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Feed discrimination and selection in self-fed European sea bass *Dicentrarchus labrax* L.

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Abstract

This study was conducted to evaluate feed discrimination and preference of European sea bass *Dicentrarchus labrax* L., taking into account the effects of feed location, previous feeding experience and light conditions. Fish (63 g) were held in tanks and exposed to a 12L:12D photoperiod and ambient temperature. The following feeding practices were applied in triplicate: three-choice feeding (self-feeding with feeds formulated for carnivorous, herbivorous and omnivorous fish rotated on a weekly basis) and monofeeding (self-feeding with one of these feeds). After 9 weeks (phase I), fish previously held in monofeeding, were subjected to three-choice feeding for 2 weeks (phase II). In phase I, fish discriminated between feeds after their rotational displacements and preferred the feed formulated for carnivorous species. This also supported the best growth. Fish used in phase II preferred the same feed. There was no preference for any location within tanks. Feeding was generally diurnal, although in some tests with the feeds for herbivores and omnivores, diurnal and nocturnal feed demands were similar and fewer in number than with the feed formulated for carnivores.

Keywords: feed discrimination, preference, European sea bass *Dicentrarchus labrax* L., self-feeding behaviour

Introduction

Self-feeders are useful for the study of feeding behaviour in fish (Boujard, Dugy, Genner, Gosset & Grig 1992) and have been used in studies of feed palatability (Adron, Grant & Cowey 1973; Boujard & Le Gouvello 1997) and nutrient selection (Hidalgo, Kentouri & Divanach 1988; Cuenca, Diz & de la Higuera 1993).

The European sea bass *Dicentrarchus labrax* L. is a species that adapts well to self-feeders (Boujard, Jourdan, Kentouri & Divanach 1996; Azzaydi, Madrid, Sánchez-Vázquez, & Martinez 1998; Paspatis, Batarias, Tiangos & Kentouri 1999). However, the use of these devices in behavioural studies must take into consideration the fact that factors such as self-feeder location (Davrinch 1985; Hidalgo *et al.* 1988), light (Sánchez-Vázquez, Zamora & Madrid 1995; Alanärä 1996; Alanärä & Brännäs 1997) and previous experience (Rottiers & Lemm 1985) may influence the results.

This work was directed to the investigation of feed discrimination and selection in sea bass that self-fed in a three-choice feeding regime. Rotation of feeds in tanks provided the opportunity of evaluating the discriminative capacity and selectivity of the fish. Effects of self-feeder location, previous experience and influences of light–dark cycles on feeding responses were also considered.

Materials and methods

The experiment was conducted indoors at the Institute of Marine Biology of Crete, Greece, using cylindrical 500-L tanks. Water flow to each tank was 720 L h^{-1} (60% renewal and the remainder recycled). Water was monitored at 09.00 each day, and temperature was 18.4 ± 1.6 °C (mean ± SD), dissolved oxygen was 5.8 ± 0.4 mg L^{-1}, salinity 29.1 ± 2.9 g L^{-1} and alkalinity 7.4 ± 0.1. Artificial light was used to provide a 12L:12D photoperiod (lights on at 06.00), and light intensity at the water surface during lights-on was 330 lux.

The fish (initial weight 63 ± 2 g) had been held under similar conditions for *c*. 6 months and were familiar with pendulum self-feeders (Anthouard & Wolf 1988). The black tips of the pendulum feeders extended *c*. 2 cm beneath the water surface, and self-feeder activation was recorded using a computer. Feed reward (0.09 g per trigger activation) was similar for all self-feeders, which were checked weekly. Three types of commercial feeds (Biomar S.A., Nersac, France) were used: one formulated for herbivorous fish (feed H: 26% protein, 7% lipid, 13% moisture), one for carnivores such as sea bass (feed C: 55% protein, 11% lipid, 11% moisture) and one for omnivorous fish species (feed O: 32% protein, 4% lipid, 13% moisture). The feed composition information is that given by the manufacturer.

