First description of agonistic behaviour in *Chondrostoma polylepis* (Pisces: Cyprinidae) with notes on the behaviour of other *Chondrostoma* species

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Abstract. In this paper we describe for the first time the occurrence of agonistic behaviour in *Chondrostoma polylepis* (Pisces: Cyprinidae) in captivity. In this species agonistic behaviour was present in adults of both sexes and juveniles, during spring and summer, well after the end of the breeding season. Qualitative observations revealed the presence of a similar pattern of agonistic behaviour in *Chondrostoma duriensis*. Despite intense observation effort, no signs of agonistic behaviour were detected in three other *Chondrostoma* species of the same geographical area, *C. macrolepidotus, C. lemmingii* and *C. lusitanicum*. It is hypothesized that agonistic behaviour in *C. polylepis* and *C. duriensis* may be functionally linked to their feeding ecology.
Key Words: Agonistic behaviour, aggression, food defence, Iberian *Chondrostoma*, Cyprinidae.

Resumen. *Primera descripción de comportamiento agonístico en* Chondrostoma polylepis *(Pisces: Cyprinidae) con notas sobre el comportamiento de otras especies de* Chondrostoma. En este trabajo describimos por primera vez el comportamiento agonístico en *Chondrostoma polylepis* (Pisces: Cyprinidae) en cautividad. En esta especie el comportamiento agonístico estuvo presente tanto en adultos de ambos sexos como en jóvenes, fue observado durante la primavera y el verano, después de terminado el periodo reproductivo. Observaciones cualitativas revelaron la presencia de un modelo similar de comportamiento agonístico en *Chondrostoma duriensis*. A pesar de intensos esfuerzos de observación, no fueron detectadas señales de comportamiento agonístico en tres otras especies de Chondrostoma que viven el la misma área geográfica, *C. macrolepidotus, C. lemmingii* y *C. lusitanicum*. Se plantea la hipótesis de que el comportamiento agonístico en C. *polylepis y C. duriensis* puede estar funcionalmente ligado a su ecología alimenticia.

Introduction

Although the family Cyprinidae is "the largest family of freshwater fishes and, with the possible exception of Gobiidae, the largest family of vertebrates" (Nelson, 1994), reports on the occurrence of agonistic behaviour are relatively infrequent in this taxon. Most references report only male aggression in the context of reproduction (for an example of agonistic behaviour in a temperate cyprinid occurring out of the reproductive context see Rincón & Grossman, 2001). Among north American minnows, although egg broadcasting without territoriality is found in the majority of the species and was considered ancestral (Jonhston, 1999), several instances of male breeding territoriality, nest guarding and even nest-building have been reported (e.g. *Campostoma anomalum pullum*, Miller, 1962; species of the genera *Luxilus, Semotilus, Nocomis*, Jonhston, 1999). Among European cyprinids, agonistic behaviour by breeding males seems even more rare (e.g. *Leucaspius delineatus*, *Rhodeus sericeus amarus* Wheeler, 1969; *Abramis brama*, Poncin et al., 1996; *Rutilus rutilus*, Wedekin, 1996). In temperate cyprinids, it seems safe to state that agonistic behaviour and territoriality in non reproductive contexts are rare phenomena, a situation that, as Barlow (1993) points out seems to hold in many other freshwater fish groups. In European cyprinid species, we could not find a single reference in the literature on agonistic behaviour occurring outside the breeding season, except for Wheeler (1969) statement about *Leuciscus cephalus*, that "large chubs are usually solitary possessing and defending from others of the same species, a "territory" in the river".

In Portuguese freshwaters there are at least six, possibly seven, cyprinids of the genus *Chondrostoma* Agassiz, 1835 (SNPRCN, 1992; Zardoya & Doadrio, 1998), all endemic to the Iberian Peninsula.

In this paper we describe the patterns of agonistic behaviour observed in captive groups of *Chondrostoma polylepis* Steindachner, 1865 and present qualitative behavioural observations on four other *Chondrostoma* species of the same geographical area, *Chondrostoma duriensis* Coelho, 1985, *Chondrostoma macrolepidotus* Steindachner,

Table 1. Summary of the information on the fishes used in this study. For each species, the number of individuals and groups, total observation time (*ad libitum*) and capacity of the observation tanks. (*information referring to the group studied in Aquário Vasco da Gama).

