

## The territorial behavior of the naked goby, *Gobiosoma bosci*, (Pisces: Gobiidae)

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The territorial behavior of the naked goby, *Gobiosoma bosci*, was observed in 80-liter aquaria. Social behavior was observed for an extended time in daily observation periods. Individuals of *G. bosci*, regardless of size and sex, exhibited agonistic behavior. The aggressive behaviors of approaching, threatening, attacking, and fighting were recorded as agonistic behavior. All individuals are capable of changing their color and camouflaging themselves by matching the color of bottom. Especially, the resident and the intruder are of the same size, the fighting duration was prolonged and the variability of coloration was at its peak.

### Introduction

The relationships of territoriality to other aspects of social behavior have been the subject of extensive research (Greenberg, 1947; Phillips, 1971a; Myrberg, 1972; Black and Wiley, 1977; Elwood and Rainey, 1983; Ketele and Verheyen, 1985). Many fishes are known to exhibit territoriality which is important in fishes because the establishment and maintenance of a discrete territory is usually directly related with feeding, growth, reproduction, and defense against conspecifics. Many studies have shown that the occurrence of territorial behavior in fishes is related to several factors.

The habitat of *Gobiosoma bosci* are usually soft-mud substrates and burrows on logs or in the holes of the mud banks in estuaries, muddy sloughs, marsh pools, and shallow mud flats that are partially exposed at low-tides, but the fish mostly prefers oyster beds or bars to other habitats (Hoese, 1966). Specimens of *G. bosci* have been found at temperatures and salinities ranging from 1.5-33.2°C and 0.0-17.2‰, respectively (Pearcy and Richards, 1962; Dawson, 1966, 1969; Dahlberg and Conyers, 1973; Fritzsche, 1978).

Casual observations revealed that aquarium-held specimens readily defended territories against conspecifics. After a preliminary study, it became clearly evident that the territorial behavior of *G. bosci* was extremely variable.

The primary purpose of the present paper is to evaluate agonistic behavior and movements in the naked goby, *G. bosci*, a common brackish-water fish of the northern Gulf of Mexico. In addition to a descriptive study of the territorial behavior of this species, a

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qualitative description of aggression, associated color changes, and observations on the variability of the territorial behavior patterns were included.

## Materials and Methods

The specimens used in this work were collected over a 150m stretch of the tidal-influenced shore of Turtle Cove, Pass Manchac in Louisiana. During April 1987, collections were made in daytime along the edge of the bank at depths up to 1.0 m. The salinity and temperature of the collection area varied from 0.0 to 0.8‰ and 14.9 to 25.2°C, respectively. The beach at Turtle Cove is usually exposed during low tide, and the substrate mostly consists of hard mud and sand.

Fish were collected with hand-held dipnets and beach seines with a mesh diameter of less than 1 mm. Within 6 hours of capture, collected individuals were transported to the Louisiana State University, Museum of Natural Science (LSUMNS), in Baton Rouge where they were kept in a 80liter aquarium, measuring 38 x 60 x 41 cm. Specimens were identified using Dawson (1966, 1969) and Hoese and Moore (1977), and catalogued specimens in the Museum (*Gobiosoma bosci*, LSUMZ Group No. 59).

All specimens were acclimated for several days in two 40liter aquaria, measuring 25 x 50 x 30 cm. These tanks had 5 cm of sand covering the bottom. Twenty fish were kept in each tank and fed daily on Tetra Min or frozen brine shrimp.

Each fish was measured and marked after anesthetizing with tricaine methanesulfonate (MS 222) (Gibson, 1967; McErlean, 1967). Standard length (SL) was recorded with a millimeter ruler. The size of males ranged from 23 to 42 mm (mean 31 mm) and the size of females ranged from 15 to 34 mm (mean 26 mm).

The males and females were separated in two 40liter aquaria. In accordance with the secretive habits of this species, several types of enclosures were provided to the fish for sheltering sites. One type was empty oyster shells. Others included several pieces of opaque and transparent PVC pipes and some rotten logs with several holes. After one week these specimens were tested. Diagram of the experimental tank is shown in Fig 1. Experimental tanks consisted of two 80liter aquaria that provided the fish a limited number of closely packed enclosures (PVC pipes). Space between the enclosures was large enough for some small individuals to pass. A sheet of glass in each experimental tank leaned backward from the floor against the rear glass of the aquarium at an angle of 45 degrees. The sloping plate was designed to allow ready access to pipes by the animals for use in hiding, sheltering, and other forms of behavior, and to make observation easy and convenient. Each experiment tank was filled with dechlorinated water to a point 7 cm above the upper row of enclosure, and each tank contained a 5cm bottom layer of sand. Water temperature ranged only between 18 and 19. A light-dark cycle of 14 hours of light and 10 hours of darkness was established.

