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Ontogenetic shifts in patterns of microhabitat utilization in the small-headed clingfish, *Apletodon dentatus* (Gobiesocidae)

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Synopsis

The patterns of microhabitat utilization by the clingfish *Apletodon dentatus* were investigated, based on SCUBA diving surveys at the Arrábida Marine Park (Portugal). In all inspected microhabitats, this species was only found in algal turfs, sea urchins and boulders. The association of *A. dentatus* with sea urchins is here analysed for the first time. There was a differential utilization of the microhabitats, with small juveniles recruiting to algal turfs, intermediate individuals found in association with the sea urchins *Paracentrotus lividus* and *Sphaerechinus granularis* and larger fish occurring mainly in boulders. The depth distribution patterns are also analysed.

Introduction

The patterns of microhabitat distribution in small cryptobenthic fishes (sensu Miller 1979) of the temperate regions have been poorly studied when compared to tropical environments. Although there are some studies on species of the north-eastern Pacific (e.g. Stephens et al. 1970, Lindquist 1985, Daniels 1987, Norton 1991) and north-eastern New Zealand (Jones 1988), the eastern Atlantic and Mediterranean cryptobenthic fauna has been scarcely investigated (but see Zander 1980, Patzner & Santos 1992, Hofrichter 1995, Gonçalves et al. 1996, 1998, Hofrichter & Patzner 1997, 2000, Kovacic 1997, Faria et al. 1998, Faria & Almada 1999, Patzner 1999a,b).

The Gobiesocidae are widely distributed along temperate and tropical regions (Briggs 1955), occupying a great variety of habitats and generally occurring in very specific microhabitats such as: (i) boulder fields: *Aspamichthys ciconiae* and *Aspasma minima* (Shiogaki & Dotsu 1972), *Conidens laticephalus* (Shiogaki & Dotsu 1971), *Gobiesox marmoratus* (Mongard 1981), *G. rhessodon* (Wells 1979), *Lepadogaster candollei* (Gonçalves et al. 1998, Patzner 1999a, Hofrichter & Patzner 2000), *L. lepadogaster* (Gonçalves et al. 1998, Hofrichter & Patzner 2000); (ii) exposed rocky substrates: *Chorisochismus dentex* (Stobbs 1980), *Sicyases sanguineus* (Paine & Palmer 1978, Mongard 1981); (iii) coarse gravel: *Gouania wildenowi* (Kovacic 1997, Hofrichter & Patzner 2000); (iv) empty bivalve shells: *Apletodon incognitus* (Hofrichter & Patzner 1997), *Diademichthys lineatus* (Sakashita 1992), *Diplecogaster bimaculata* (Hofrichter & Patzner 2000), *Gobiesox strumosus* (Runyan 1961); (v) sea urchins: *Acyrtus rubiginosus* and *Arcos decoris* (Schoppe & Werding 1996), *A. incognitus* (Patzner & Santos 1992, Hofrichter & Patzner 1997, Patzner 1999b), *Dellichthys morelandi* (Dix 1969), *Diademichthys deversor* (Pfaff 1942), *D. lineatus* (Sakashita 1992), juvenile *L. candollei* (Patzner 1999a, Hofrichter & Patzner 2000, personal observation); (vi) crinoids: *Lepadichthys caritas* (Allen & Starck 1973), *L. lineatus* (Fishelson 1966); (vii) steams and bulbs of kelp: *Apletodon dentatus* (Gordon 1983, Breining & Britz 2000, Hofrichter & Patzner 2000), *Rimicola muscarum* (Roland 1978); and (viii) seagrass beds: *Acyrtops beryllinus* (Gould 1965), *A. dentatus* (Bini 1968, Almeida 1988, Costa et al. 1994), *A. incognitus* (Hofrichter & Patzner 1997, Patzner 1999a), *Opeatogenys gracilis* (Reina-Hervás & Nuñez Vergara 1985, Hofrichter & Patzner 1997, 2000).

