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Presence of Food as an Entraining Factor of Rhythmic Activity in *Chaenogobius laevis* in Captivity

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It is well known that light condition has an important influence on the activity of freshwater fish species (Reynolds and Casterlin, 1976; Eriksson, 1978; Katz, 1978; Mashiko, 1979), and light-dark cycle has often been used as an entraining factor of rhythmic activity of fishes in laboratory experiments (Eriksson and van Veen, 1980; Kavaliers, 1980; Mashiko, 1981).

On the other hand, although predators are known to synchronize their activity with the main activity of their prey (Curio, 1976), laboratory experiments in which prey itself was used as an entraining factor are not so many (Davis and Bardach, 1965; Nishikawa and Ishibashi, 1975). In the present study, the capability of entrainment to an artificial 24 hour feeding rhythm was studied experimentally in a freshwater gobiid fish *Chaenogobius laevis* (Steindachner) in captivity.

Methods and material

The experiment was made by using an apparatus shown diagrammatically in Fig. 1. The glass tank ("A" in Fig. 1, 44×27 cm, 25 cm height) was the experimental aquarium and its bottom was covered with sand. The water level was maintained at 22 cm depth. Three infrared beams (940 nm wave length) passed through the tank. Photocells were connected to recorders through amplifiers. When a fish intercepted a beam, a spike was recorded on the paper. Thus, the activity of fish was recorded as the number of spikes on the recording paper. At first, it was thought that the rhythmic pattern of swimming activity in the water column might be different from that of locomotive activity on the bottom. Therefore one beam was set at the bottom level and the others at a height of 16 cm above the bottom. However, as the daily patterns of occurrence of spikes were in fact similar between the upper beams and the lower beam, the numbers of spikes appeared in the three beams were summed and treated as data.

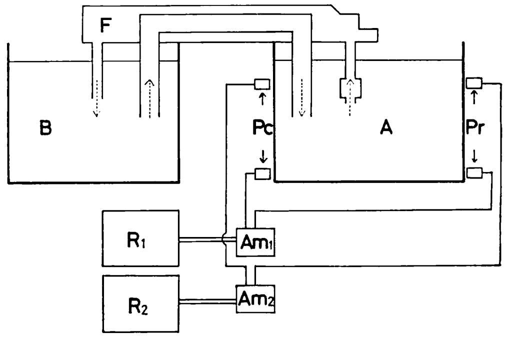

Fig. 1. An outline of the apparatus used for the experiment. The symbols are as follows. A, experimental glass tank; B, tank for water circulation; F, glassfiber filter; Pr, infrared light beam projector; Pc, photocell; Am_1, Am_2, amplifiers; R_1, R_2, recorders. Arrows of broken lines show the direction of water circulation.

Four fish (0+ aged, about 35 mm body length) were caught in a reservoir in Hirosaki City, Aomori Prefecture, on October 22, 1980. They were introduced into the experimental aquarium on that day, after a few hours for acclimation to the room temperature. They were maintained unfed for 5 days, and then were fed 60 chironomid larvae at 18:00 every day for 26 days, from October 27 to November 21. Again the feeding was ceased and they were maintained unfed for 10 days until December 1. The recording of their activity was made throughout the experimental period, changing recording papers every 6 days. The fish were well healthy at the end of this period of food deprivation.

The above experiment was conducted under constant conditions, i.e., water temperature at 19.4°C and complete darkness. A dim red light was used only at the times of feeding and changing the recording papers.

Results

Some examples of the daily change of the number of spikes per an hour are shown in Fig. 2. For the first 5 days of food deprivation, no significant rhythmicity was observed in the activity of the fish. Even after they were given daily food, rhythmicity was not observed for about 5 days. However, after about 6th day