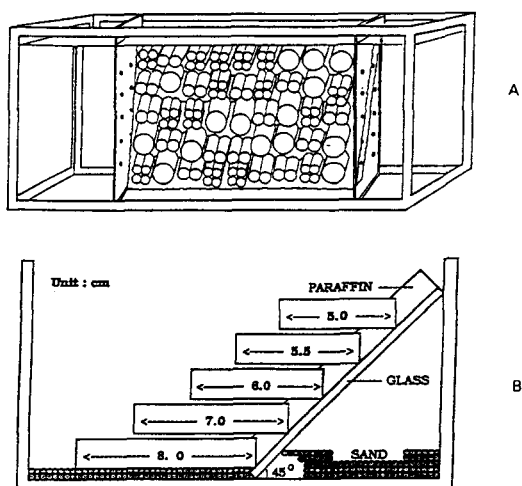


Fig. 1. Diagram of the experiment tanks. A: Frontal view. B: Side view: the enclosures are sections of opaque PVC pipes of five sizes, ranging from 5.0-8.0 cm in length.

After releasing the fish into the test aquarium, observations were begun immediately. The order of releasing fish into the experimental tanks was as follows: one fish was put in an experimental tank, after 24 hours, the second resident or first newcomer was added to the same tank, and so on till the 6th day, when six individuals had been placed in the same tank. This procedure was designated as one series. Six days were spent for each series. There were seven series of six observations of different-sized fish with the same sex group, male or female, and a mixed group. A total of 21 series comprised this experiment. The entire size ranges of fish were used as intruders or newcomers. An actual observation

period was 90 minutes at an average distance 0.5 m.

During the experiment, no food was given to the fish. After each series of experiments, all experimental fish were returned to the stock tank and fed Tetra Min or frozen brine shrimp; the experimental tanks were emptied and the substrate changed.

During observations of behavioral events, every position and movement of the animals were recorded along with the duration (read from a stop watch). After transcription, observations were analyzed. The Mann-Whitney test, Spearman rank correlation coefficient, and chi-square method were used for statistical analyses.

## Results and Discussion

Although the territorial behavior of *Gobiosoma boscii* is similar to that of a number of other species of gobies (MacGinitie: blind goby, 1939; Weisel: mudsucker, 1947; Grossman: bay goby, 1980; Cole: blackeye goby, 1984), the following qualitative description of the territorial behavior of *G. boscii*, necessary for properly interpreting social interactions, is based upon observations throughout this study.

When fish were introduced into an aquarium, they settled to the bottom and, at first, remained in contact with the substrate (bottom, paraffin or pipes), and, within a few minutes, they chose a pipe or suitable shelter - including the shaded corners or interstices between pipes. The fish then usually moved in and out of its shelter at irregular intervals and established it as a territory. The fish then remained quietly within the pipe,

and often moved in and out of the shelter, but stayed very close to the pipe.

The most striking morphological feature of this species was its coloration: however, no sexual differences in coloration were observed. The color pattern differed from individual to individual: furthermore, the coloration was variable, transitory, and sometimes disappeared as quickly as it appeared in response to different backgrounds and social situations associated with the responses of the individuals to aggressive behavior. Variations and intensity in color varied from jet black through a series of browns and tans to milky-white or bright ivory color.

Each individual was in its accustomed place at various times, and it maintained, dominated, and defended its particular territory indefinitely by exhibiting aggressive territorial behavior toward conspecifics. When the animals were crowded, or few or no shelters were provided for adequate territories, the dominant fish attacked the subordinate animals, and fighting and general aggressive behaviors were observed. The subordinate animals unable to find a shelter were chased away: these animals retreated to higher levels and clung to the sides of the aquarium with their fused pelvic fins. Although isolated fish remained inside the interstices of the pipes or their shelter all over one observation period (90 minutes), they always defended the site against intruders.