The small-headed clingfish, *A. dentatus* (Facciola 1887), is a small clingfish (SL max. = 4 cm) that occurs from Scotland to the Mediterranean (Briggs 1986) where it is one of the rarest gobiesocids (Hofrichter & Patzner 2000). The ecology of this species is virtually unknown and only scattered information is available on the association of very few specimens with the brown algae *Cystoseira* in the Mediterranean (Hofrichter & Patzner 2000), bulbs of *Saccorhiza polyschides* in the Atlantic coast of Scotland and France (Gordon 1983, Breining & Britz 2000), and seagrass beds on the Portuguese west coast and the Mediterranean (Bini 1968, Almeida 1988, Costa et al. 1994). In this paper, the patterns of microhabitat utilization and depth distribution of different ontogenetic stages of *A. dentatus* are investigated.

Material and methods

The study area is located on the west coast of Portugal at the Arrábida Marine Park (38°28′N, 8°59′W), 50 km south of Lisbon. This Marine Park is adjacent to the Arrábida Nature Park on land and the coastline consists mainly of steep calcareous cliffs. The underwater rocky habitats present are highly heterogeneous resulting from the disintegration of the cliffs. At shallow depths, boulder fields occur in some places.

A total of 43 dives on 25 stations were performed along this coast using SCUBA from August 1999 to June 2000. The first dives were aimed at sampling all microhabitats where this species could be found (holes, crevices, caves, isolated stones and boulders, boulder fields, sea urchins and algae). In this region, the kelps *Saccorhiza polyschides* and *Laminaria digitata* used to be very abundant (Saldanha 1974), but are now quite rare and short (personal observation). After the identification of the microhabitats where fish were present, a systematic sampling of those microhabitats was initiated. Since no previous data on the ecology of this species was available, the stations chosen represent a random selection of the main rocky habitat types present in the Marine Park.

In each station, sampling started at the interface of the rocky substrate with sand (in this area the extent of the rocky substrate is usually only a few dozen meters wide) and progressed towards shallower depths in a perpendicular direction to the coastline. The microhabitat items where fish were found (boulders and the sea urchins *Paracentrotus lividus* and *Sphaerechinus granularis*) were randomly inspected. The size of each item and the depth where it occurred (depth range: 1.5–14.8 m) were recorded. For the sea urchins, size refers to shell diameter. Total length (TL) of each fish was estimated to the nearest millimetre by measuring with a caliper topographic marks where the fish had laid. All sizes are TL unless stated otherwise. The colouration patterns were also recorded and closely followed the general substrate colour. Colour patterns of *A. dentatus* varied greatly and are similar to those described by Hofrichter & Patzner (2000) for *A. incognitus*.

The presence of juveniles of this species in algal turfs was only found for the first time on 25 May 2000. We collected 21 algal turfs opportunistically in late May and early June 2000. Among these, 13 were of the red algae *Gelidium latifolium*, one of *Gigartina acicularis*, six of *Codium* sp. and one of *Halopteris scoparia*. Each turf was approximately 30–40 cm high and formed a unit isolated from other algae. The turfs collected reflect the relative abundance of the main algae present in the sampled habitats at that time. For this microhabitat the depth distribution was not analysed in detail. We collected the algal turfs with plastic bags that were tightly closed underwater. At the surface, the turfs were minutely inspected and each fish was collected, killed with an overdose of the anaesthetic quinaldine and preserved in 70% alcohol for identification purposes (it is not possible to identify with certainty such small fishes in the field).

Due to the similarity between the genus *Apletodon* and *Diplecogaster* and to the recent description of a new species of the genus *Apletodon* (*A. incognitus*, Hofrichter & Patzner, 1997), a small sample of fishes (n = 26) were collected for identification purposes in a few preliminary sampling surveys. Fish were collected with the aid of the anaesthetic quinaldine diluted to 1 : 15 with alcohol (Patzner 1999a), killed with an overdose of quinaldine and preserved in 70% alcohol. All biometric and meristic characters conform to the ones ascribed to *A. dentatus* (Briggs 1955, Hofrichter & Patzner 1997). Additionally, since the related species *A. incognitus* is known to be associated with sea urchins in intertidal pools at the Azores (Patzner & Santos 1992), the presence of *A. dentatus* in pools where the sea urchin *P. lividus* is very abundant was also investigated at another two sites: Mexilhoeiro (38°41′N, 9°26′W) and São Pedro do Estoril (38°41′N, 9°22′W). We have chosen these sites because there are no intertidal rocky platforms at the Arrábida coast.

