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SOME ASPECTS OF THE BREEDING ECOLOGY OF *GOBIUS COBITIS* PALLAS AND *GOBIUS PAGANELLUS* L. IN THE WEST COAST OF PORTUGAL

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INTRODUCTION

Gobius cobitis (PALLAS, 1814) and *Gobius paganellus* (LINNAEUS, 1758) are the most abundant gobies in Portuguese rocky shores (ARRUDA, 1990). The distribution of *G. cobitis* ranges from the Eastern English channel to Morocco, Mediterranean, Black Sea and Golf of Suez, and that of *G. paganellus* from Western Scotland to Tropical West Africa (Senegal), including Oceanic Islands, Mediterranean and Black Sea, Golf of Eilat and Red Sea (MILLER, 1986).

Their biology as been the subject of considerable interest (HOLT & BYRNE, 1898; LO BIANCO, 1909; LE DANNOIS, 1913; LEBOUR, 1919; SPARTA, 1934 and 1950; VIVIEN, 1939; CAVINATO, 1950; WHELLER, 1960 and 1969; MILLER,

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1961; GIBSON, 1967, 1970 and 1972). In Portuguese waters, some data on their vertical distribution and abundance are provided by ARRUDA (1990).

In what concerns the reproduction of these species, the available evidence indicates that the breeding season exhibit considerable geographical variation (MILLER, 1961; GIBSON, 1970).

There is no information on the breedind ecology of these gobies in Portuguese waters. Since the data available refer to the British Isles and the west coast of France, and to the Mediterranean, it is important to have information about the Portuguese coast, where conditions are intermediate between the two most studied areas, to get a better understanding of the influence of the environmental conditions in the reproduction of these gobies.

In this paper, the ecology of nests, eggs and breeding season of the two species is described for Parede, near the mouth of the Tagus river (Lisbon).

MATERIAL AND METHODS

Data was collected at Parede (38° 41' N, 9° 22' W), from February 1993 to July 1994.

In the study area, during low tide, a number of rocky platforms crossed by ridges and small channels, roughly parallel to the sea, are exposed together with many tide pools.

Both *G. cobitis* and *G. paganellus* nest in the flattened underside of boulders, situated in these channels, that even during low tide are filled with water and connected to the sea. Eleven on these channels, making a total of 500 meters, were inspected at monthly intervals. Each boulder was carefully turned to expose the underside.

The eggs of the two species could easily be distinguished following the descriptions of HOLT & BYRNE (1898), LO BIANCO (1909), LE DANNOIS (1913), LEBOUR (1919), SPARTA (1934, 1950), VIVIEN (1939), CAVINATO (1950), WHELLER (1960, 1969), MILLER (1961) and GIBSON (1970). The eggs of *G. cobitis* are longer and more pointed than those of *G. paganellus*. While the eggs of *G. cobitis* are of an intense yellow, those of *G. paganellus* are yellowish cream. The identification of the eggs was also facilitated by the presence, in both species, of the male, that guards and cares for the eggs until hatching. To confirm the identification of the eggs of *G. cobitis*, for which less descriptive data were available, a number of eggs were collected and incubated in the laboratory, and larva and juveniles were reared to a size when the fish could be identified with certainty (GIL *et al.*, in preparation). All the eggs classified in the field as belonging to *G. cobitis* originated fishes that were undoubtedly of this species.

For a sample of boulders containing nests, the following data were collected: species of guarding male and the eggs; total area covered by the egg layer (measured by gently applying one square centimeter grid, drown on a flexible plastic sheet, to the egg layer and counting the number of squares occupied by the spawn); density of eggs (counting the eggs in one square centimeter of each egg layer); number of development stages that could be macroscopically distinguished (embryo lacking eyes versus embryo with pigmented eyes); lengths and width of the boulder and the composition of its algal cover. After inspection, each boulder was carefully placed in the position in which it had been found.

A small sample of eggs of each species was collected for measurement, preserved in 70% alcohol and measured under a stereomicroscope.

Data analysis was performed using the computer program Statgraphics (version 4.0) (Copyright 1985-1989 STSC, Inc. and Statistical Graphics Corporation).

RESULTS

Eggs and Nests

Males of both species were found guarding eggs under boulders with flattened undersides. In both cases, the fusiforme eggs, were attached to the substrat by threads that surrounded the micropyle, and formed a single layer.