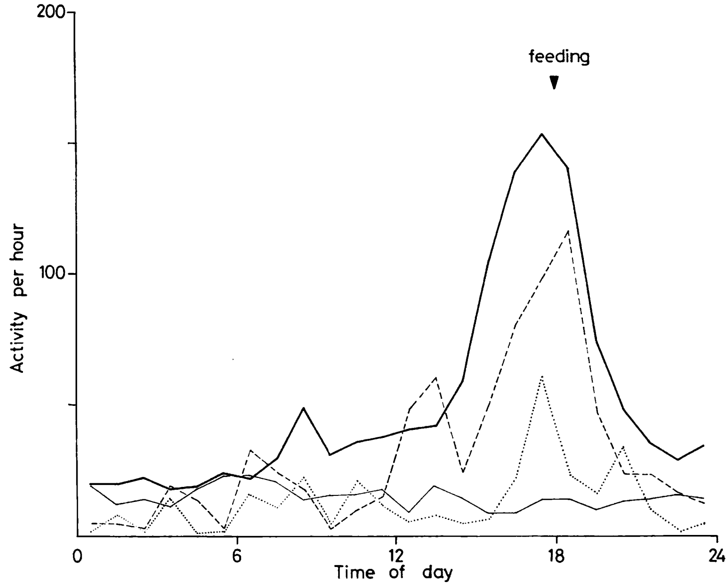

Fig. 2. Daily pattern of activity of *Chaenogobius laevis* in the experiment. Activity is indicated by the number of interruptions of three beams per an hour. Solid line (light tracing), average of 5 days before feeding; solid line (heavy tracing), average of 26 days of feeding period; broken line, the 5th day after cessation of feeding; dotted line, the 10th day after cessation of feeding.

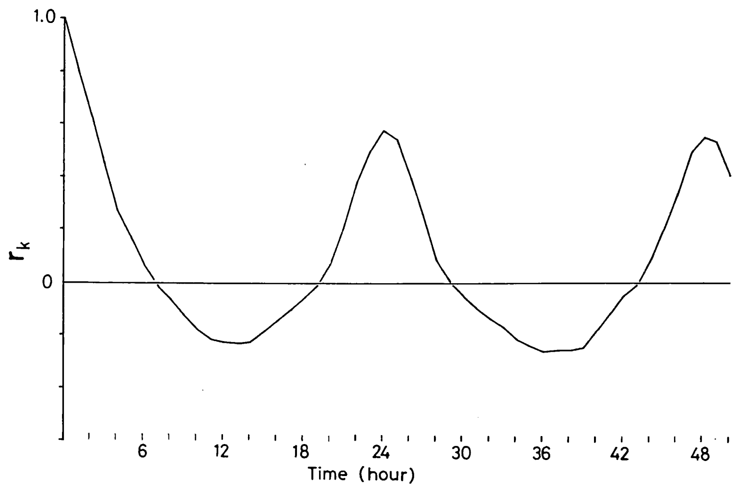

Fig. 3. The correlogram prepared from the data obtained in the 10 days of food deprivation. r_k: serial correlation coefficient.

from the onset of feeding, the activity began to increase about 3 hours before the scheduled time of feeding (18: 00) and decrease soon after the introduction of chironomid larvae into the aquarium. This daily rhythm persisted to the end of feeding period. When the feeding was stopped and no more food was given for 10 days, the rhythm still continued in this period, though the activity level decreased day by day. In Fig. 2, the daily changes of activity in the 5th and the 10th days of the food deprivation period are illustrated. By a correlogram analysis (Itô and Murai, 1977), the daily change of activity during these 10 days showed a statistically significant rhythm ($P<0.01$) of about 24 hours (Fig. 3).

Discussion

It was clarified by the present experiment that *C. laevis* had an ability to take live food in a complete darkness, though it takes food apparently by sight in the light. It is known that some fishes considered to be day-active such as the guppy *Poecilia reticulata* can also take live organisms in darkness (Yamagishi, 1966). In the present case, *C. laevis* seems to behave as a visual predator in the light and as a nonvisual one in the darkness. Though it is unknown how the fish detected their food in darkness, it is probable that a tactile or chemical sense is used.

Moreover, *C. laevis* was able to learn the time of feeding. It is reasonable to consider that the increase of activity preceding the scheduled time of feeding is not a result of hunger but is related to expectation for food, because the activity rhythm of about 24 hours persisted throughout the period when no food was given. The ability of synchronizing the animal's own activity rhythm to cyclic feeding has been known experimentally in other fishes. Davis and Bardach (1965) observed pre-feeding activity in the kilifish (*Fundulus heteoclitus*) in their daily cyclic feeding experiments under constant light conditions. Nishikawa and Ishibashi (1975) reported that it was possible to entrain a 12 or 24 hour rhythm in a tidal fish, the mud-skipper *Periophthalmus cantonensis,* by cyclic feeding in constant environments. The present case is another example.

During some preliminary studies on the feeding ecology of the present species in the field, it was noted that feeding occurred during both the daytime and at night, individuals taking more food in the nighttime. The main food item was chironomid larvae such as were used in this experiment. However, it is necessary to study in more detail the relationship between the diurnal prey and fish activities in their natural habitat.

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ジュズカケハゼの周期活動の同調要因としての餌の存在

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ジュズカケハゼ *Chaenogobius laevis* の活動を，恒暗条件下で赤外線ビームを用いて記録し，ユスリカ科幼虫を 24 時間おきに与えてその影響を調べた．給餌開始後 6 日目ほどから，給餌予定時刻の約 3 時間前から活動性が高くなり，給餌の 24 時間周期に自分の活動を同調させた．この活動周期は給餌終了後も少くとも 10 日間にわたって継続した．

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