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A comparative study of two goby shrimp associations in the Caribbean Sea

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Abstract
In Curacao (Netherland Antilles, Caribbean Sea), two species of gobies, *Nes longus* (*N. longus*) (Nichols 1914) and *Ctenogobius saepepallens* (*C. saepepallens*) (Gilbert & Randall 1968) with their associated shrimp *Alpheus floridanus* (*A. floridanus*) (Kingsley 1878) were observed. Data were collected on feeding behaviour, distances from their burrows, and interactions among conspecifics. Results confirm that the partnership of *C. saepepallens* and its shrimp is facultative, but show differences to former observations. Possible reasons for this are discussed.

Keywords: Symbiotic association, *Alpheus floridanus*, *Nes longus*, *Ctenogobius saepepallens*

1. Introduction

The association between gobiid fishes and burrowing shrimps is a symbiosis where the shrimp maintains a burrow while the goby stands watch, retreating quickly into the burrow when danger approaches and thereby warning the shrimp, which has poor vision compared to the goby (Karplus, 1987). The symbiotic relationship between members of the family Gobiidae and shrimps has been described and investigated in various locations of the world, mainly the Indo-Pacific region (Karplus et al., 1972, 1974; Karplus, 1981; Karplus et al., 1981; Yanagisawa, 1982; Migita and Gunji, 1996; Yoshino and Shimada, 2001; Thompson, 2004, 2005; Thompson et al., 2005). Little information is available on associations from the Atlantic (Weiler, 1976; Karplus, 1987, 1992; Randall et al., 2005; Wirtz, 2005). Karplus (1992) concluded that *C. saepepallens* and *N. longus* both live in an obligatory partnership, though he had not observed *C. saepepallens* in detail due to its rare occurrence within the study area. He compared *N. longus* to another facultative fish partner, *Bathygobius curacao*, which he observed with the same alpheid species, and concluded that the fish partners differ in complexity and efficiency of their communication system which resulted in different times spent outside the burrows. When associated with *B. curacao* shrimps show similar behaviours as when associated with *C. saepepallens*: a significantly lower frequency exiting and retreating into burrows when antennal contact can not be established with a goby (Karplus, 1992). He observed tail flicking signals in both *N. longus* and *C. saepepallens,* but not in *B. curacao* and concluded that the development of tail flicking signals is a step into an obligatory partnership which allows the goby to warn the shrimp while staying outside the burrow.

Randall et al. (2005) sum up the results of two studies in Belize, one conducted on the ecology of Caribbean gobies focused on stomach contents and the other on behavioural underwater observations documented by video and photography. They suggest that Karplus' observations of *B. curacao* and *A. floridanus* in combination with their observations of *C. saepepallens* and their shrimp suggest a first evolutionary step towards the more complex interactions that exist for *N. longus and* 13 genera of Indo-Pacific gobiid fishes.

Random observations by the first author (AK) led to conclusions that the goby shrimp associations found in Curacao differed in their behaviour and ecology to the two previous studies in the following ways: 1) The relationship

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between *C. saepepallens* and its shrimp appeared to be less well established with large distances existing between them, unlike in Karplus' (1992) study, but in accordance to Randall et al. (2005). 2) No competition for food or territory between the two species of gobies *C. saepepallens* and *N. longus* could be observed as had been reported by Randall et al. (2005).

The present study adds new data to the poorly studied goby-shrimp association of *C. saepepallens* and shows evidence for a non-obligatory association by providing data on the behaviour of the fishes, their shrimps, and the relative distances to each other. These data are compared to *N. longus,* which lives in an obligatory partnership, and to the two previous studies. We were focused on looking for evidence which indicates that the *C. saepepallens* association may be evolving into an obligatory partnership.

The observation sites of all three studies (including the present study) are similar; sandy to silty bottoms in shallow water with adjacent sea grass areas: Karplus' (1992) study was conducted in a channel; Randalls' et al. (2005) study area inside a lagoon bordered by mangroves to one side.

2. Material and Methods

The study area is located next to the Curacao Sea Aquarium in Curacao, Netherland Antilles, Caribbean Sea. It is situated inside a channel which divides the facility from the mainland. The depth ranges from 1.5 to 2.5 m and comprises an area of approximately 300 m^2. There are two openings which connect the channel to the surrounding sea, currents are usually flowing from south to north and are variable in strength from 0 to 50 cm/sec. The bottom consists of fine sand and mud with areas of dense seagrasses. The dominant species of fishes in the area, apart from *C. sapepallens* and *N. longus* were *Coryphopterus* spp. (Gobiidae), mullets (Mugilidae), snappers (Lutjanidae), parrotfish (Scaridae), doctorfish (Acanthuridae) and grunts (Haemulidae).

