 3 days, became free-swimming fry (postlarvae).

The 5-mm-long fry were tested during the daylight portion of their light cycle in an opaque Plexiglas Y-maze (9 cm high, 6 cm wide, and 13 cm from start gate to choice point). Filtered, aerated water flowed from a reservoir through silicon tubing into two 15-gal (56.8 liter) stimulus tanks; each tank then fed one arm of the maze. Tests with dye showed that the water from both arms traveled down the alley in laminar flow, without mixing. The water emptied into a drain. The rate of flow (22.5 ml/sec) and the temperature (27–28°C) of the water entering each arm of the maze were about equal.

Before each test, both parents were removed from their home aquarium; one was placed in a stimulus tank, the other held in a separate aquarium. This procedure ensured that, on any day of testing, all fry had been exposed to both sexes for equal times. Five minutes after an adult was put in the stimulus tank, two fry were transferred by net to a start box. (If only one fry were used, it would remain motionless, but two fry swim up the maze readily). They remained there for 15 sec, then a gate was opened by raising a screen. After the first fry made a choice by entering an arm of the maze, or if no choice was made within 3 min, they were retrieved with a small net and discarded; thus, no fry was tested more than once.

Two more fry were put in the start gate and the process was repeated following Cole's (1962) modification of a sequential sampling design. This design determines the preference of the brood as a group by sequentially sampling the individual preferences of the fry. Fry were tested until the brood showed either a significant ($P < 0.05$) preference for one side or no preference at all.

Broods that showed a significant preference for one side were retested by reversing the hoses leading into the maze and repeating the test for brood preference using additional untested fry. Only if a significant preference were now shown for the other side, ruling out a bias to swim consistently to one side, would the brood preference be considered valid.

The number of individual fry to swim toward each stimulus was also recorded, whether they came from a brood that showed a preference or from one that did not. Broods were tested on 8 of the first 10 days in which they were free-swimming.

RESULTS

The fry in a brood can distinguish between water from their own mother and plain water and between water from another mother and plain water.

TABLE 1. RESPONSES OF FRY TO WATER FROM PARENTAL ADULTS AND TO PLAIN WATER^a

| Stimulus | No. of times brood showed | | Number of fry | χ^2 value | <i>P</i> |
|-----------------|---------------------------|---------------|---------------|----------------|----------|
| | A preference | No preference | | | |
| All days (1-10) | | | | | |
| Mother | 6 | | 113 | | |
| Plain water | 0 | 2 | 25 | 56.12 | 0.001 |
| Mother | 1 | | 42 | | |
| Other mother | 1 | 3 | 54 | 1.50 | ns |
| Other mother | 3 | | 74 | | |
| Plain water | 0 | 2 | 19 | 32.52 | 0.001 |
| Father | 0 | | 83 | | |
| Plain water | 0 | 8 | 67 | 1.71 | ns |
| Day 1 | | | | | |
| Mother | 4 | | 60 | | |
| Plain water | 0 | 0 | 2 | 54.26 | 0.001 |
| Father | 0 | | 47 | | |
| Plain water | 0 | 4 | 38 | 0.95 | ns |
| Day 10 | | | | | |
| Mother | 2 | | 53 | | |
| Plain water | 0 | 2 | 23 | 11.84 | 0.001 |
| Father | 0 | | 36 | | |
| Plain water | 0 | 4 | 29 | 0.75 | ns |

^a Brood preference ($P < .05$) was determined by sequentially sampling the preferences of individual fry in the brood. This yielded three data for each brood: the number of fry to choose one stimulus, the number of fry to choose the other stimulus, and the overall brood preference. Even broods showing no preference contained fry that chose one stimulus or the other. The number of fry making each choice was summed across all broods tested, both those that showed a preference and those that did not. The χ^2 value was calculated for number of fry only.

They do not distinguish between the two mothers offered together, or between their father and plain water (Table 1). Both mothers had fry of about the same age.

