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Transfer and isolation effects on the feeding behaviour of the angelfish, *Pterophyllum scalare*

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Abstract. The feeding behaviour of juvenile angelfish (*Pterophyllum scalare*) has been used as an indicator of their recovery following handling and transfer to a new environment, both with and without conspecifics. Isolated specimens fed less readily than group-housed fish, or those transferred to the test aquaria in groups of three or five, and continued to do so for at least ten days following isolation. Feeding rank-order frequently changed following isolation, suggesting that better foragers may not take the greatest risks in isolation.
Key words. Handling; new environment; post-isolation; fish.

Laboratory studies on animal behaviour frequently involve the exposure of individuals to a test situation which requires the transfer of single animals to a novel environment. This process may itself affect the behaviour patterns shown[1,2], making interpretation of the results more difficult. The recognition of this fact has led workers to allow a period of acclimation to the test conditions before further experimentation. The duration of such periods varies considerably, ranging from a few minutes to many hours even for a single species[3-5], and the rationale on which the choice is made is usually unclear, with little attention being paid to the social life style of the species involved[6-8]. Moreover it is difficult to establish whether the results are due to the effects of transfer or to the solitary state itself. In fish, one way of examining the persistence of the transfer effect is by studying changes in the feeding response which may provide a good index of the adaptation of the individuals to a new situation[9,10].

In social fish species, the importance of companions has been demonstrated in social facilitation of feeding[11-13] and foraging behaviour[14-16], which increases as shoal size increases, at least within certain limits. In common with a number of other animal species[17], individual fish of social species typically show a low feeding rate[7,12].

In the present work we investigate the feeding response of juvenile angelfish, *Pterophyllum scalare*, when transferred individually to a new environment. The influence of transfer, and that of isolation, were studied by observing feeding behaviour immediately after transfer and for several days afterwards. Fish transferred in groups of 3 and 5 were used as controls, and the effect of the isolation period on subsequent feeding was evaluated in a post-isolation test.

Materials and methods

Juvenile angelfish (3–3.5 cm S.L.), were obtained from a local supplier and kept in groups of 14 (three groups) or 15 (two groups) in 70-litre home aquaria at 25 ± 1 °C under a L:D 14:10 h lighting regimen. Fish were individually identified from drawings indicating peculiarities in the fins and body patterns. They were then observed in the home tanks and also after transfer to identical experimental aquaria, either singly or in groups of 3 or 5 fish. In the home tanks, the feeding behaviour of one group of 14 fish and of one group of 15 fish was quantified for 5 days. The feeding behaviour of the other groups was essentially similar and was therefore not quantified. All individuals of the three 14-fish groups were isolated in the experimental tanks (N = 42). Isolates from two of the groups were kept thus for 4 days, while fish of the third group were maintained for 10 days in isolation. Fish from the two 15-fish groups were transferred to the experimental aquaria in sub-groups of 3 and 5 respectively and observed for 4 days in this situation. To investigate post-isolation transfer effects, fish isolated for 4 and 10 days were transferred to a novel, identical aquarium on the morning of the fifth and eleventh days in isolation (90–150 min after the morning feeding session). Fish were kept individually in the novel tank for one day, feeding being observed for a 10-min period in the afternoon of the day (i.e., approximately 6 h after transfer) and in the morning of the next day. An additional group of 14 fish not previously isolated was used as control.

The fish were fed twice daily, at 09.00–10.00 h and 17.00–18.00 h. The first feeding session in the experimental tanks took place 10 min after transfer in the morning. Each feeding session lasted 10 min, during which two aliquots of Tetramin flakes (approximately 15 mg per fish) were placed centrally on the water surface at intervals of 5 min, using a long-handled spoon. This allowed the observer to be hidden from the fish behind a screen. Feeding behaviour was monitored by direct observation and with the aid of a video-recorder, during the morning and afternoon sessions, and measured as the number of bites per fish in each minute at the water surface, during the 5-min period after each presentation of food. Biting was considered to have occurred each time the fish touched the water surface with its jaw and picked up food, and was recorded for each fish separately. To reduce heterogeneity of variance, analyses were carried out on the log transforms.