The observations were made by two divers, one of them the first author, AK, and a field assistant, JGBR: The densities of *C. saepepallens* and *N. longus* were estimated visually to be between eight to ten *C. saepepallens* and one to two *N. longus* per square meter, within the study area. Fish were randomly chosen for each observation, their size estimated and their behaviour recorded on underwater slates. A total of 24 fish of each species were observed. Observations took place in the morning (07:00 – 08:00 h), at noon (13:00 – 14:30 h) and in the afternoon (17:00 – 18:00 h) to observe any changing activity pattern throughout the day.

Both species were observed for a period of 20 min, between Dec. 2nd and Dec. 9th, 2005. The observations started after a 5 min period for the fish to become acclimated to the diver's presence. The numbers of times the fish or shrimp exited and entered the burrows were counted and maximum distance between the fish and the burrow was estimated.

The Mann-Whitney Rank Sum Test was used to compare mean values of different counts and the results are presented as mean ± standard deviation (SD) in Table 1 and 2. Statistical analyses were performed using SigmaStat 2.03 (SPSS Inc., Chicago).

Table 1. *Alpheus floridanus* mean number of exits and entries (± standard deviation) when associated with *Ctenogobius saepepallens* (*Cs*) and *Nes longus* (*Nl*). Results compared between the two species show statistically significant differences ($P<0.001$).

	Exits		Entries	
	Cs	*Nl*	*Cs*	*Nl*
Morning	9 ± 7	22 ± 24	9 ± 9	41 ± 14
Noon	5 ± 8	17 ± 25	10 ± 14	25 ± 20
Afternoon	7 ± 6	32 ± 26	11 ± 6	34 ± 24

Table 2. Minimum, maximum and mean distances (± standard deviation) in cm from burrow for *Nes longus* (*Nl*) and *Ctenogobius saepepallens* (*Cs*). Results compared between the two species show statistically significant differences ($P<0.001$).

	Cs	*Nl*
Min. – max. distance	5 – 170	1 – 15
Mean	44 ± 35	8 ± 10

3. Results

The shrimp *A. floridanus* was observed with both gobiid species. This species has been reported to live in association with *N. longus* and *C. saepepallens* in the western tropical Atlantic (Karplus, 1987; Randall et al., 2005). When observed with *C. saepepallens,* shrimps came out less frequently, for shorter periods of time, and stayed closer to the burrows, than when associated with *N. longus* (Fig. 1 and Table 1). The shrimps never lost antennal contact with *N. longus*. Whenever two shrimp were observed in a burrow, only one of them stayed outside the burrow for extended periods of time (>5 sec – 1 min) picking through the sediment with their chelae, or constructing a trench. When entering, the shrimps were frequently observed taking sediment into the burrows. Shrimps not in contact with a goby remained in the burrow, protruding no more than half way.

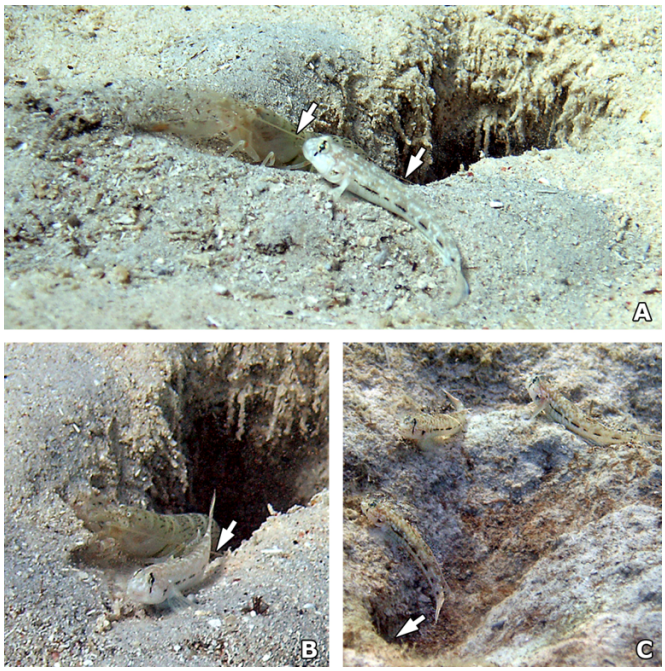

Figure 1. *Ctenogobius saepepallens*. A. and B. *C. saepepallens* with *Alpheus floridanus*. Arrow indicates the shrimp's antenna which is in contact with the goby. C. Three individuals of *C. saepepallens* next a burrow.

