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Visual Cues in the Sheltering Behavior of the Cichlid Fish *Pelmatochromis pulcher*

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ABSTRACT The sheltering behavior of the tropical freshwater cichlid, *Pelmatochromis pulcher*, was analyzed using open rectangular glass boxes having opaque (black or white) and/or transparent walls. The tendency for the fish to stay in shelters was greater as the number of black opaque walls increased. Among shelters having an equal number of opaque walls, the sheltering ratio was higher when the ceiling was opaque (Exp. I). In another experiment (Exp. II), shelters having one opaque (black or white) wall were illuminated vertically from above, or horizontally. Results showed that there are at least three visual cues involved in this behavior: (i) sheltering behavior was greater when the opaque wall was black rather than white (*'blackness'*), (ii) in the case of horizontal illumination through the shelter opening, the tendency to stay inside the shelter was greater when the side wall was opaque rather than transparent (*'visual isolation'*), and (iii) sheltering behavior occurred more frequently when the shelter provided shade as opposed to when it did not (*'shading'*). (*Zool. Mag. 89: 118-124, 1980*)

Some fishes such as eels (Teichmann, 1959) and blennies (Phillips, 1974; 1977) enter tubular objects and stay there. Their behavior does not seem to be due to fear, because they behave so even when they are not in immediate danger. In these fishes, shelters may play a role as the center of their territory or as a defense against predators. In spite of the possible importance for survival, their sheltering behavior has not received much attention. Heiligenberg (1964) published an extensive description and some experimental analyses of the instinctive behavior of a typical sheltering cichlid *Pelmatochromis subocellatus kribensis*, however, he did not refer to its sheltering behavior.

Teichmann (1959) made use of the sheltering behavior in the eel to examine its learning ability, and Yamagishi *et al.* (1974) studied the social relations in a population of eleotrid gobies using a shelter as a refuge. Recently Phillips (1974, 1977) researched the relationship between social behavior and the use of space in the blenny, a sheltering species. Although there has been much concentration on the actual sheltering behavior in these fishes, few studies have been performed on the sensory mechanisms underlying this behavior, except for some studies on the eel (Watanabe *et al.*, 1969) and a tropical cichlid (Watanabe & Terami, 1973, 1974; Terami & Watanabe, 1974, 1978).

According to our observations, the tropical freshwater cichlid *Pelmatochromis pulcher*, prefers a particular type of shelter when many types of shelter are available. What characteristics of the shelter determine the preference towards that shelter? This problem led us to a series of experiments designed to analyze the sensory mechanisms involved in fish behavior.

Material and Methods

Animals used in the present study were the tropical freshwater cichlids *Pelmatochromis* (subgenus *Pelvicachromis*) *pulcher* B[1] (Register number to British Museum: BM NH. 1976. 3. 31. 1-6). In a tank, the cichlids often settle on the bottom or stay suspended in the water near the bottom with slight rhythmical motions of their pectoral and dorsal fins.

The experimental fish were reared in groups of four to five in tanks 90×30×45 cm deep under constant aeration and a controlled temperature between 23.0° and 26.0°C. The bottoms of the tanks were covered with white gravel in which some aquatic plants were rooted. The fish were fed pellets daily. All the fish were individually identified by the number, size and position of black spots on their dorsal and caudal fins.

A variety of open rectangular boxes made of various combinations of opaque (black- or white-enameled) and/or transparent 4×8 cm glass plates were employed as shelters (Fig. 1). The twelve types of shelters used in Exp. I consisted of black and/or transparent walls. In Exp. II, shelters having one opaque (black or white) and three transparent walls were placed in the tank so that the opaque wall was located in the position of ceiling, side wall or floor of the shelter. When a shelter with a black ceiling was used, the situation was labeled B_c. The other situations were labeled B_s, B_f, W_c, W_s and W_f in regard to color (black/white) and position (ceiling/side/floor) of the opaque wall.