Results and discussion

Figure 1 shows the results for surface biting frequency of the fish during the feeding sessions. In the home tanks, group-housed angelfish rapidly approached the surface when presented with food, and ate at a high rate. The level of feeding in both 14- and 15-fish groups was equivalent ($p > 0.05$), and the overall mean number of bites per fish per session calculated for all 29 fish over the 5-day observation period is indicated in figure 1.

In the experimental tanks, the surface biting frequency of isolated fish was very low, although it increased with time in isolation ($F(9, 396) = 9.34$, $p < 0.01$). Feeding behaviour increased with group size, the fish transferred in groups of 5 reaching a feeding level equivalent to that recorded in the home tanks. Fish transferred in groups of 3 showed a significantly higher biting frequency than that of isolates but were still significantly lower in their feeding rate than those transferred in groups of 5 (all $p < 0.005$). In the first feeding session after transfer the biting rate was lower than in subsequent sessions in all group sizes, but even so increased significantly with shoal size ($F(2, 69) = 148.58$, $p < 0.001$). Based on their biting frequency, no significant correlation was found between the ranks assigned to individual fish in the home and isolation conditions, indicating that individual differences observed in the grouped condition did not persist in the solitary state ($r_s = 0.20$, $p > 0.05$, Spearman rank-order correlation coefficient).

In the post-isolation condition, the feeding frequency of fish following transfer to the novel tank after 4 and 10 days in isolation was unchanged (all $p > 0.05$), whereas the number of feeding bites of fish from the control group, isolated for the first time, was very low. The mean number of feeding bites by 4- and 10-day isolates during the last two feeding sessions in the isolation tank, and during the first two sessions following transfer to an identical but novel tank are shown in figure 2. Feeding increased significantly with period in isolation before transfer. In both 4- and 10-day isolates, individual differences in surface feeding persisted between the experimental tank sessions and those in the novel tank (all $p < 0.01$), indicating that feeding rank in the experimental tanks is a good predictor of the feeding rank in the novel tank.

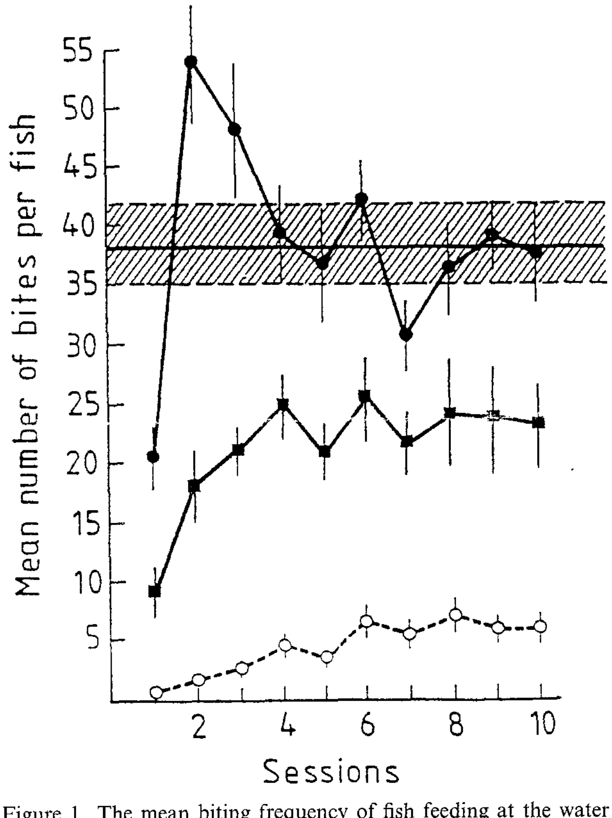

Figure 1. The mean biting frequency of fish feeding at the water surface after transfer to the experimental tanks in groups of five ● (3 groups), three ■ (5 groups) and individually ○ (42 fish). The shaded area indicates the standard error of the overall mean biting frequency per fish per session of one group of 14 fish and one group of 15 fish studied in the home tanks. Bars = SEM. Two-way repeated measures ANOVA showed a significant effect of the group size ($F(2, 69) = 89.74$, $p < 0.001$), sessions ($F(9, 621) = 11.58$, $p < 0.001$) and of the interaction between group size and sessions ($F(18, 621) = 2.14$, $p < 0.005$).