The differences in fish length according to microhabitat and the depth distribution of the microhabitat items where *A. dentatus* occurred, were evaluated by the Kruskal–Wallis test (Zar 1996). Whenever the test statistics were significant, a posteriori multiple comparisons were performed using the Dunn's test (Q-test). The occurrence of *A. dentatus* in the two species of sea urchins was assessed by a chi-square test. The Mann–Whitney test was used to compare the size of sea urchins with and without fishes. Finally, the relationships between fish and sea urchin size, fish size and depth where sea urchins were found and sea urchin size and depth, were evaluated by Spearman rank correlations.

Results

In the microhabitats analysed in this study (see Methods), only boulder fields, sea urchins and algal turfs revealed the presence of *A. dentatus*. We have inspected a total of 1669 microhabitat items and the number of fish found in each is presented in Table 1.

There was a significant difference in the size distribution of *A. dentatus* in the microhabitats analysed (Kruskal–Wallis ANOVA: H(3, N = 267) = 175.71, p < 0.001). The smaller fish occurred in algal turfs, the intermediate in the two sea urchins species, and the larger ones in boulders (algal turfs: mean = 0.70 cm, S.D. = 0.08, range = 0.48–1.05 cm, N = 119; *S. granularis*: mean = 1.7 cm, S.D. = 0.80, range = 0.5–3.2 cm, N = 29; *P. lividus*: mean = 2.0 cm, S.D. = 0.77, range = 0.5–4.0 cm, N = 99; boulders: mean = 2.8 cm, S.D. = 0.58, range = 1.0–4.0 cm, N = 20) (Figure 1).

Table 1. Number of *Apletodon dentatus* present in the microhabitats investigated in this study (boulders, the sea urchins *Paracentrotus lividus* and *Sphaerechinus granularis*, and algal turfs) and total number of inspected microhabitat items. The 119 *A. dentatus* found in the algal turfs are all juveniles (see text).

	Boulders	*P. lividus*	*S. granularis*	Algal turfs
A. dentatus	20	99	29	119
Total number of inspected microhabitat items	843	603	202	21

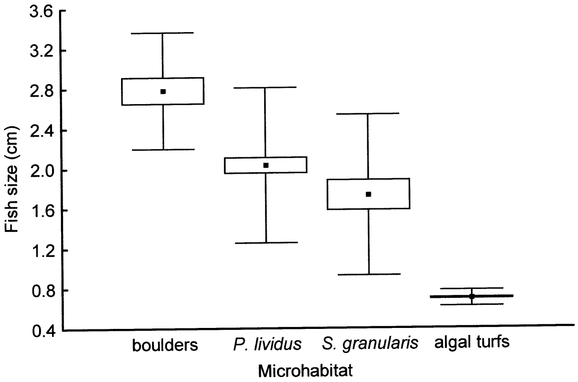

Figure 1. Fish size (cm) distribution (total length) in the microhabitats analysed. All fish found in each microhabitat are included (boulders: n = 20; *Paracentrotus lividus*: n = 99; *Sphaerechinus granularis*: n = 29; algal turfs: n = 119). Small square = mean, box = standard error, lines = standard deviation.

The fish present in the algal turfs were exclusively early recruits with a TL smaller than 1cm (with one exception: TL = 1.05 cm). Most fish were associated with the red algae *Gelidium latifolium* (96%) and presented a red coloration. For the algal turfs that contained fish, the mean number of individuals found was 8.5 (S.D. = 7.10, range = 1–21, N = 14). In the other microhabitats, only a small number of these early recruits (TL ≤ 1 cm) were present (boulders: n = 1; *P. lividus*: n = 18; *S. granularis*: n = 10).