Recognition of individuals was of importance. When the intruder approached the resident, a response was always forthcoming from the resident, and the resident emerged from its area or pipe and performed aggressive behavior. When the intruder came close to the resident animal, the initial response of the resident was a defensive display, consisting of elevating the dorsal fin, erecting the pelvic disc, opening the mouth broadly, and approaching the newcomer in what seemed to serve as a warning signal to the intruder. Without significant differences in respect to size and sex, this approach was either direct and rapid or indirect and slow, but the quick skimming and dart approaches were more frequent than the slow ones. If the resident was larger than the intruder, the latter animal turned away slowly or quickly darted to another place. The resident then turned and re-entered its own territory or shelter. Although chases were common, residents did not chase intruders insistently. More extensive, vigorous, and mutual combat was in encounters between fish of about equal size. In such case, two individuals approached each other while erecting their fins, especially dorsal and anal fins. A head-on (face to face) formation occurred at first. The head was then elevated, the body arched backward, the mouth and operculum widely gaped, and the throat expanded to its fullest extent. The two gobies then pitched downward movement in sagittal plane (Phillips, 1971a) or stroked (rearing and striking out without contact), the highest degree of threatening action, either alternately or simultaneously more than twice. The subsequent action was a "head-to-tail" or "O-ring" position (Southwick and Ward, 1968), which was a more intensified bout form. These behaviors then were followed by "circle-fighting", the peak of fighting involving contact, such as nipping or biting, butting the opponent's caudal

area or caudal fin, or tail beating the opponent's face or head while gaping and quivering. In medium-sized and large fish, an intensive and distinctive change of coloration (milky-white or bright ivory on the anterior part of the body) was observed. However, the coloration of small fighting individuals was often unchanged from the usual types matching the background. The combat lasted up to one minute. During this encounter, the bout ended anytime that either fish retreated from the immediate area. Fighting took place sporadically in each series of experiments, however, no serious injuries were observed. After interactions between individuals in which a dominant-subordinate relationship was established, the dominant fish showed a quick and direct dash, and attacked the subordinate fish with or without displaying agonistic behavior, while the subordinate fish retreated or escaped from the dominant fish.

The frequency of agonistic behavior determined the level of the aggressiveness and was different in each observation because the total available space was different for individual fish. Intraspecific aggressive behavior also might primarily play an important role in insuring access to partially or potentially limiting resources, such as food, shelter or space, and mates. The more dominant individual has more chance of access to limited resources and can grow faster than other individuals.

The basic measure of social interaction in this study was the number of social exchange

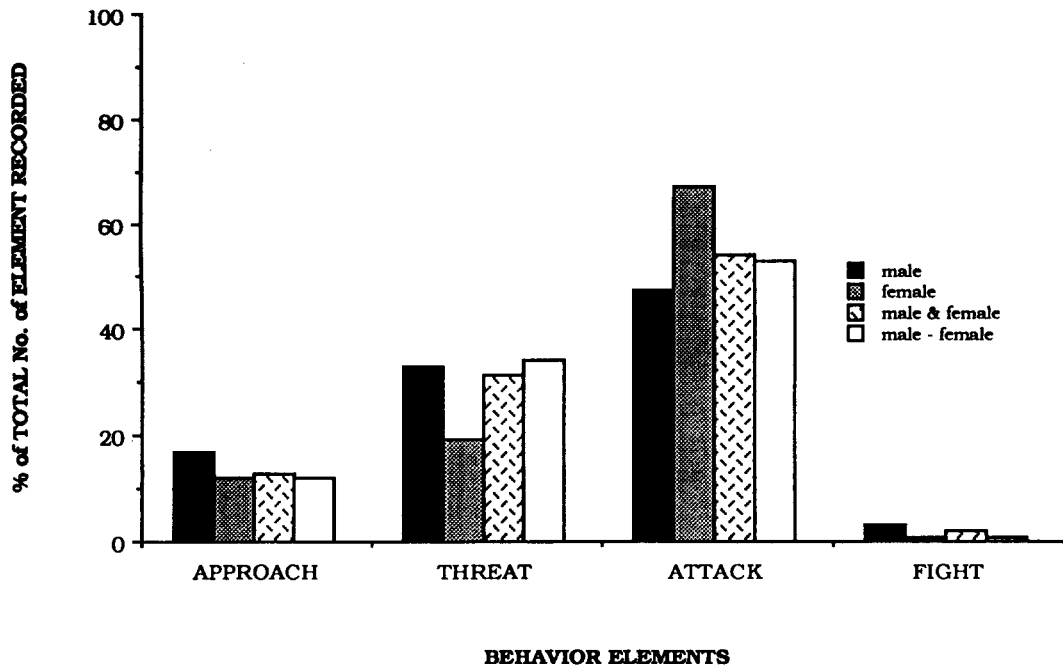


Fig. 2. Relative frequency of performance of individual elements of agonistic behavior by group. Black bars: males; shaded bars: female; checkered bars: mixed group (male and female); white bars: male vs. female.