Fish were fed a mixture of the feeds for 1 month before the experiment. Then, they were weighed individually and distributed among tanks to give 30 fish per tank. The experiment was divided into two phases. In phase I, triplicated groups of fish self-fed with access to one of the three test feeds or all three feed types simultaneously for 9 weeks. In the first situation, each tank was equipped with a single self-feeder located between the water inlet and outlet (monofeeding regimes). In the three-choice feeding regime, there were three self-feeders per tank, and these were located close to the water inlet, close to the water outlet and between these two locations. Each week fish were bulk weighed and returned to their tank. In the three-choice feeding regime, feeds were rotated among the three self-feeding locations on a weekly basis. In phase II, fish previously exposed to monofeeding were subjected to the three-choice feeding regime for 2 weeks. In this case, the original feed given to each monofed group was located randomly.

Checks were made for dead fish and feed waste twice a day. There were no mortalities during the course of the experiment. Growth and feed efficiency were assessed by calculation of specific growth rate [SGR (% day^{-1}) = 100 × (ln final biomass–ln initial biomass) × no. of days^{-1})] and feed efficiency ratio (FER = weight gain × feed supply^{-1}) respectively.

Data were analysed by analysis of variance (ANOVA), and *post hoc* comparisons were made using the Scheffé *F*-test ($P < 0.05$). Principal component analysis (PCA) was used for the classification of mean weekly profiles of self-feeding activity, and the Wilcoxon matched pairs test was applied to compare diurnal and nocturnal self-feeding activity.

Results

Feed discrimination and preference

Under the three-choice feeding regime, there were significant ($P < 0.05$) differences in quantities of the feeds distributed. Distribution of feed C (15.4 ± 9.9 g day^{-1} per tank) was higher than that of feed O (10.3 ± 9.6 g day^{-1} per tank), whereas distribution of feed H (12.4 ± 22.6 g day^{-1} per tank) was intermediate. The increased demand for feed C was apparent throughout phase I, despite the weekly change in feed location. Figure 1 shows the percentage contribution of each feed to the daily feed input during the three-choice regime. After each change in feed location, the fish needed some time to relocate feeds but, towards the end of the week, demands for feed C were usually greater than for the other two feeds.

Fish fed with feed C during monofeeding had better growth than those fed the other two feeds (Table 1). Although the inputs of feeds C and O were lower than that of feed H, growth of fish fed feed H was poorer than that of fish fed feed C, and feed efficiency was poor. Direct observations indicated that fish fed on feeds H and O left pellets uneaten on the bottom of tanks, whereas fish fed feed C did not. Although feeding conditions in the three-choice feeding were not comparable because of the rotational displacement of feed and the expected feed waste, the estimation of SGR (0.32 ± 0.03% day^{-1}) showed that these fish had an intermediate growth rate, significantly lower than that of fish fed feed C in monofeeding but higher than the groups fed on feeds H and O.

Effects of extraneous factors on feed preference

The rotation of feed locations in tanks with three-choice feeding indicated no significant effect of location on feed demands ($P > 0.05$), although there seemed to be some avoidance of the location close to the water inlet (11.42 ± 8.76 g day^{-1} per tank) compared with that at the water outlet (12.55 ± 9.23 g day^{-1} per tank) and at the intermediate position (14.09 ± 23.43 g day^{-1} per tank).