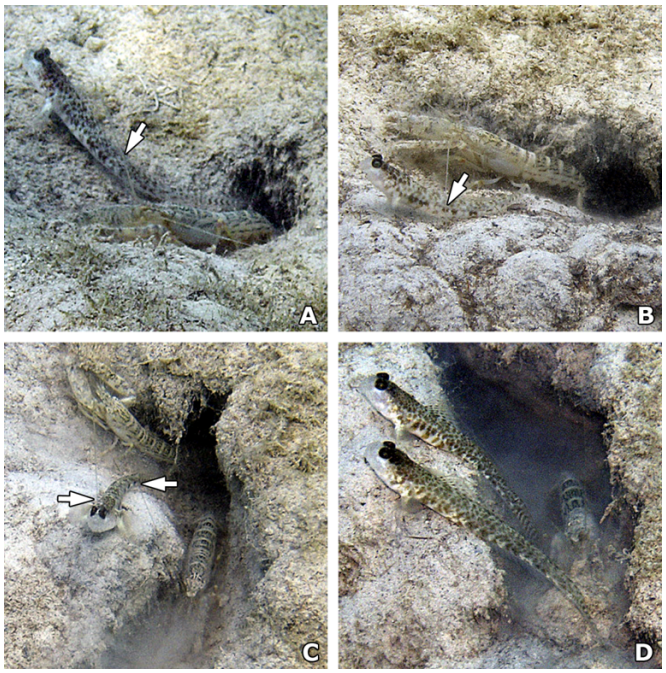

Figure 2. *Nes longus*. A. and B. *N. longus* with *Alpheus floridanus*. Arrows indicate antenna of shrimp in contact with the goby. C. *N. longus* with two shrimps. Arrows indicate antennae of gobies on shrimp. D. Two *N. longus* with one shrimp.
See cover illustrations.

The *N. longus* observed were always found in association with shrimp, *C. saepepallens* were not always in association with shrimp. They never were found close to a burrow during the entire observation period of 20 min. That behaviour resulted in few exits of the shrimp (Table 1). While observed, *C. saepepallens* moved 3 to 4 m in distance, whether they were associated with a shrimp or not, and fed almost continuously from the sediment. In contrast, *N. longus* generally sat outside their burrows without moving more than 10 to 15 cm from the entrance (Table 2). The two fishes were not observed competing for food or territory.

Ctenogobius saepepallens. Fish were between 3 and 7 cm in total length (TL), their associated shrimps between 3 and 8 cm. When associated with a burrow, *C. saepepallens* stayed at a distance of 5 to 170 cm from it, often too far for the shrimp to establish contact with its antennae (Table 2 and Fig. 1). In 67% of the observations two to five *C. saepepallens* were around one single burrow (Fig. 1c). *C. saepepallens* was observed on four occasions entering various burrows, within one observation time period. They were observed expelling conspecifics but never interacting with *N. longus*. A commonly observed behaviour between *C. saepepallens* was for two fish to approach each other and for one of them to start swimming around the other, stopping at times and moving its body up and down through use of the ventral fins.

In 13% of the morning and noon observations two shrimps were observed in a burrow with *C. saepepallens*, in the afternoon only one shrimp was observed. Whenever the goby shares a burrow with a shrimp, the shrimp will push sediments completely away from the opening and behind the goby. If a goby is not near the entrance, sediment was pushed out only to the opening of the burrow. On several occasions *C. saepepallens* entered small burrows in the substratum, without a shrimp and in three cases they showed maintenance behaviour such as moving sediment and algae by mouth or tail.

In one observation *C. saepepallens* was at the entrance of a burrow with a shrimp, flicking its tail. This behaviour has been reported as warning signal in goby shrimp associations by Karplus et al. (1979) and Karplus (1987), but did not cause any reactions in the shrimp. In another occasion two *C. saepepallens* were sitting at a burrow flicking their tails with no shrimp in sight.

Nes longus. Fish measured between 3 and 12 cm, their shrimps between 6 and 10 cm. The maximum distance between *N. longus* and their burrows ranged from 1 to 15 cm (Table 2 and Fig. 1). Each fish was associated with a shrimp; there were two shrimp in the same burrow in 25% of the morning and noon observations and 63% of the afternoon observations (Figs. 2a–c). In 42% of all observations, two individuals of N. longus were sitting outside a burrow (Fig. 2d), and in 20% of the observations *C. saepepallens* was exiting or entering the same burrow.