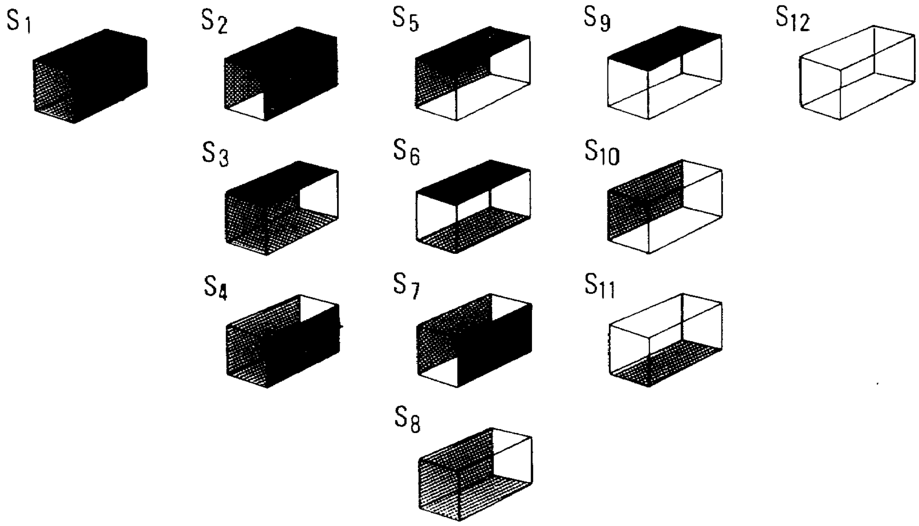

Fig. 1. Twelve shelters having black-enameled and/or transparent walls used in Exp. I. S_1, S_2-S_4, S_5-S_8 and S_9-S_{11} and S_{12} are the shelters having 4, 3, 2, 1 and no opaque (black) walls, respectively.

A fish was put into an experimental tank 16×30×20 cm deep and a shelter was gently placed in the center of the tank bottom. In most cases the fish entered the shelter at once and stayed in it. The fish periodically left the shelter, patrolled around it and re-entered it. The frequency of leaving the shelter was fairly constant over a long time. Even if the fish

[1] According to personal communication with Dr. P. H. Greenwood of the British Museum (Natural History), some species names in the genus *Pelmatochromis* have recently been altered. The fish that had been described as *P. kribensis* in our previous reports (Terami and Watanabe, 1974; Watanabe and Terami, 1973, 1974) was identified by him as *Pelmatochromis* (subgenus *Pelvicachromis*) *pulcher* B.

did not immediately enter after introduction of the shelter, it entered at once when it was gently nudged with a small glass rod. When the fish entered shelters that seemed to have no value as a refuge, *e.g.* a transparent shelter, it left soon and rarely re-entered the shelter.

From one minute after putting the shelter into the tank, the presence of the fish inside or outside the shelter was recorded ten times at 1-minute interval and the value obtained was divided by 10. This figure was referred to as the *sheltering ratio* and the ratios were averaged for each shelter.

Experiment I

The tendency for this cichlid to stay in shelters is very strong, and even when a shelter containing a fish is moved towards the surface of the water, the fish remains inside the moving shelter and does not leave until the shelter leaves the water. In Exp. I, the effects of the number and position of black opaque walls in a shelter on the sheltering behavior were investigated.

Method

Twenty-four male cichlids 6.7 to 7.7 cm in total length were tested for each of twelve types of shelters S_1-S_{12}. Tanks were illuminated from above, with the intensity being 1960 lux at the bottom of the tank.

The relationship between the sheltering ratio and the type of shelter was analyzed using the Friedman two-way analysis of variance (Siegel, 1956, p. 166-172), and the difference between the sheltering ratios were analyzed by means of the Wilcoxon matched-pairs signed-ranks test (two-tailed) (Siegel, 1956, p. 75-83) using data obtained from individual fish.

Results and discussion

The results of Exp. I are shown in Fig. 2. Friedman's test showed that the sheltering behavior was strongly correlated with the type of shelter ($S=134.288$, $p<0.001$), while it was not correlated with the individual used ($S=$