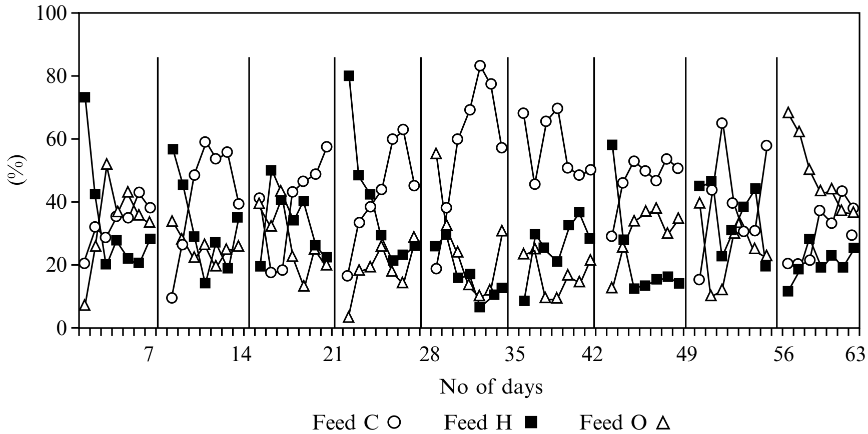

Figure 1 Percentage of each feed type (H, C and O) in the daily feed supply to sea bass held under three-choice feeding conditions. Vertical lines indicate the weekly change in feed locations. See text for information about feeds and feeding conditions.

Table 1 Initial and final body weight, feed input, specific growth rate (SGR) and feed efficiency ratio (FER) (mean ± SD, $n = 3$) of sea bass that had free access to one type of feed: feed H for herbivores, feed C for carnivores (e.g. sea bass), feed O for omnivores.

Type of feed	H	C	O
Initial body weight (g)	60.5 ± 1.0	63.2 ± 4.9	64.8 ± 4.7
Final body weight (g)	68.7 ± 4.9	81.1 ± 8.9	70.4 ± 1.0
Feed input (g)	3073 ± 860 a	1216 ± 328 b	1066 ± 362 b
SGR (% day^{-1})	0.20 ± 0.02 b	0.40 ± 0.03 a	0.13 ± 0.01 c
FER	0.08 ± 0.03 b	0.45 ± 0.22 a	0.15 ± 0.08 ab

Within each row, means with different letter are significantly different ($P < 0.05$).

The effect of previous feeding experience on feed preference was examined in phase II. When fish exposed to monofeeding were subjected to three-choice feeding, they showed diversification in their feed preference (Fig. 2). All fish seemed to have an ultimate preference for feed C, but the temporal development varied between groups. Fish (body weight 68.7 ± 4.9 g) that originated from tanks of monofeeding with feed H demanded most feed C from day 7 onwards. Fish fed with feeds C and O (body weight 81.1 ± 8.9 g and 70.4 ± 1.0 g respectively) during monofeeding initially demanded most of the feed type with which they were familiar, but the fish given feed O during phase I changed their preference to feed C after day 11.

Light–dark alternation influenced feeding activity, with feeding activity being greater during the photophase in monofeeding independent of feed type (Fig. 3). In three-choice feeding, activity differed with feed: feed C was demanded mostly during the photophase ($P < 0.05$), but the percentage of demands for the other two feeds was not statistically different between day and night (Fig. 3). The analysis of the total number of weekly activations per feed and light condition in three-choice feeding showed that feed C (840 ± 410 activations) was demanded significantly more ($P < 0.05$) than feed H (437 ± 211 activations) and feed O (369 ± 219 activations) during the light phase, whereas during the dark phase, demands for the three feeds were