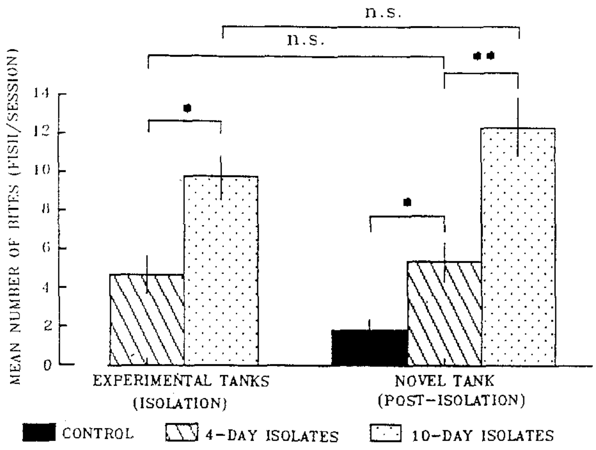

Figure 2. The mean number of surface feeding bites made by fish isolated for 4 and 10 days, recorded during the last two feeding sessions in isolation in the experimental tanks, and during the two feeding sessions following solitary transfer to an identical novel tank. Data for novel-tank feeding of the control group of fish, not previously isolated, are also included. $N = 14$ in each group. Bars = SEM (Student's t-test: $*p < 0.05$, $**p < 0.001$, n.s. = not significant). Two-way repeated measures ANOVA showed that duration of isolation ($F(2, 39) = 13.09$, $p < 0.005$), sessions ($F(1, 39) = 4.92$, $p < 0.05$) and the interaction between isolation period and sessions ($F(2, 39) = 4.69$, $p < 0.025$) all had a significant effect on feeding frequency.

The reduced feeding response during the first session shown by solitary and group transferred fish following their introduction to the experimental tanks (fig. 1) is perhaps best attributed to the transfer process, including the effects of handling and novel environment. A similar reduction in feeding activity on transfer to the solitary state has been described for a number of animal species, and has been interpreted as a response to a real or perceived threat[1,2,18]. It is reasonable to assume that the reduced feeding behaviour of isolated *Pterophyllum* may be interpreted similarly. In nature this species frequently forms mixed shoals with a larger but morphologically similar cichlid, *Cichlasoma festivum*[19], and it would be advantageous for individual angelfish to reduce their conspicuousness when removed from the protection of the group[20]. This could result in reduced feeding behaviour (fig. 2).

A similar relationship between group size and feeding behaviour has been reported for a diversity of fish species with the advent of threatening predation[16,21]. It seems likely therefore that even the initial response to transfer is moderated by social factors. The absence of any significant decrease in the feeding rate of 4 and 10 day isolates following transfer to a novel but similar tank supports this hypothesis. Their feeding rates both in isolation and following transfer to a novel tank were nevertheless significantly higher than that of fish isolated for the first time, suggesting that they could have adjusted to the absence of conspecifics.

Differences in feeding rate during the later feeding sessions are most readily explained in terms of social facilitation[11-13]. The feeding rate of solitary fish and of those transferred in groups of 3 increased gradually to asymptote with time following transfer, that of the group-housed fish being significantly higher. Fish transferred in groups of 5, however, showed a more rapid recovery of feeding rate to reach the home tank pre-transfer level (fig. 1), when they were housed as a group of 15. A heightened competition for food may account for this result, as such a factor may represent a disadvantage occurring as group size increases[20]. In this context it is interesting to note that feeding rank order frequently changed following isolation, indicating that the most competitive foragers may not necessarily be the greatest risk-takers in the solitary state.

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