produced by the encounters. There were several categories of characteristics in the agonistic behavior of *G. bosci*. The fish demonstrated several agonistic behaviors such as alert (watch), approach, threat, charge-strike, attack, fight, flee, and chase according to different levels of aggressive motivation and escalation. However, these behaviors were categorized into four main elements: approach (moving close to the other fish); threat (agonistic or aggressive behavior display); attack (assault the other fish); and fight (participate in bouts)(Fig. 2.). Threat and attack were most frequent, regardless of sex and size difference, which comprised 80-87% of the total performance. At the first encounter the intruders were at least as active as the residents. With respect to all agonistic behavior, the residents did not exhibit significant amounts of agonistic behavior toward the intruders (regardless of size and sex) except when attacking (Fig. 3.).

With regard to residency status, approaching, threatening, and attacking were perform-

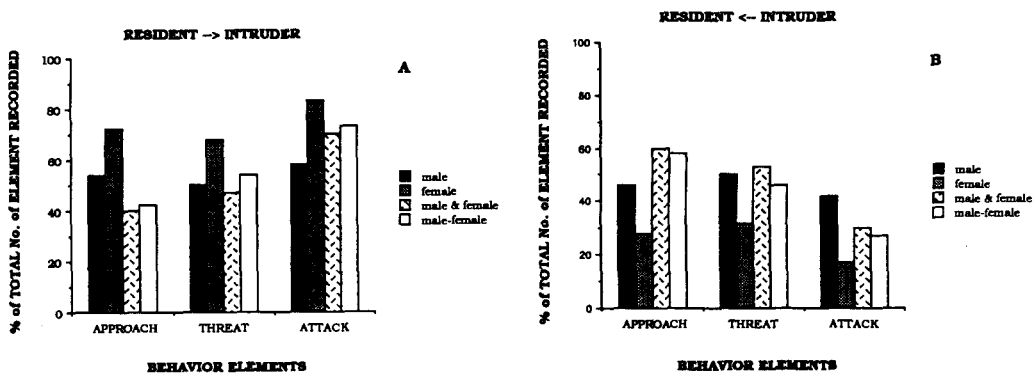


Fig. 3. A: Percentage frequency of selected individual elements of agonistic behavior performed by resident fish toward intruder fish.  
 B: Percentage frequency of selected individual elements of agonistic behavior performed by intruder fish toward resident fish.

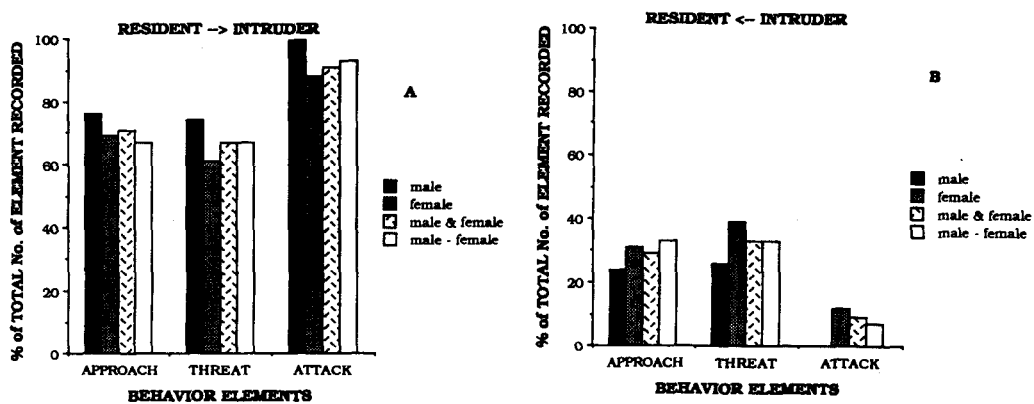


Fig. 4. A: Percentage frequency of individual behavior elements performed by prior resident fish toward intruder with regard to residency status.  
 B: Percentage frequency of individual behavior elements performed by intruder fish toward prior resident with regard to residency status.

