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Notes on the Social Behaviour of *Gobius cobitis* (Pisces, Gobiidae)

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The agonistic and reproductive behaviour of *Gobius cobitis* (Pisces: Gobiidae) are described based on observations of fishes kept in captivity. It is argued that some features of agonistic and reproductive behaviour of this species share many functional similarities with those of other taxa of benthic fish, while others seem to be convergent traits typical of fishes with male parental care. The behaviour of the larvae is also described.

Key words: Reproductive behavior, agonistic behavior, littoral fish, larval behaviour.

Introduction

There is a considerable body of literature concerning gobiid reproduction and behaviour (e.g. Nyman, 1953; Tavolga, 1954; Breder & Rosen, 1966; Gandolfi, 1972; Wirtz, 1978; Cole, 1982; Miller, 1984; Thresher, 1984; Foster & Fuiman, 1987). However, little is known about the behaviour of *Gobius cobitis* (Pallas, 1814), one of the most common gobies in European shores (Miller, 1986). Gibson (1970) provided basic information on the reproductive biology of this species. Its breeding season and

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breeding ecology in Portuguese waters were described by Faria and Almada (1995), and the embryonic and larval development by Gil et al. (1997).

In this paper we describe the agonistic and reproductive behaviour of this species, based on aquarium observations, along with some data on larval behaviour.

Methods

Observations on the social behaviour of *Gobius cobitis* were made on 3 groups, each consisting of 6 juveniles (3-6 cm total lenght - TL). Each group of fish was kept in a 65 l tank for a period of 17 days, between October and December 1993. The bottom was covered with sand and gravel, with several stones. Fishes were fed with pieces of common cockle. Temperature varied from 10 to 14°C and illumination consisted only in natural light.

Descriptions of juvenile behaviour were based on *ad libitum* observations (total= 72hr: 2hr per day, 24hr per group). Courtship, spawning and parental care were described for a pair of *G. cobitis* (male= 25cm TL, female= 18cm TL), that was kept for several years at Aquario Vasco da Gama (Lisbon), on a large community tank together with other gobiids. Only one pair of fish was used since these were the only fish available at the Aquarium. For this reason, results on the breeding behaviour and parental care should be taken with caution. The pair spawned repeatedly from February to May in 1992 and 1993 (temperature: 14.5-19°C in 1992, 12-18°C in 1993). A smooth vertical surface of a large boulder placed in a corner of the tank was used as nest site. Further details on the maintenance of these fishes and rearing of larvae are provided in Gil at al. (1997).

The frequency and duration of fanning behaviour, time intervals between fanning bouts, time out of the nest and the number of times that the male touched the eggs, were quantified for 10 min periods each day, from spawning to hatching. The behavioural descriptions of both juvenile and adults were complemented by frame-by-frame and slow motion analysis of videotape recordings. A video camera (Sony Hi8 CCD-V600E) was used with no additional illumination of the tank.

Descriptions of larval behaviour were based on *ad libitum* observations (total= 10hr: 30min per day), from hatching to metamorphosis (21 to 35 days after hatching). A test of substrate preference was performed on a group of 36 day old larvae (n=130). This group was kept in a 17l tank with the bottom covered with a layer of sand on one half, and with a layer of small flat stones with a smooth surface (quite common in the natural habitat of *G. cobitis*) on the other. In randomly selected days, the observer immediately upon approaching the tank, counted the number of fish that were resting on both types of substrate. These results were analysed with a χ^2 goodness-of-fit test assuming as expected values that half the fishes occupied each of the substrates.

Results

Larval Behaviour

After hatching, the larvae swam directly to the surface. Feeding behaviour consisted of turning towards the prey, followed by a quick dart. This could be done either in the water column or the prey could be picked from the aquarium walls. The characteristic "S" posture common to many fish larvae was not observed. Young larvae avoided sinking

by keeping in constant movement. As they grew larger, they showed an increasing capacity to hover and keep stationary in the water column. When two larvae came in close proximity, they changed direction with a quick darting movement. They began to contact the substrate 21 days after hatching. The change to a benthic mode of life was gradual, with larvae spending an increasing proportion of time on the substrate. Most individuals began this process 35 days after hatching. Aggressive interactions could already be observed 37 days after hatching. In these interactions, one larva swam at high speed directly to another. This charge caused the flight of the other larva upon witch a brief chasing ensued. The charging fish was usually the largest.

Substrate Preference

The counts of settling fish in the two substrates tested (sand vs. small flat stones) are present in Table 1. Young fish clearly preferred the stones to the sand ($\chi^2 = 66.9$, d.f.=11, $p<0.001$). The reduction of the total number of fishes counted as time progressed was due to mortality.