In the study area, the mean length of the eggs of *G. cobitis* was 4.2 mm (SD = 0.025, range 4.1-4.3 mm, N = 6), and the mean width was 1.4 mm (SD = 0.025, range 1.3-1.5 mm, N = 6). Those of *G. paganellus* were smaller, with a mean length of 1.8 mm (SD = 0.025, range 1.6-1.9 mm, N = 6), and a mean width of 0.06 mm (SD = 0.025, range 0.04-0.09 mm, N = 6).

Although many tide pools and crevices were inspected, no eggs were found in other microhabitats than the underside of boulders found in the channels.

The channels were filled with water even during low tide, and were permanently connected to the sea. During low tide the water depth ranged from 3 cm to 50 cm (average = 19.45 cm, SD = 10.07, N = 33). The algal cover of the boulders was typically dominated by *Litophyllum incrustans*, *Corallina officinalis*, with some *Gellidium* sp and *Ulva* sp. Thus they correspond to a facies of a low intertidal level.

Nests of both species were found in the same microhabitat, often in adjacent boulders. Apparently, each male defends the space available beneath an entire boulder. In 116 boulders containing eggs of *G. paganellus* and 33 with eggs of *G. cobitis*, a single egg layer and a only single male were found under each boulder.

Although the two species nest in the same habitat, they differ markedly in the size of boulders that are used as nest sites. To compare the boulders, maximal length and width of 20 boulders containing eggs of each species were measured. They differed significantly in both dimensions (Mann--Whitney U-Test: boulder length $Z = -3.779$, $p < 0.001$, $N = 20$, and boulder width $Z = -2.278$, $p < 0.05$, $N = 20$): for *G. cobitis* the average boulder length was 46.50 cm ($SD = 9.15$, range 30-67 cm, $N = 20$) and the average boulder width was 30.80 cm ($SD = 8.40$, range 14-40 cm, $N = 20$), and for *G. paganellus* the average boulder length was 34.25 cm ($SD = 7.07$, range 23-45 cm, $N = 20$) and the average boulder width was 25.35 cm ($SD = 4.30$, range 20-32, $N = 20$).

In both species, in some cases one male was undoubtedly guarding eggs in different stages of development (5 out of 116 nests for *G. paganellus* and 6 out of 33 nests for *G. cobitis*), thus at least, some males may guard multiple broods silmutaneously in both species, a finding also noted by MILLER (1961) and GIBSON (1970). It is important to stress that this value is probably underestimated, since eggs that could not be distinguished to the naked eye, were classified as being in the same developmental stage.

Egg densities were measured for 10 nests of each species. The nests of *G. paganellus* had a significantly higher number of eggs per square centimeter than *G. cobitis* (Mann-Whitney U-Test: $Z = 3.677$, $p < 0.001$, $N = 10$): for *G. paganellus* the average density was 208 eggs per square centimeter ($SD = 53.82$, range 100-340 eggs/cm^2, $N = 10$) and for *G. cobitis* the average density was 85 eggs per square centimeter ($SD = 31.10$, range 70-100, $N = 10$). This finding is easily explained by the larger size of the eggs of *G. cobitis*.

Although the density of eggs in *G. cobitis* is lower, the males of this species guard many more eggs than those of *G. paganellus*. For the same nests used to measure egg densities, the total number of eggs present was estimated by multiplying the number of eggs in a square centimeter by the total number of similar squares occupied by the egg layer. The area covered with eggs was significantly greater for *G. cobitis* than for *paganellus* (Mann-Whitney U-Test: $Z = -5.818$, $p < 0.001$, $N = 10$): for *G. cobitis* the average area was 125.25 cm^2 ($SD = 122.26$, range 13.82-389.4 cm^2, $N = 10$), and for *G. paganellus* the average area was 19.42 cm^2 ($SD = 16.79$, range 5.66-28.26 cm^2, $N = 10$). And the number of eggs was also significantly higher in *G. cobitis* (Mann-Whitney U-Test: $Z = 3.746$, $p < 0.001$, $N = 10$): for *G. cobitis* the average number was 11395 eggs ($SD = 5696.7$, range 3000--24000 eggs, $N = 10$) and for *G. paganellus* the average number was 1505 eggs ($SD = 874.47$, range 320-2800 eggs, $N = 10$).