Species	*C. popylepis*	*C. duriensis*	*C. macrolepidotus*	*C. lemmingii*	*C. lusitanicum*
Number of individuals	20+30* juveniles 25 adults	30 juveniles 33 adults	50 juveniles 150 adults	6 juveniles 12 adults	23 juveniles 90 adults
Groups	3+1*	4	15	3	4
Observation time	60+30*h	80 h	>300h	40 h	>200 h
Tanks	80L, 450 L and 600L*	15 to 450 L	15 to 450 L	80 L	80 L and 450 L

1866, *Chondrostoma lemmingii* Steindachner, 1866 and *Chondrostoma lusitanicum* Collares-Pereira, 1980, and discuss hypotheses about their function.

Methods

A group of 30 juveniles of *C. polylepis*, bred in captivity from a stock originated on a population of the Tagus basin, were kept in a public aquarium (Aquário Vasco da Gama). Fishes were born in 1999 and were observed during 2000 and 2001. The 600l tank was illuminated 8h per day and was equipped with biological filters. The bottom of the tank was covered with a layer of sand and several large flat stones, and enriched with some aquatic plants. Fishes were fed with *Artemia* sp. and red chironomid larvae.

Behavioural descriptions were made using ad libitum and focal observations (sensu Martin & Bateson, 1993). A total of 40h of *ad libitum* observations were made: 20h during the winter period and 20h that were video recorded (with a Sony Hi8 CCD-V600 E camera), during the spring and summer period. In addition, also using video recording, a total of 189 min. of focal observation was made. During the focal observations, the location of the focal fish in the tank and all the agonistic encounters in which it participated were recorded. Each focal observation lasted 3 min. and this procedure was repeated for 10 fishes in each observation period (30 min.). If a fish went out of sight, or could be confused with other, its focal observation was discarded. As the fishes were not tagged these observations must not be considered independent, as some fishes could be observed more than once in a session, although differences of size and the presence of small scars on the body and fins considerably reduced this risk.

A fish was classified as the loser of an encounter if at the end of the interaction it withdrew or fled from the opponent, or was threatened or attacked without retaliation. When both fishes withdrew without an apparent asymmetry, the outcome was classified as inconclusive. Groups of *C. polylepis*, *C. duriensis*, *C. macrolepidotus*, *C. lemmingii* and *C. lusitanicum* were observed to check for the presence of agonistic behaviour. In Table 1 we summarize, for each species, the information about the number of individuals observed, number of groups observed, total *ad libitum* observation hours and total capacity of the tanks in which observations were made. The fishes were kept in outdoor tanks with natural photoperiods and temperatures.

For each species we tried to cover the entire spectrum of juvenile sizes and some of them were collected when about 2 cm long and were reared in the tanks to full maturity. The observations were conducted throughout the year and were distributed throughout the day. As the tanks were located outdoors and were only observed during daylight hours the observation schedules changed according with the annual variations of the daylight cycle. The fish were observed in a variety of contexts, including the spawning of adults of *C. lusitanicum* and *C. macrolepidotus*. As the agonistic and the reproductive behaviour of these species was previously unknown we decided to perform ad libitum observations and tried to describe and record all types of behaviour that we could differentiate and the relative positions of the fishes when they were observed interacting.

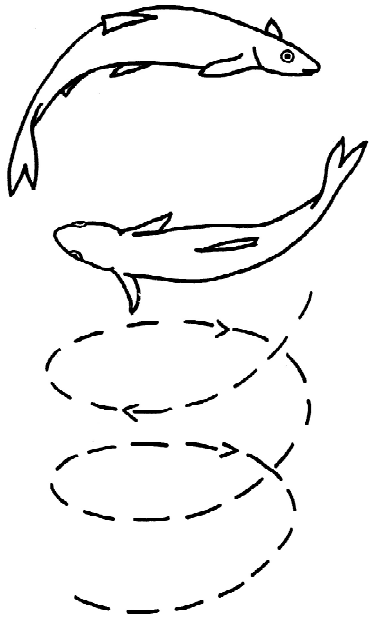

Figure 1. Serpentine.

As feeding could affect the behaviour of the fishes, many observations were made well before and after feeding had taken place.

As we didn't know to what extent group size and tank size could affect the behaviour of the fish, each species was observed in tanks of different size and in groups that ranged from a minimum of six individuals to a maximum of 40 individuals. As the aim of the study was descriptive no attempt was made to standardize the number of group size and number of tank sizes per group sizes.