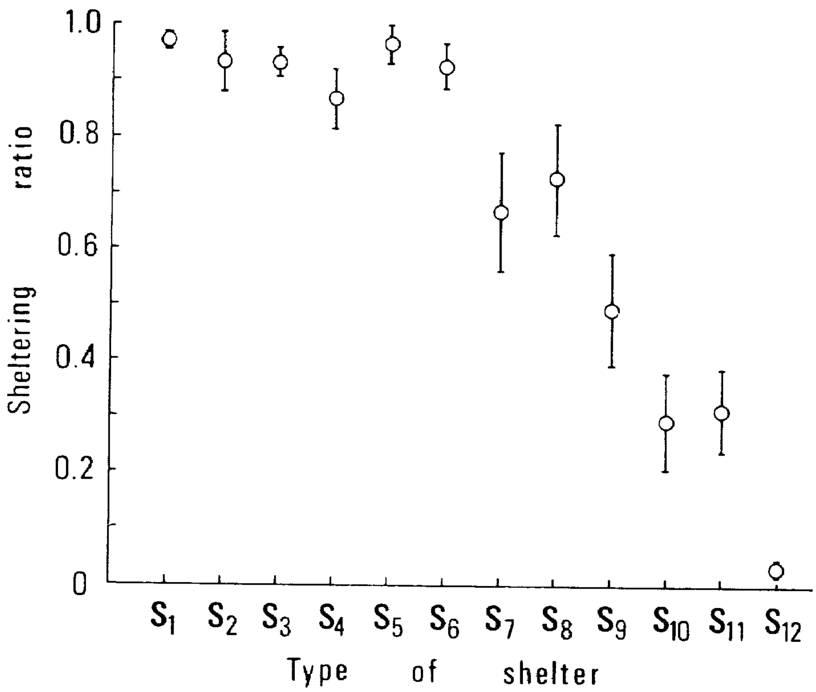

Fig. 2. Sheltering ratios (mean±S.E.) of 24 fish in shelters S_1-S_{12} under illumination from above in Exp. I. S_1, S_2-S_4, S_5-S_8, S_9-S_{11} and S_{12} are 4-, 3-, 2-, 1- and no-opaque-walled shelters, respectively.

Table 1. The Wilcoxon's statistic ((n), T) calculated between the sheltering ratios of the fish in Exp. I in the Wilcoxon matched-pairs signed-ranks test. (a) : between 3-opaque-walled shelters. (b) : between 2-opaque-walled ones. (c) : between 1-opaque-walled ones. (n) : the number of matched pairs minus the number of pairs whose $d=0$. T: the smaller sum of the same-signed ranks. Symbols * and ** represent the significances at 0.05 and 0.01 levels (two-tailed), respectively.

(a)

	S_2	S_3
S_3	(8) 15	
S_4	(11) 20	(10) 18

(b)

	S_5	S_6	S_7
S_6	(9) 9		
S_7	(12) 5**	(12) 6.5**	
S_8	(13) 11*	(13) 14.5*	(14) 37.5

(c)

	S_9	S_{10}
S_{10}	(18) 35.5*	
S_{11}	(19) 14**	(20) 89.5

27.157, $p>0.10$).

The sheltering ratios in all shelters except the transparent one were much larger than the probability calculated on the basis of the ratio of the area of the shelter bottom to that of the tank bottom (32/480=0.067).

The sheltering ratio became greater in general, as the number of black opaque walls increased. Among shelters having an equal number of opaque walls, the ratio markedly increased when the ceiling was opaque: S_2, S_3 in 3-opaque-walled shelters, S_5, S_6 in 2-opaque-walled ones, and S_9 in 1-opaque-walled ones (Table 1).

It should be noted that the sheltering ratio in the transparent shelter (0.021) was less than the ratio of the area of shelter bottom to the area of tank bottom (0.067). This suggests that the transparent shelter plays no role as a refuge.

Experiment II

Experiment I showed that under illumination from above the sheltering ratio was greater when the ceiling of the shelter was opaque (black). This condition contains at least three physical factors that may possibly induce sheltering behavior: (i) the ceiling was black (*'blackness'* factor), (ii) the ceiling visually isolated the inside of the shelter from above (*'visual isolation'* factor), and (iii) the ceiling shaded the shelter from light coming from above (*'shading'* factor). Experiment II was intended to test whether or not these three possible factors in fact serve as visual cues for sheltering behavior.

Method

Shelters having three transparent walls and one black- or white-enameled wall were used. The shelters were illuminated from above or horizontally with a 20 W fluorescent bulb (60 cm in length). The distance from the bulb to the shelter was 30 cm under all conditions and the intensity of illumination at the center of the shelter bottom was 100 lux. A preliminary observation confirmed that the behavior of the fish under 100 lux illumination was similar to that under 1960 lux illumination used in Exp. I. It has also previously described that the critical illumination under which sheltering behavior occurs was between 0.8 and 0.2 lux and that the behavior under the former level of illumination was similar to that under daylight (Terami & Watanabe, 1974).

In Exp. II A, shelters were illuminated through the shelter opening when lit horizontally, thus, no shade was provided. In Exp. II B, the light source was placed so as to face an opaque side wall (either black or white), shading the fish from the light.

Thirty-six fish (24 males and 12 females) ranging from 4.5 to 7.7 cm were tested for each condition. Since there were no apparent differences due to sex as far as sheltering was concerned, the data obtained from both sexes were pooled. The data were analyzed using the Wilcoxon matched-pairs signed-ranks test (two-tailed).

Results and discussion

A. Figure 3 shows the results of Exp. II A. More fish stayed in black-floored shelters than in white-floored ones under both vertical (B_f : W_f, $n=32$, $T=16$, $p<0.01$) and horizontal (B_f : W_f, $n=18$, $T=28$, $p<0.01$) illumination. From these facts it is evident that *blackness* is a factor involved in sheltering behavior.

Under horizontal illumination there were significant differences in the sheltering ratios between W_c : W_f ($n=22$, $T=33$, $p<0.01$) in spite of the fact that here both possible factors, *blackness* and *shading*, were absent. This result shows that *visual isolation* from upper sight is also a factor involved in this behavior.