Breeding Season

The number of boulders containing eggs of each species is given in Figure 1.

Inspection of Figure 1 shows that in February 1993, when the study began, *G. paganellus* was already breeding, and the eggs of this species were found until early June. The subsequent breeding season of this species lasted from late December 1993 to early July 1994.

In 1993, the breeding season of *G. cobitis* lasted from early April to early July, while in 1994 eggs were found from early March to early July.

It is important to note that in all the other months in which no eggs were found, the same channels and boulders were regularly inspected.

It may be concluded that the breeding season of *G. paganellus* extends from late December to June/early July. The breeding season of *G. cobitis* is shorter, extending from March/April to early July.

DISCUSSION

The nest sites of both species studied were found in a similar habitat, and often under adjacent boulders. In both cases, the males probably defend the space available under an entire boulder.

Competition for nest sites between the two species is, however, unlikely. *G. cobitis* nests in boulders that are much bigger than those used by *G. paganellus*. Additional evidence for the lack of competition between the two species, at least in our study site, was the finding that in each month of the breeding season only a small proportion of boulders with the characteristics that seem suitable for nests were occupied.

The difference in the size of boulders used is to be expected, since adult males of *G. cobitis* attain much larger sizes than those of *G. paganellus* (MILLER, 1986; GIBSON, 1970). MILLER (1986), refers that *G. cobitis* may reach 27 cm while *G. paganellus* may reach 12 cm. Probably *G. cobitis* requires boulders big enough to accommodate both a bigger fish and a larger egg layer in the space formed between the boulder and the underline rock.