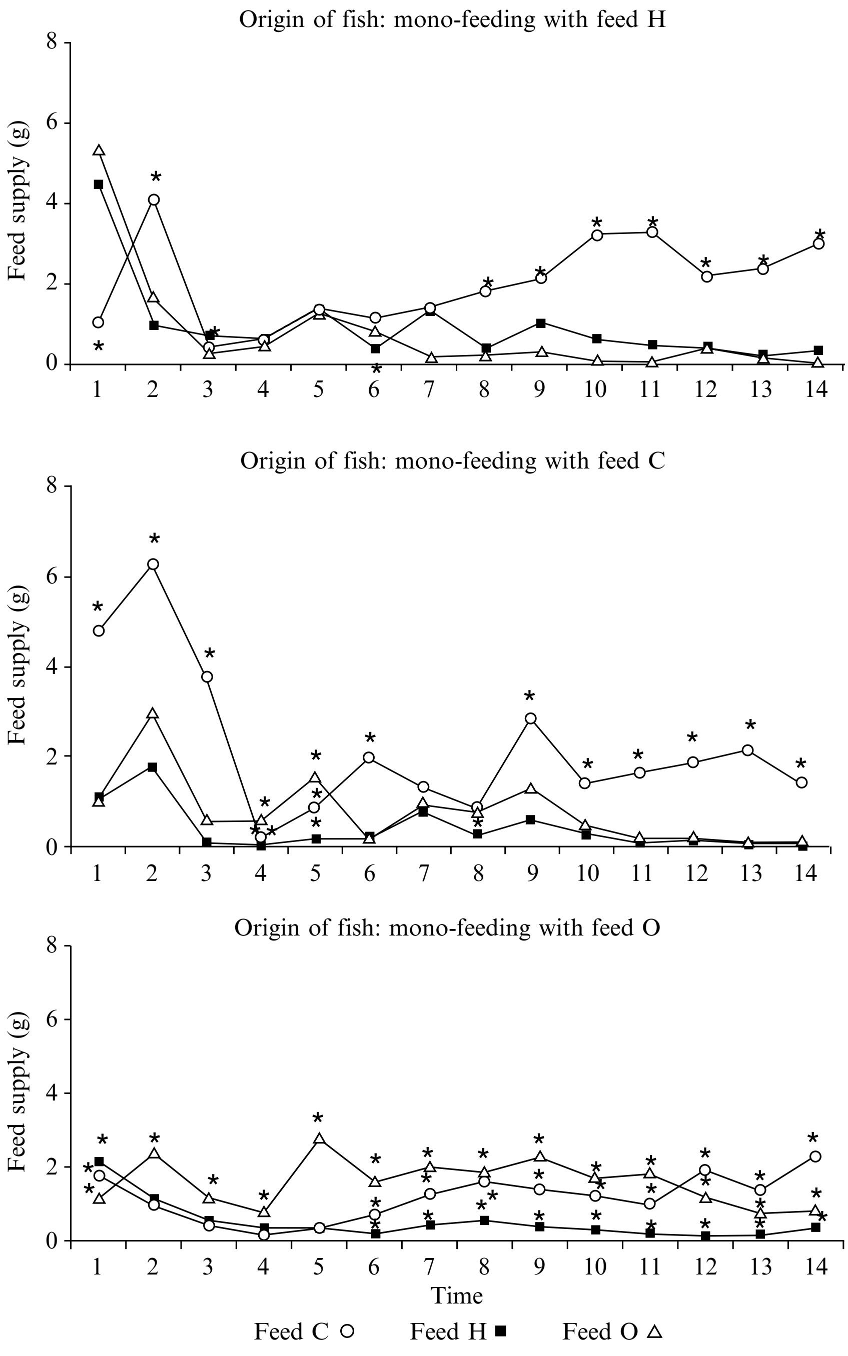

Figure 2 Daily feed supply during three-choice feeding in sea bass initially subjected to monofeeding (phase II). H, C and O correspond to the feed types in the three-choice regime. Points of significant differences are noted with asterisks (*). See text for additional information about the feeds and feeding conditions.

similar (C: 360 ± 193 triggers; H: 513 ± 358 triggers; O: 432 ± 221 triggers). These findings were supported by the results of PCA, which grouped weekly self-feeding profiles into the following categories: high activity during the scotophase and low at 06.00 and 1100–12.00 (profiles for feeds H and O under the three-choice feeding regime); high daylight activity (0600–17.00) with peaks at 06.00,