On the first day of free-swimming, 97% of the tested fry preferred their own mother over plain water. This percentage dropped significantly ($\chi^2 = 16.83$, $P < 0.001$) to 70% on the tenth day. The number of broods preferring the mother also dropped.

During every run, both the water temperature and the rate of flow were recorded in each arm. No correlation could be found between slight fluctuations in these values in one arm of the maze and a preference for or avoidance of that side.

DISCUSSION

The impact of predators on the brood in nature suggests a function for the fry's differential abilities to chemically recognize their parents. Mated pairs of Midas cichlids defend territories up to about 1 m in diameter in front of rocky outcrops along the shores of freshwater lakes. Territories often abut one another, and each usually contains a crevice or cave into which the parents put the brood at night. During the day, parents chase away potential predators such as *Cichlasoma managuense*, *C. dovii*, *C. nigrofasciatum*, *Neotroplus nematopus*, *Gobiomorus dormitor*, and juvenile Midas cichlids. Without such parental defense, the brood would be consumed in minutes (Barlow, 1976; McKaye and Hallacher, 1973).

Although separation from the parents is fatal, a fry may become lost or may be displaced by the disturbance from an intense, territorial, agonistic encounter between its parents and another mated pair. In clear water both cichlid parents and their fry can find each other by using visual cues, but if the water is murky, as it often is in the Midas cichlid's natural habitat (Barlow, 1976), then parent and fry may orient by chemical cues. Since a brood contains up to 5000 fry, the parents presumably cannot retrieve every errant offspring, thus placing greater pressure on the fry's ability to find its parents. Chemical orientation could also occur at night, since predatory, nocturnal catfish (*Rhamdia nicaraguense*) sometimes scatter the brood from the cranny in which the parents have bedded it down (McKaye, unpublished, Yale University).

Because the parents have different roles in defending the brood, the fry respond to them differently. The male parent spends more of his time defending the territory—swimming out to threaten encroachers—than does the female, who, conversely, spends more time with the brood (McKaye, unpublished, Yale University). If a fry is displaced from its parents, an

approach to the male has a greater probability of placing it away from the brood and at the periphery of the territory, where predation is most intense. Thus, the fry's failure to swim toward the father in the maze may reflect an adaptive strategy rather than a lack of motivation.

This negative response to the father does not apply to all behavioral interactions. Noakes and Barlow (1973) have observed in the laboratory that, by day 25, fry contact and ingest dermal mucus from the father in preference to the mother; before day 25, contacts are equally distributed. The sensory basis for this choice has not been experimentally determined.

The fry's inability to distinguish between its own and another mother may also be adaptive. Because breeding sites are separated from one another by about a meter, the closest female to a separated fry is likely to be its mother. Thus, merely approaching the nearest female will usually return the fry to its brood. However, if a fry is displaced relatively far from its home territory, it can gain protection by approaching another female's brood. Parents have been shown to accept foreign fry into their brood if the foreign fry are the same age or younger than their own (Noakes and Barlow, 1973). and McKaye and McKaye (1977) have mathematically demonstrated that it is advantageous for them to do so. I am suggesting, therefore, that fry can survive by detecting "femaleness." I am conducting tests to determine whether the fry can discriminate maternal females from nonmaternal ones.

Myrberg (1966) suggested that cichlid parents recognize wriggling (nonswimming) young primarily by chemoreception and then shift mainly to vision as the fry become free-swimming. It is possible that the dominant modality for recognition of the parent by the fry also changes from chemoreception to vision with increasing age. I am currently testing this hypothesis because the increase in the proportion of fry failing to recognize their mother on day 10 indicates a decline in sensitivity to maternal chemical cues.

Little (1975), working with crayfish larvae, has obtained parallel results. His studies, and those on Cichlidae, suggest that a chemically polluted environment can interfere with the success of parental care.

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