Table 1. Percentage of settling fishes observed in the two types of substrate present in the tank

Days after hatching	44 (n=70)	56 (n=38)	57 (n=40)	62 (n=38)	84 (n=15)	85 (n=15)
Flatten stones (%)	57	79	75	79	100	100
Sand (%)	43	21	25	21	0	0

Reproductive Behaviour

Courtship

The courting male displayed a black coloration with the unpaired fins bordered with white and fully erected ("fin exhibition"). The male approached the gravid female and opened and closed the mouth once. The female slightly approached the male, upon which he turned and swam to the nest in fin exhibition, showing the caudal fin ("leading"). The female approached the nest following the male, swimming near the substratum with very marked lateral movements of the body. Both fish swam in semi-circles in front of the nest, and the male gave small buttings on the female flank ("stimulation"). Male and female assumed an antiparallel position, with the male turning rapidly and moving in front of the female in fin exhibition. The female quivered.

Fertilization and Spawning

The male moved in fin exhibition, skimming in semi-circles over the stone with simultaneous movements of the pectoral fins, and with slow and very pronounced lateral movements of the posterior part of the body. The abdomen was in close contact with the stone, with the genital papillae rubbing against the nest surface. Between successive fertilizations, the male rested in the substratum near the nest.

The female approximately followed the path of the male (Fig. 1), with simultaneous movements of the pectoral fins, the dorsal fin opened, and slight lateral movements of the posterior part of the body. The abdomen was also in close contact with the stone and the genital papilla was very swollen and showed rhythmical contractions, while being pressed repeatedly against the nest surface. Most of the time the female was quivering. The eggs were deposited in a layer, that grew by successively longer half-

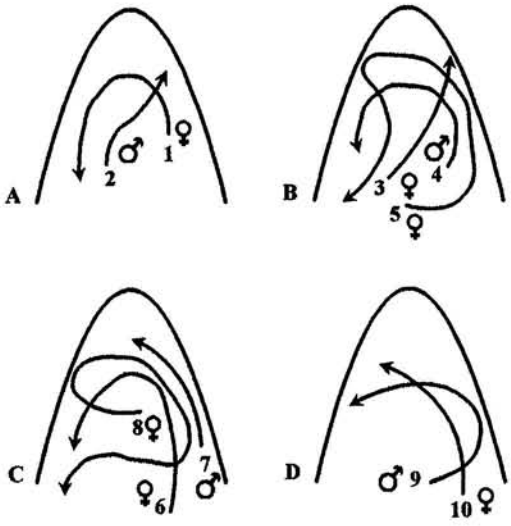

Fig. 1. Male and female path on the nest observed during fertilization and spawning.

circles, surrounding the edge of the previous spawn. The female frequently interrupted spawning to rest, either over the eggs or on the bottom. In Table 2 we present the duration of spawning, fertilization and female and male resting during spawning observed in 18 occasions.

Table 2. Duration of spawning, fertilization and female and male resting during reproduction (n=18)

Behaviour	mean (sec) ± STD	range (sec)
Spawning	110.2 ± 99.6	20-417
Fertilization	26.3 ± 10.0	10-46
Female Resting	27.3 ± 16.1	3-57
Male Resting	259.1 ± 117.3	74-522

The male sometimes approached and touched the female with the head during spawning. When the female rested, the male often nudged her, causing the female to quiver. In general, both fishes alternated their movements over the stone, but in some occasions, they were both on the nest. Spawning could last more than 10 hrs.

Parental behaviour

The nest was guarded by the male. Parental care included fanning, touching the eggs with the mouth, and rubbing the dorsal fin, throat or abdomen on the egg mass.

The fanning movements were performed in bouts, interspersed with resting periods. The male was supported by the pelvic sucker, and his orientation could vary from almost horizontal to an oblique head down position, about 45° relative to the substratum. The mouth was closed or slightly open, and the movements included a simultaneous flexion of the tail to one side, while the pectoral fin of the opposite side moved in the opposite direction. Simultaneously, a wave passed along the dorsal fin, in a posterior direction. This movement took about 1 sec. The male fanned the eggs in bouts with a mean (±STD) duration of 11.9 ±8.83 sec (range: 93.97-1.13 sec, n=790), interspersed with mean (±STD) intervals of 18.2 ±16.0 sec (range: 123.57-0.95 sec, n=810).

In some occasions, the male began to swim while performing fanning, so that its undulating dorsal fin rubbed the egg layer. In ventral rubbing, the male after resting some time (1 or 2 sec) on the egg layer, moved along the spawn, with the ventral surface or occasionally the throat rubbing the eggs. The male could also touch the eggs with the mouth, while it was swimming slowly over the nest.

Agonistic Behaviour of Juveniles

Advancing - A slow swimming towards another fish. The advancing fish stoped at a short distance from the other, with the dorsal fin erected, the caudal fin opened and the head pointing forward, instead of being slightly raised. An advance could precede a charge.

Threatening - The fish raised the anterior part of the body with the help of the ventral sucker, the mouth was open and the opercules and branquiostegal membrane were expanded, increasing the volume of the head. All the fins were fully erected. Sometimes the fish also raised the caudal fin. The longest threat observed lasted 30 sec Threatening could also precede a charge.

Charging - A rapid swimming directed to the flanks or caudal fin of another fish, with very rapid movements of the posterior part of the body. The caudal fin was opened. The pectoral fins stayed close to the body, the dorsal fins were erected and the head pointed forward. Charging could precede biting.