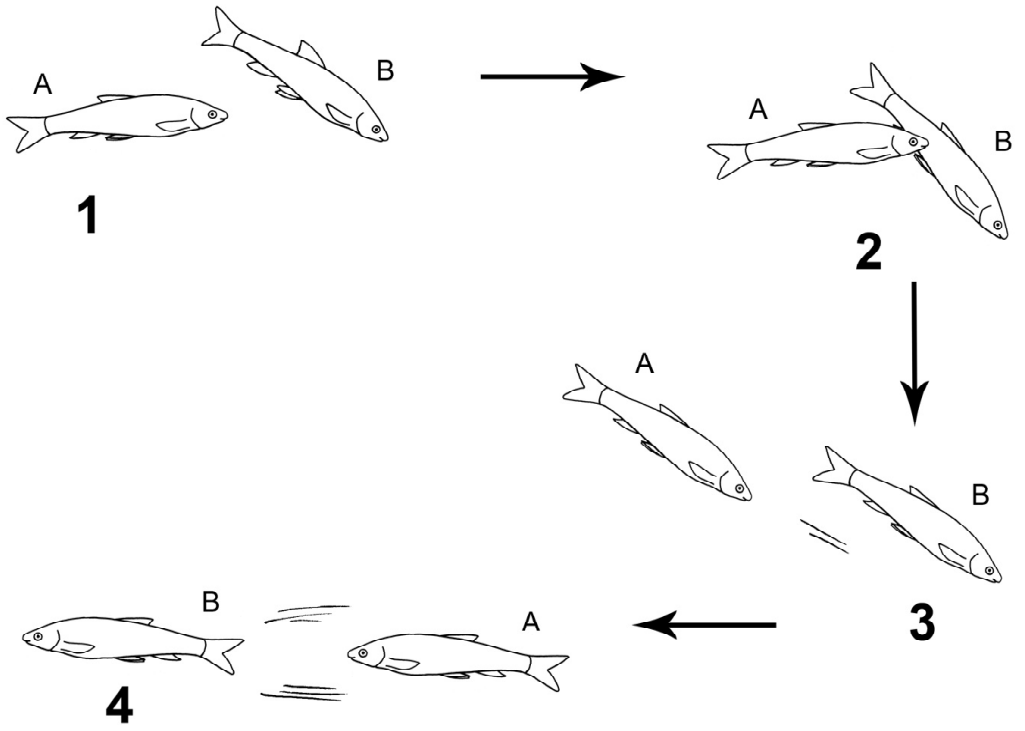

Figure 2. Illustration of the most common sequence of agonistic behaviour. 1- Charge; 2- Butting; 3- Fleeing; 4-Chase.

Results

Agonistic Ethogram (in parenthesis we present the frequencies of occurrence of each behaviour observed, in a total of 178 behavioural acts recorded during 40 agonistic interactions analysed from video records):

Charge – One fish moves rapidly toward another by movements of the caudal peduncle, with all fins closed (30%).

Butting – One fish buts with his snout in another fish, generally in the posterior ventral region or in the caudal peduncle. Sometimes it can give successive buts. Butting often occurred during charges and the attacked fish was frequently hit at the caudal peduncle or the posterior end of the dorsal fin (25%).

Fleeing – One fish moves rapidly away from another (32%).

Chase – One fish rapidly pursues another that is fleeing (8%).

Serpentine – Two fishes swimming rapidly in circles, or semi-circles, both direct their head to the other fish tail, while orienting its own tail away from the other (Fig. 1). The fish look like if they are trying to bite one another at the caudal peduncle. When one of the fishes bites the opponent this movement ceases.

Sometimes there are more than two fishes interacting (2%).

Threaten – One fish initiates charging but stop soon after (2%).

Mouth to mouth – two fishes move rapidly toward the opponent, apparently directing an attack to the opponent's mouth (0.6%).

Like death – A fish lays on its side in the water column, when other is swimming around butting it (0.6%).

Normally, the fishes that participate in an interaction became darker, with the lateral line more conspicuous. The sequences of agonistic behaviour shown by these fish usually followed the pattern: charge → butting → fleeing → chase (ilustrated in Fig. 2).

Normally the agonistic interactions had a short duration (mean=1.23 s; S.D.=0.57; range: 1.00-3.00 s; n=40). They were performed in the water column with no apparent association with stones or other objects present in the tank. After an interaction the fishes tended to return to the place where they were previously. The average number of agonistic interactions was 1.62 per fish per min. (S.D.=1.33; range: 0-9; n=63 fishes). In 80% of the agonistic interactions analysed using the videotape recording (n=40), the fish that initiated the interaction was the winner.

When fishes were placed in the 600l tank, in February 2000, they formed one school, without showing any aggressive behaviour. One week later, they began to be more aggressive and spaced, appearing to hold small territories, continuously swimming in circles in a restricted area (patrolling). During all the summer period they showed this aggressive behaviour, but in September/October they began to school again. After winter, in April they began to show aggressive behaviours again. First, only one or two fishes stayed out of the school expelling other fishes away from their territories by charging and butting, sometimes

driving all the school to the surface. The aggressive behaviour tended to spread to more fishes as time passed: one week after four fishes were out of the school; 20 days after, six fishes were out; 50 days after, there was no school at all. The first two fishes that initiated this process seemed to be the largest.