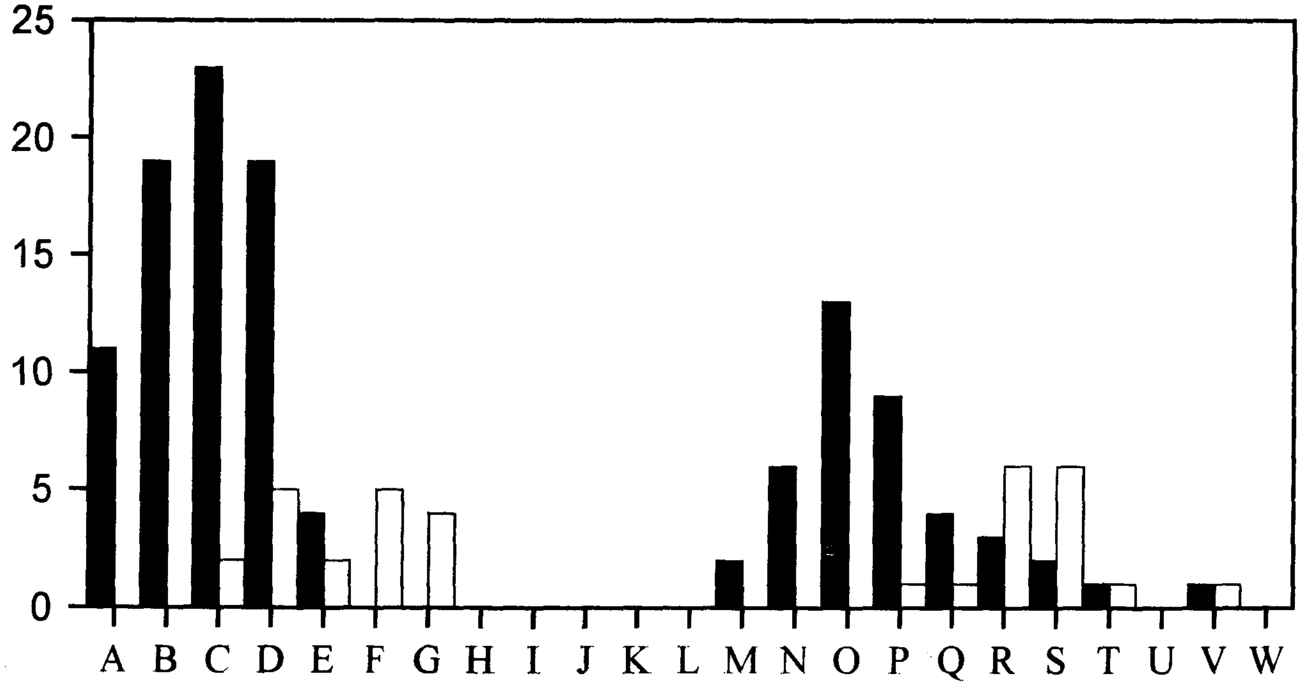

FIG. 1 — Number of boulders containing eggs of *Gobius paganellus* (black bars) and *Gobius cobitis* (hollow bars) during February 1993 to July 1994. The exact date of each visit for each mont is as follows: 1993-A-8 Feb., B-9 and 10 March, C-9 April, D-4 and 5 May, E-3 and 5 June, F-21 June, G-7 July, H-19 July, I-9 Aug., J-17 Sept., L-15 Out., M-13 Nov., N-1 Dec., O-30 Dec., 1994-P-11 and 13 Jan., Q-10 and 11 Feb., R-11 March, S-15 April, T-10 and 11 May, U-8 and 9 June, V-10 July, W-21 July.

In both species, the breeding season is longer than the one found around the British Isles and the west coast of France (GIBSON, 1970 — May to June for *G. cobitis*, and HOLT & BYRNE, 1898 — Spring to early Summer; MILLER, 1961 — mid-April to mid-June; LEBOUR, 1919 — mid-Spring to late-Summer; VIVIEN, 1939 — April to June, and LE DANOIS, 1913 — April to August for *G. paganellus*). This contrast is specially marked when the beginning of the breeding season is compared.

The breeding season in Portugal approaches that given for Naples (January-June, LO BIANCO, 1909). In Venice, located at a higher latitude, breeding season of *G. paganellus* (February-May, CAVINATO, 1950) is shorter, and starts later. In the Black Sea, where waters are even cooler, the breeding seasons of the two species approaches those found at higher latitudes in west Europe (MILLER, 1986).

ALMADA *et al.* (1990) found that *Lipophrys pholis*, which in British waters is a late Spring and early Summer breeder, breeds in Portugal during all the Winter and Spring.

Coryphoblennius galerita displays in Portugal a much longer breeding season than in the British Isles, and this phenomenon is also specially marked in what concerns the beginning of the breeding season (ALMADA *et al.*, in preparation).

Thus, this pattern of variation in duration and timing of the breeding season with temperature is a common pattern found in several inshore fishes.

DAHLBERG & CONYERS (*in* MILLER, 1979), found that along the Atlantic coast of North America, many species at their southern limit of distribution tend to have longer breeding seasons, begining earlier and ending later than in their northern limit.

This phenomenon was well documented by MILLER (1961), who presents evidence for a number of European species. This author argues, based on ecological considerations, that fishes that in high latitudes breed in Spring and Summer, should exhibit more marked differences in the beginning of their breeding seasons than in the end, towards their southern limit.

MILLER (1961) argues that if the breeding season was extended to later months of the year, larvae and juveniles would be subject to unfavourable conditions, both in terms of reduced food availability and temperature, with the consequent reduction in growth and increased mortality. The evidence presented in this paper, and in the references cited above, agrees with this hypothesis.

In what concerns the number of eggs per square centimeter, MILLER (1961) provided figures for *G. paganellus* in the Isle of Man, that are lower that those found in our study. Since the eggs of these species in the Isle of

Man are larger (2.4-2.6 mm), the differences in egg density between the two sites, may be explained by the differences in egg size, if females tend to place new eggs in close proximity of already existing ones.

As a final comment on conservation, it is important to stress the extreme vulnerability of the reproductive processe of both species to the disturbances that human activities may cause. In the intertidal zone many boulders are dislodged by people for a variety of reasons, that range from the fishing of octopus and large crabs to the gathering of worms for bait. This human actions may inadvertendly destroy a great number of nests of both species.

SUMMARY

The eggs, nests and the breeding seasons of *Gobius cobitis* and *Gobius paganellus* in the west coast of Portugal are described.

The breeding season of *G. paganellus* lasts from late December to June/ July, and *G. cobitis*'s from February/March to early July.

SUMÁRIO

Os ovos, ninhos e as épocas de reprodução de *Gobius cobitis* e *Gobius paganellus* na costa ocidental de Portugal são descritos.

A época de reprodução de *G. paganellus* estende-se do fim de Dezembro a Junho/Julho e a de *G. cobitis* de Fevereiro/Março ao início de Julho.

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