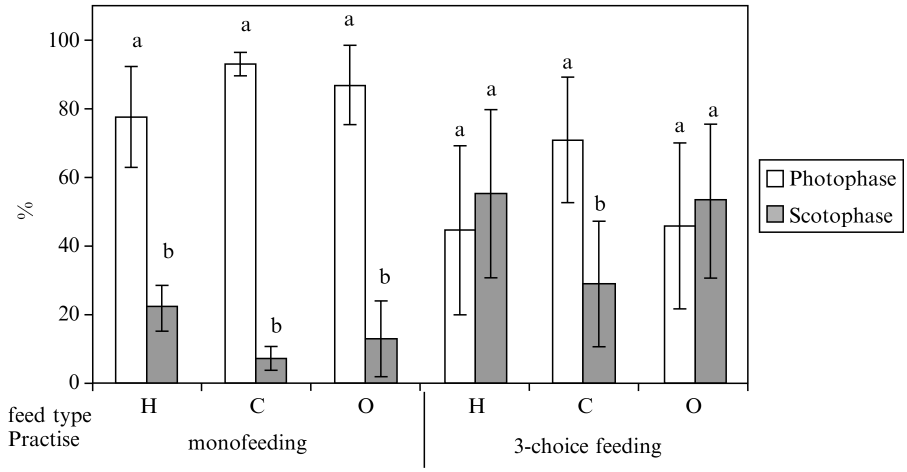

Figure 3 Percentage of weekly self-feeding actuations ($n = 9$, vertical bars indicate one standard deviation) during the photophase and scotophase in sea bass fed with feeds H, C and O under monofeeding and three-choice feeding conditions. Significant differences ($P < 0.05$) between light phases within feed types are marked with different letters. See text for additional information about the feeds and feeding conditions.

the onset of photophase, and 1100–12.00 (all feeds under the monofeeding regime, and feed C under three-choice feeding).

Discussion

The results indicate that sea bass exposed to multiple-choice feeding had the ability to self-select a feed that supported good growth. The experimental conditions in this feeding group (repeated weekly change of feed locations, similar external appearance of feeds, the same colour of self-feeder trigger) meant that the fish had to relearn feeding location and probably discriminated between feeds by taste rather than vision. Feed discrimination by sea bass was investigated by Hidalgo *et al.* (1988), who reported that young juveniles (body weight *c.* 2 g) discriminated between feeds of different methionine content, whereas older, larger fish (*c.* 200 g) did not.

The results obtained under monofeeding conditions showed that feed C was the best for promoting growth. Although this work did not focus on the nutritional quality of the specific feeds, the nutritional value of feed C (high percentage of dietary protein and lipid) was expected to be high for carnivorous fish, such as sea bass (Ballestrazzi, Lanari, D'Agaro & Mion 1994; Pérez, Gonzalez, Jover & Férnandez-Carmona 1997; Peres & Oliva-Teles 1999). The joint presentation of other feeds in the three-choice feeding did not hinder the fish from selecting most feed of high nutritional quality. This is in accordance with the general rule applied in animals (de la Higuera 2001). The results of phase II of this experiment verified a preference for feed C.

The time taken for feed relocation in the three-choice feeding following the weekly rotation of feeds was not consistent throughout the experiment, and fish needed 0–6 days to relocate feeds. This was similar to that recorded in rainbow trout *Oncorhynchus mykiss* (Walbaum), which discriminated feeds successfully in less than 6 days (Adron *et al.* 1973; Cuenca *et al.* 1993). Feed location seemed to have little effect on selection, feed C being selected independently of its point of delivery in the tank. There is some discrepancy between these findings and those of Davrinch (1985) and Hidalgo *et al.* (1988). The latter reported that spatial location affected feed preference in 200 g sea bass.

The fish typically displayed diurnal feeding activity under monofeeding conditions and in their selection of feed C under three-choice feeding conditions. In contrast, the self-feeders that distributed feeds H and O under the three-choice regime were activated by both day and night, although the total number of activations was less than for feeders with feed C. It was not possible to tell whether the nocturnal activity was the result of voluntary or accidental actuation of the triggers: direct observations indicated that fish usually swam close to the tank bottom during the photophase and rose to the surface to activate the self-feeder but, during the scotophase, most fish moved near to the water surface. This could have increased the numbers of accidental triggerings of the self-feeders. This is supported by the observation that the demands for the three feed types in the three-choice feeding were similar during the scotophase. Coves, Gasset, Lemarié & Dutto (1998) recognized the existence of unintentional contacts with the trigger in sea bass, although they also found that bass had the ability to locate and activate the trigger of self-feeders in total darkness.

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