Although no quantitative data were collected, our observations showed that the agonistic behaviour of *C. duriensis* corresponds to the descriptions provided for *C. polylepis*. Juveniles of this species having only 2 cm already displayed overt aggression. In both species, both males and females performed agonistic behaviour. This behaviour was not linked to reproduction, since it occured outside the breeding season and in fishes with no signs of being ripe. In groups of large fish, even in a 450l tank, only a few fish were able to keep territories and the losers of fights showed very serious wounds, especially near the base of the dorsal fin and had to be removed to avoid more serious injury.

In *C. macrolepidotus*, *C. lemmingi* and *C. lusitanicum*, we could not identify any kind of behaviour that could be plausibly classified as agonistic. During the reproduction of *C. lusitanicum* (Carvalho et al., 2002) and *C. macrolepidotus* (J. Robalo, unpublished data), no territoriality was observed in males and no inter-male aggression could be found. We assume that, with the variety of group and tank sizes, the large numbers of individuals studied and the large amount of observation time dedicated to each species, it is safe to conclude that agonistic behaviour is absent or at least very uncommon in *C. lemmingii*, *C. lusitanicum* and *C. macrolepidotus*.

Discussion

The results of the present study provide strong evidence that species of the genus *Chondrostoma* vary sharply in the expression of agonistic behaviour, which is frequent and intense in *C. polylepis* and *C. duriensis* and virtually absent in *C. macrolepidotus, C. lemmingi* and *C. lusitanicum*. In addition, in the species in which it is present, aggression is not limited to males or to reproductive contexts, being already present in very small juveniles. Although the evidence does not prove that the agonistic behaviour observed corresponds to territorial defence, the observations presented above suggest that territoriality may occur in *C. polylepis* and *C. duriensis*.

These two species are very closely related (Zardoya & Doadrio, 1998) and together with a third Iberian species, *Chondrostoma willcommi*, belong to an ecologically specialized group of nase, that like the central European *Chondrostoma nasus* have a ventral straight mouth with the lower lip reinforced by an horny blade (e.g. Coelho, 1987; Doadrio, 2001). These fishes feed largely on algae, detritus and other materials that they scrape from the surface of rocks and other substrata (Wheeler, 1969; Lobón-Cerviá & Elvira, 1981; Bellido et al., 1989). They often occur in deep waters with moderate currents, exploiting the algal growth on large stones and boulders. This feeding habitat does not correspond to the spawning ground of these species, as they are known to leave their feeding habitats to spawn (Granado-Lorenzio & García-Novo, 1986; Coelho, 1987; Rodriguez-Ruiz & Granado-Lorencio, 1992; Doadrio, 2001). We hypothesised that the agonistic behaviour of these species may be linked to the defence of areas rich in algal growth on objects like large rocks that may provide some shelter against the currents. We suggest that in the feeding habitat, defending a territory may be a very profitable strategy that may allow the fishes to occupy places sufficiently sheltered from the main current on which algal production is enough to support the fishes.

This hypothesis would be especially plausible for the summer conditions, when many fishes are forced to congregate in pools, where algal growth may quickly become a scarce resource. It is interesting to note that, in our observations, the highest levels of aggression were observed in the summer and aggression virtually ceased in the winter. If future field work confirms our interpretation, the behaviour of *C. polylepis* would be analogous to the defence of algal gardens by herbivorous cichlids (Barlow, 1993) and to the territoriality of salmonids (Keenleyside & Yamamoto, 1962; Grant & Kramer, 1990) with the difference that while most salmonids tend to rely on drifting food these nase species may find adequate food on the surface of rocks and boulders that provide them shelter. An example of aggression on a drift feeding cyprinid is provided by Rincón & Grossman (2001), for *Clinostomus funduloides*.

In preliminary field observations of *C. duriensis* (J.Robalo, unpublished data) fish were observed defending algae covered stones against other fish.

The remaining species of *Chondrostoma* observed in this study that lack agonistic behaviour, also lack the morphological and behavioural specializations of head and mouth for feeding on algae and have an omnivorous diet (e.g. Doadrio, 2001). They are frequently found in waters with abundant vegetation and week currents in which the feeding mode of *C. duriensis* and *C. polylepis* is unlikely to be functional and where territorial defence may be uneconomical.

Although the data are not sufficient to draw definitive conclusions on the validity of this hypothesis, we think it is worth testing, with field experiments and observations in the future.

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