The larger individuals of *A. dentatus* were associated with boulders (Figure 1). In the last months of the study (May and June 2000) we recorded males with a bright colouration and dark spots on the dorsal and anal fins, which is the breeding colouration pattern (Briggs 1986).

With the exception of the early recruits in algal turfs, most fish occurred in one of the two species of sea urchins (Table 1). In three occasions, we found two and in one occasion three *A. dentatus* under the same *P. lividus*, and in two occasions two *A. dentatus* under the same *S. granularis*. A total of 16% of *P. lividus* and 13% of *S. granularis* had one or more fish associated.

There was a significant difference in the depth distribution of the sampled microhabitats where individuals of *A. dentatus* were found (Kruskal–Wallis ANOVA: H(3, N = 155) = 65.25, p < 0.001) (Figure 2). With the exception of algal turfs, the other

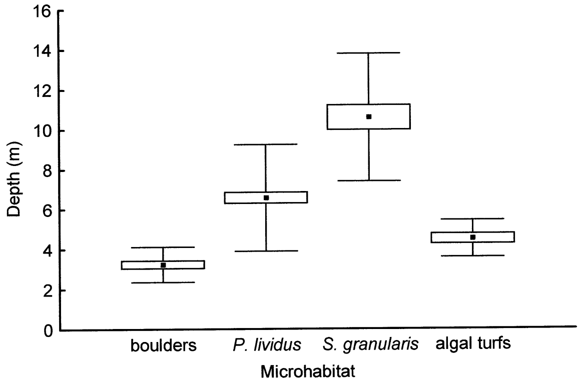

Figure 2. Depth (m) distribution for the microhabitat items analysed. All microhabitat items inspected are included (boulders: n = 843; *Paracentrotus lividus*: n = 603; *Sphaerechinus granularis*: n = 202; algal turfs: n = 21). Small square = mean, box = standard error, lines = standard deviation.

microhabitats were sampled in all depths at which they were found (see Methods). The boulders where *A. dentatus* occurred were located in shallower areas compared to both species of sea urchins (*P. lividus*: Q-test = 5.24, $p < 0.001$; *S. granularis*: Q-test = 7.73, $p < 0.001$). *S. granularis* occurred significantly deeper than *P. lividus* (Q-test = 4.53, $p < 0.001$).

Concerning the distribution patterns of *A. dentatus* according to sea urchin species, there was no preference for either species of sea urchin in the number of fish present in relation to the total number of sea urchins analysed (chi-square test = 0.81, d.f. = 1, p = 0.37). However, the sea urchins where *A. dentatus* was found were significantly larger (mean = 5.5 cm, S.D. = 1.84, range = 2.2–10.0 cm, N = 121) than those without fish (mean = 4.6 cm, S.D. = 1.92, range = 1.0–11.0 cm, N = 604) (Mann–Whitney U-test: U = 32384.5, $p < 0.05$). The fish associated with *P. lividus* did not differ significantly in size from the ones associated with *S. granularis* (Mann–Whitney U-test: U = 1121, p = 0.073).

Considering only the sea urchins that were associated with fish, fish size and sea urchin size were negatively correlated (Spearman rank correlation: Rs = −0.258, $p < 0.01$, N = 128). This was unexpected since larger sea urchins could theoretically provide a greater protection and thus should be preferred by the bigger fish. There was also a negative correlation between fish size and depth for the *A. dentatus* present in sea urchins (Spearman rank correlation: Rs = −0.241, $p < 0.01$, N = 128). Moreover, the larger sea urchins occurred significantly deeper (Spearman rank correlation: Rs = 0.565, $p < 0.001$, N = 128). These data suggest that the larger fish associated with sea urchins occur preferentially at shallower depths.

In the tide pools investigated no fish could be found in a total of 80 *P. lividus* sampled, although three dives performed in the nearby subtidal area revealed the presence of this species associated with sea urchins.