Under illumination from above, the sheltering ratio in W_s was significantly larger than that in W_f ($n=25$, $T=24.5$, $p<0.01$). This difference may be due to *visual isolation* from lateral sight, since the other possible factors *blackness* and *shading* were lacking.

During the experiment, it was frequently observed that under horizontal illumination the fish were apt to leave the shelter and swim about. The tendency seen in Fig. 3 for sheltering ratios to be somewhat smaller under horizontal illumination than under that from above may be due to some unknown inhibiting effect of horizontal illumination on sheltering behavior.

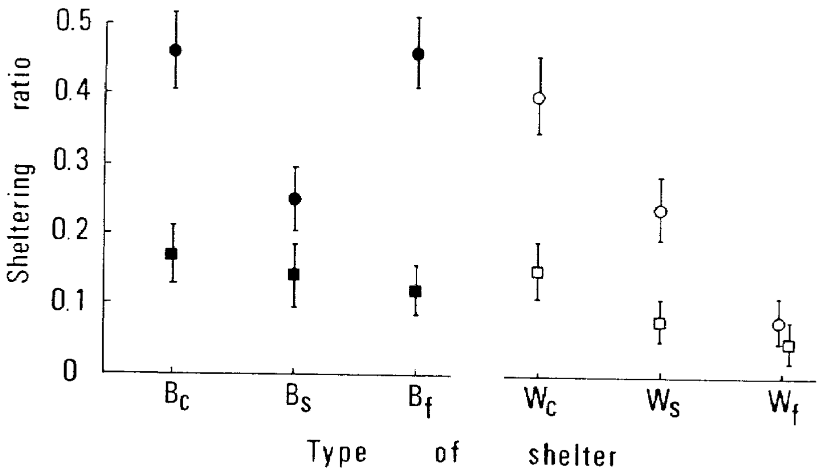

Fig. 3. The relationship of the sheltering ratios (mean±S. E.) of the fish to the position of an opaque (black or white) shelter wall in Exp. II A. ●: black wall, illuminated from above. ■: black wall, illuminated horizontally. ○: white wall, illuminated from above. □: white wall, illuminated horizontally. The conditions of shelters are labeled B_c, B_s, B_f, W_c, W_s and W_f in regard to color (black/white) and position (ceiling/side/floor) of the opaque wall.

It is noteworthy that vertically illuminated shelters having opaque (either black or white) ceiling had markedly high sheltering ratios which were influenced by both *visual isolation* and *shading* factors.

B. The shelters B_s and W_s were used to ascertain the effect of a possible *shading* factor. When the effects of the type of illumination (from above or horizontal) on sheltering behavior were compared, no significant differences were found in either B_s ($n=21$, $T=96.5$, $p>0.10$) or W_s ($n=18$, $T=62$, $p>0.10$). This is in contrast with Exp. II A in which different types of illumination had marked effects on sheltering ratios in both B_s ($n=25$, $T=16.5$, $p<0.01$) and W_s ($n=21$, $T=6$, $p<0.01$). The difference between both experiments is that in Exp. II A, shelters provided no shade from horizontal illumination, while in Exp. II B, the inside of the shelter was shaded. This points out the importance of the *shading* factor in this behavior.

General Discussion

The results of Exp. I showed that the occurrence of sheltering behavior became greater as the number of opaque shelter walls increased, and the ratio was largest when the opaque wall was located in the ceiling position. A transparent shelter did not serve as a refuge for the fish.

Experiment II confirmed that all three factors, *blackness*, *visual isolation* and *shading*, are important in the elicitation of this behavior.

A sheltering ratio greater than 0.6 in shelters having two or more black walls (Exp. I) may be ascribed to the cumulative effects of all or some of the three factors we proposed.

The tendency of cichlids to approach black objects or settle on them has been noticed by some workers. Baerends and Baerends-van Roon (1950) stated that young *Tilapia* approached black spots on a flat silver disc. Watanabe and Terami (1974) reported that *Pelmatochromis* settled tenaciously on a black plate of the same size as a wall of the shelters used in the present work. Recently Terami and Watanabe (1978) found that these cichlids centered themselves within a black-taped zone as small as 4 mm long, coiled on a transparent tube. According to our unpublished observation, when a black plate was slowly moved, the fish swam along with the plate, maintaining its position above it. In addition, when fish were introduced into a tank that had a black part on a side-wall, they approached the part at once and swam only within the boundaries of the part.

In Exp. II A of the present work, there was a high tendency for fish to stay in shelter B_f under illumination from above. This condition lacked both the *shading* and the *visual isolation* factors, and the *blackness* factor which was common to B_f under horizontal illumination. Further research is necessary to explain this problem.

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