Biting - The bites often occurred at the end of a charge or during chasing. They were usually directed to the caudal fin. Frequently, the biting fish griped the opponent for a few seconds.

Opening-and-closing the mouth - A fish swam directly to another fish, with rapid and wide simultaneous movements of the pectoral fins, and small movements of the caudal fin. The dorsal fins were erected, and the mouth opened and closed in rapid succession. The throat and the opercules were also inflated.

Head turning - A fish side-by-side with another, opened and closed the mouth and simultaneously made rhythmic and slow lateral movements of the head and the posterior part of the body, in the direction of the other fish.

Chasing - A rapid swimming in the direction of a fleeing fish, with rapid lateral movements of the posterior part of the body. The dorsal fins were erected, and the head pointed forward. The mouth was closed or slightly open. The chasing fish presented a

more conspicuous coloration, with a very marked contrast between the dark and light bands.

Ready-to-charge - This posture occurred when the fish was in front of another fish. The head was pointing forward, with the body lying close to the substrate, the mouth was slightly open, the caudal fin was open, the dorsal fins were partially erected, and the opercules and the throat were inflated. This behaviour could last up to 30 sec. Sometimes the fish advanced towards the opponent in this posture, with the pectoral fins near the body, propelled by slow movements of the caudal fin.

Retreating - A short and slow swimming movement near the substrate, away from an advancing fish. The dorsal and caudal fins were folded, and the head pointed slightly toward the substrate.

Fleeing - A rapid swimming by an attacked fish, with all the unpaired fins folded. In general, the dark areas of the body becamed paler, giving the fish an almost uniform light coloration.

"Hiccup" - A fish resting on the substrate, opened and extended the mouth forward, inflated the throat, and closed the mouth again, in quick succession. During this movement, the body was projected forward and back again. The unpaired fins were all folded. This movement could be followed by a similar action by another fish. The meaning of this behaviour pattern is yet unclear, but it is likely part of the social behaviour of this species.

Shelter preparation

When a fish used the space beneath a stone, it excavated the shelter by one of two distinct ways. In one of the patterns, the fish raised the body with a stroke of the pectoral fins, while the tail stayed close to the substrate. With violent jerks of the posterior part of the body, the sand was removed from under the stone. This movement could be repeated several times, until the cavity was large enough for the fish to hide. Alternatively, fishes were observed to excavate with their mouth. After entering in the hole head first, they turned 180° and picked a mouth full of sand, subsequently leaving the hole to spit it out.

Discussion

When we consider the social behaviour patterns displayed by *G. cobitis*, it is remarkable to note the similarities with other species of a wide range of fish families, that present male parental care. Indeed, the reproductive patterns exhibited by the male can be viewed as a sequence of "advertising" to the female, leading the female to the nest and stimulating her to spawn. This type of sequence occurs in taxa as different as gobiids (Nyman, 1953; Tavolga, 1954; Cole, 1982; Foster & Fuiman, 1987), blennioids (Abel, 1964; Almada et al., 1983, 1990; Heymer, 1987), centrarchiids (Beeman, 1924), gasterosteids (Svenster, 1961), pomacentrids (Thresher, 1984), labrids (LeJeune, 1985), (for a review see Breder & Rosen, 1966; Keenleyside, 1979; Almada, 1990).

Although Wickler (1957) and Wirtz (1978) interpreted many of these features as typical of benthic fishes, they are best viewed as features typical of species in which the male guards the eggs. Indeed, even fishes that are active swimmers and spent most of their time in the water column show similar behaviour, if the males guard the eggs in a

nest. On the other hand, fishes that are benthic but show no male guarding, do not present the "syndrome" outlined above.

What is probably more characteristic of the social behaviour of benthic fishes is the ability to perform a variety of displays with minimal loss of contact with the substrate (Wirtz, 1978). Raising the head and elevating the body on the fins, make the fish conspicuous without the need to rise in the water. The agonistic behaviour of *G. cobitis*, namely the threat display, is a good example of such behaviour.

It is interesting to note that this convergent similarities in the behavioural patterns of benthic fishes, may be achieved in different phyletic lines through distinct processes. Wirtz (1978) exemplified this point, when he noted that although both blenies and gobies raise their head in several social contexts, bleniids perform it with muscular contraction of dorsal muscles of the trunk, while gobiids achieve similar results with a lever like action of the ventral fins.

A feature that is common to many gobiids (Marconato et al., 1996; Ota et al., 1996), is the apparent precedence of sperm release over oviposition. Although we could not provide firm evidence of that in *G. cobitis*, the observation that the female tends to deposit the eggs in areas of the nest over which the male as previously skimmed, is suggestive of a similar situation in this species.

It would be interesting to know if the genital papillae of the female possesses any kind of chemical sensory elements capable of detecting surfaces that already contain sperm. The genital papillae must almost certainly possesses a high degree of tactile sensitivity. This is the only way to explain the fact that the eggs are always deposited in a single layer, adjacent to each other.

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