Discussion

Gobiesocids are in general very small and cryptic fishes that can easily be overlooked. They associate with different types of microhabitats where they seek shelter from predators and/or substrates to breed. The association with sea urchins has been previously described for some species (see Introduction) and the fish can be effectively protected by the sea urchin spines against predators. In some cases, the fish also benefits from the association by feeding on the tube feet and pedicellaria of the sea urchin: e.g. *D. deversor* (Pfaff 1942) and *D. morelandi* (Dix 1969).

Until now, *A. incognitus* and *L. candollei* were the only two gobiesocids from the north-eastern Atlantic known to be consistently associated with sea urchins (Patzner & Santos 1992, Patzner 1999b), although we have made an anecdotal comment on the association of *A. dentatus* with sea urchins in a previous work (Henriques et al. 1999).

Our results suggest that there is an ontogenetic shift in microhabitat utilization by *A. dentatus* with the small juveniles recruiting on algal turfs, the intermediate fish occurring associated with the sea urchins *P. lividus* and *S. granularis*, and the larger individuals mainly present on boulders. These microhabitat shifts have been described for several fishes and can be related with different factors that range from feeding shifts associated with different microhabitat exploitation (e.g. McCormick 1998), spawning site selectivity (e.g. Marliave 1975), different size-related rates of predation (e.g. Werner & Hall 1988), or even sea water temperature (e.g. Kotrschal 1983). In gobiesocids, there are also some documented cases. In *D. lineatus* the smaller fish never leaves the protection of the spines of *Diadema* while fish larger than 30 mm have been seen foraging around corals and the males guard eggs on empty bivalve shells (Sakashita 1992). In *L. candollei*, juveniles are also mainly associated with sea urchins, but the adults occur in several other microhabitats (Hofrichter & Patzner 2000) and are frequently seen swimming around near the substrate (Gonçalves et al. 1998). For the Mediterranean populations of *A. incognitus*, the juveniles are also found in sea urchins while the adults occur mainly in bivalve shells (Hofrichter & Patzner 2000). However, in the Azorean populations of this species, all individuals were found in association with sea urchins, but no adult males were present (Hofrichter & Patzner 1997), which suggests a possible habitat segregation related to reproduction, with breeding males probably occurring in other microhabitats.

The results presented in this paper suggest that the algal turfs are probably a preferred microhabitat for the settlement of early recruits of *A. dentatus*. In fact, the occurrence of these small juveniles in other microhabitats was rare. It can be argued, however, that the differences found could be due to different predation and/or mortality rates in the different microhabitats. This could probably be true for the boulders which offer little protection. However, in the case of the two species of sea urchins where the juveniles could escape from most predators, the number of juveniles is also low and they were mainly found isolated. This contrasts with the great number of small juveniles found in the algal turfs analysed (see Results).

As fish grow, they seek protection under the spines of sea urchins. For the fish present in sea urchins, fish size and sea urchin size were negatively correlated and the larger sea urchins were found significantly deeper. The larger *A. dentatus*, some presenting the breeding colouration pattern, were found associated with boulders which are distributed at shallow depths. However, we have not found any eggs. Since the breeding season of this species in our study area is not known, it is possible that we have missed the peak of reproduction. This set of results suggests that reproduction probably takes place in the boulder fields and that the mature fish migrate from the sea urchins to the boulders to breed.

For a small species with parental care of the eggs which are attached to the substrate, it could be advantageous to breed under the protection of the sea urchin spines. However, sea urchins are known to predate fish eggs (e.g. Santos 1995). Moreover, they frequently move away from the shelter places to feed, leaving a nest-attached fish vulnerable to predation. This is probably why the breeding males of clingfishes associated with sea urchins are always found in other microhabitats (e.g. boulders, empty bivalve shells and bulbs of kelp: Gordon 1983, Sakashita 1992, Hofrichter & Patzner 2000). Further studies focusing on the breeding ecology and recruitment of *A. dentatus* are needed to confirm the shifts in patterns of microhabitat utilization suggested in this paper.

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