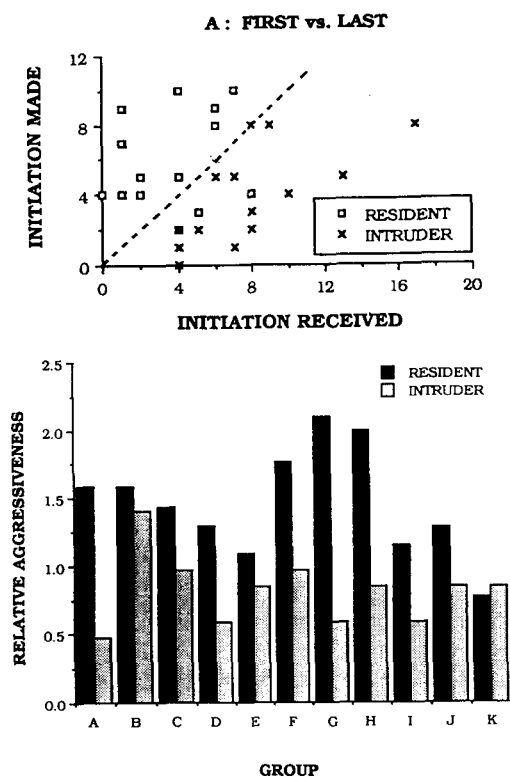


Fig. 5. Relative aggressiveness of the each group (as measured by the difference between "initiation received" and "initiation made" of agonistic behavior).

Relative Aggressiveness (R.A.) = number of initiation made/number of initiation received.

- A: 1st-day fish vs. 6th-day fish.
- B: 1st-day fish vs. 2th-day fish.
- C: 1st-day fish vs. 3th-day fish.
- D: 1st-day fish vs. 4th-day fish.
- E: 1st-day fish vs. 5th-day fish.
- F: 2st-day fish vs. 5th-day fish.
- G: 2st-day fish vs. 3th-day fish.
- H: 2st-day fish vs. 4th-day fish.
- I: 3st-day fish vs. 4th-day fish.
- J: 3st-day fish vs. 5th-day fish.
- K: 4st-day fish vs. 5th-day fish.

or territory was not continuously occupied by the resident, in which case a neighboring fish or an outsider often took it over sporadically. Nevertheless when the resident return-

ed much more frequently by the residents toward the intruders than vice versa (Fig. 4.). There were significant differences between residents and intruders with respect to the number of exchanges that they initiated. The residents made initial challenges more often than they received them from intruders (Fig. 5-A,  $P < 0.05$ ). Thus, the residents were more likely to initiate aggressive behavior as well as receive less initiation from the intruders and won significantly more of the victories in its territory (Fig. 5-B,  $P < 0.001$ ). Therefore, the resident was more aggressive, and the intruder was less aggressive in all interactions in which they were involved, as seen in other fishes (Gibson, 1968; Phillips, 1971b; Grossman, 1980). Aggressiveness of the intruders was variable, and these fish behaved in different ways to a new and different environment. Hinde (1966) explained this phenomenon as "fear motivation" that reduces the initiation of aggressive tendencies by the intruders. Thus, it takes time for the intruders to become familiar with a new environment before they become active.

Some of home range overlapped considerably. Invasion of other individuals' area caused an increase in aggression by the resident. When the intruder attempted to enter the resident's area, it was rapidly chased away. After attacking the intruder, the resident usually returned to the exact original position or the area previously occupied. However, a home range

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ed to that area, the intruder usually was driven away after an exchange of agonistic behavior.

The results from this study with artificial territories indicate that resident status and territoriality are related even if there are behavioral differences between fish in the natural environment and in small aquaria.

Although the outcome of competition for a territory is dependent partly on intrinsic factors such as size and sex, the residency effect seemed to be more important in access to resources and increased fitness. However, no one factor completely overrides the other factors influencing intraspecific aggression in the naked goby.

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### 망둑어의 一種, *Gobiosoma bosci*의 勢力圈占有 生態

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망둑어의 일종인 *Gobiosoma bosci*의 세력권 점유행동을 실험실에서 24시간 마다 관찰을 하였다. 각 개체들은 크기나 성별에 관계없이 접근, 위협, 공격, 그리고 싸우는, 세력권을 유지하기 위한 적대행동을 보였다. 실험동물의 체색변화는 실험기간동안 계속적으로 변화하였으며, 점유자와 침입자의 크기가 비슷한경우 싸우는 시간이 길었으며 체색의 변화가 심하였다.