N. longus was observed 16 times quickly retreating into the burrow: when approached by *Gerres cinereus* (5), with no apparent reason (10) and when approached by *Coryphopterus* spp. (1). On one occasion *N. longus* was observed moving from one burrow opening to another, immediately after the goby arrived a shrimp started constructing at the new location. *N. longus* was feeding in 15% of the morning, 31% of the noon and 54% of the afternoon observations. When feeding, *N. longus* attacked specific prey on or close to the substrate.

4. Discussion

N. longus lives in an obligatory association with *Alpheus floridanus* whereas *C. saepepallens* is in a facultative partnership. The facultative relationship is demonstrated by the following results:

- Only 2% of gobies were observed in an obvious association with a shrimp, the remainder were moving around or close to burrows with or without shrimp. However, if fish were close to shrimp burrows, they were not close enough for the shrimp to establish antennal contact.
- *C. saepepallens* were generally not associated with a specific burrow, but changed locations frequently.
- When associated with a burrow they did not stay close to it, but in distances up to 170 cm, which resulted in fewer shrimp activities (measured in entries and exits from the burrows) as compared to *N. longus* in the same period of time.
- Fish were observed in burrows not constructed by a shrimp.

In an investigation of the burrows of *A. floridanus* it has been concluded that shrimp were living at least in pairs (Dworschak and Ott, 1993). Earlier accounts of shrimp living in pairs as well as moving between adjacent burrows have often concluded this activity was a part of their reproductive behaviour (Karplus, 1987). Investigations on burrows of *A. floridanus* have found paired openings to the shrimp's burrows (Weiler, 1976; Karplus, 1987; Dworschak and Ott, 1993). Looking at the results for *N. longus*, where in most of the observations in the afternoon two shrimps were seen, it is obvious that they were there during the entire day, only more active in the afternoon. The situation could be similar for *C. saepepallens,* where two shrimps were observed in the morning and at noon, but never in the afternoon. However, the observations for *C. sapepallens* and their shrimp were too few for conclusions to be made.

The shrimp were frequently observed taking sediment into the burrows, a behaviour which has been documented in alpheids: the shrimps were reported to harvest sea grass, introduce detritus of the upper sediment layers into their burrows and eat it (Karplus, 1987; Palomar et al., 2004). Our conclusions about facultative and obligatory partnerships of *N. longus* and *C. saepepallens* are the same as Randall et al. (2005), except for three differences:

- They state that the shrimp come out of the burrow without or only initially trying to establish antennal contact with the goby. We observed the shrimp searched for the goby with its antennae, if present, it remained in contact and increased its digging activity. If the goby was not present, the shrimp did not come out of the burrow.
- Regarding their feeding behaviour, they observed that both fish take up sediment when feeding, in the present study only *C. saepepallens* showed that behaviour. They state that *N. longus* quickly captures prey further away from the burrow, which we also observed. Randall et al. (2005) conclude that the gobiids are competing for food and that *N. longus* defends the vicinity of its burrow against *C. saepepallens* for that reason. They refer to previous studies of stomach contents of both species in Belize. In the present study no competition for food or territory between the two gobies was observed. Stomach contents analysis to support these data would be desirable.
- They did not observe tail flicks as warning signals. According to Karplus (1992) communication between gobies and shrimp consists of tail warning flicks and head first entries of the goby into the burrow. Head first entries into the burrow of both species of gobies could be observed in the present study, while tail flicks could only be observed with individuals of *C. saepepallens*. As the communication system between gobies and shrimps is complex and often very rapid, detailed studies of their behaviour will ideally have to be conducted by film analyses (Karplus et al., 1979; Karplus, 1987).

Differences in the development of a relationship between the shrimps and gobies may explain the variation in observations as described by several authors. Ecological adaptations in this context may also play an important role and remain a topic for further studies. As the sites for all three studies were very similar regarding their ecological conditions, they are not considered to have a major impact.

The partnership between *C. saepepallens* and their shrimp certainly is more advanced than between *Bathygobius curacao* and *A. floridanus*, which have not been observed to produce tail flicks (Karplus, 1992). To understand the development into modern goby shrimp associations, like those reported from the Indo-Pacific region, further detailed studies of the associations in the Atlantic Ocean, especially facultative ones as *C. saepepallens* and their communication system will have to be conducted and compared.

Our results show that the partnership of *C. saepepallens*

and its shrimp is facultative. It could be developing into an obligatory association as seen in *N. longus* and *A. floridanus*. However, we can not assume that evolution is a linear process, results can be altered by ecological conditions and lead to a different outcome.

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