Reef fish foraging associations: "Nuclear-follower" behavior or an ephemeral interaction?

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Abstract. A widespread feeding association among reef fishes involves nuclear and attendant species. The former causes a bottom disturbance attracting several species known as followers, which feed on items exposed by this activity. Herein we propose a novel classification for foraging associations namely "ephemeral foraging association" formerly grouped together as nuclear-follower behavior. For this classification, the interaction between the goldspotted eel *Myrichthys ocellatus* and other six reef fish species was taken as a study case. The present study was conducted in the Tamandaré Reef Complex, Pernambuco State, Northeastern Brazil (8º44'26''S and 35º05'11''W). Observations were performed during daylight periods while snorkeling with a total of 55 hours of direct observation. We recorded 18 occurrences of the "ephemeral foraging association", while 42 individuals were observed. Interactions lasted from 30 seconds to 5 minutes and total fish lengths (TL) ranged from four to ten centimeters. Most ephemeral foraging species were carnivores and territorial omnivores. Based on factors such as the way the associations are triggered, time spent in the association, cognitive reactions and territoriality of attendants the recorded interactions may be separated into a different category.

Key words: Foraging behavior, ephemeral foraging association, opportunist interaction, *Myrichthys ocellatus*

Introduction

A foraging association is characterized by the joining of individuals from two or more species in feeding activity, ranging from simple to complex, and from highly transient to obligate (Baird 1993; Strand 1998; Lukoschek and McCormick 2000; Bshary et al. 2006). Multi-species fish foraging interactions can be classified into two major categories: shoaling and attendant associations, by the latter composed by four different types: 'nuclear-follower', 'interspecific joint hunting', 'hunting by riding' and 'aggressive mimicry' (Lukoschek and McCormick 2000).

Nuclear-following associations are common among reef fishes, whereas species can act as nuclear or followers (Karplus 1978; Dubin 1982; Lukoschek and McCormick 2000; Sazima et al. 2007; Araújo et al. 2009). Other reef animals are also known to engage in such interactions performing the "nuclear" function (Strand 1988; Gibran 2002; Sazima et al. 2004; Sampaio et al. 2007; Machado and Barreiros 2008). The nuclear species are believed to maintain interaction cohesion by facilitating feeding, allowing the species to rely on items that would be otherwise not accessible, and/or anti-predator pay off, reducing predation risk while feeding in groups (Diamant and Shpigel 1985; Strand 1988; Srinivasan et al. 2010). Therefore, such interaction plays a significant role on reef trophodynamics, as they are frequent and usually benefit the follower species (Bshary et al. 2006).

Several studies describe multiple feeding interactions of reef fishes as nuclear-following associations (e. g. Dubin 1982; Strand 1988; Sazima et al. 2007; Araújo et al. 2009). However, descriptions of novel events of nuclear-follower interactions do not take into account the complexity and importance implied by these associations, considering the energy allocated to maintain the association during long periods of time and distances. For instance, there are rapid opportunistic events where the attendant species spend fewer time and energy to get involved on the association. In fact, grouping these feeding interactions together as 'nuclear-follower associations' ultimately simplifies the more complex ones, being biologically meaningless, as species significance in associations are not put in perspective.

Herein we propose a novel category for foraging associations namely "ephemeral foraging association" formerly grouped together as nuclear-follower behavior. For this classification, the interaction between the goldspotted eel *Myrichthys ocellatus* and six other reef fish species were taken as a study case.

Material and Methods

This study was conducted between November 2009 and May 2010, in the Tamandaré Reef Complex, Pernambuco State, Northeastern Brazil (8º44'26''S and 35º05'11''W). Habitats surveyed comprised algal beds and sandbanks adjacent to reef crests, with depths ranging from 0.5 to 2.5 m (Fig. 1). Macroalgae

from the genera *Sargassum, Padina, Caulerpa, Udotea, Gracilaria, Dictyota,* and *Dictyopteris* compose the algae mats. The ichthyofauna present is mostly composed of juvenile herbivores, such as *Stegastes* spp., *Acanthurus* spp., and *Sparisoma* spp., and small carnivores such as *Halichoeres* spp., *Haemulon* spp., *Labrisomus* spp., *Chaetodon striatus* and *Epinephelus adscencionis* (unpub. data).

Observations were performed during daylight while snorkeling. Each observational session lasted for at least one hour, with a total of 55 hours of direct observation. Feeding associations were photographed and video-recorded and focal animal methodology recording all occurrences was used (Altmann 1974). Total length (TL) was visually estimated and recorded on PVC slates. Sessions began when an individual of *M. ocellatus* was sighted foraging over sandy bottoms immediately attracting attendants.

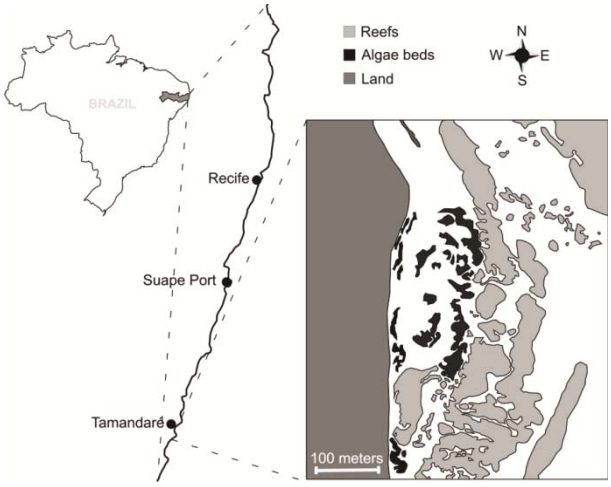

Figure 1 – Map of study area, showing the reefs and algal beds on Tamandaré reef complex – Northeastern Brazil.

Results and Discussion

Recorded species in association with *M. ocellatus* while feeding were *Acanthurus bahianus* (juvenile), *Halichoeres poeyi, Labrisomus nuchipinnis, Labrisomus cricota, Stegastes fuscus* and *Stegastes variabilis* (juvenile) (Fig. 2). Were observed 18 occurrences for the "ephemeral foraging interaction" (EFA), while 42 individuals were recorded. Interactions lasted from 30 seconds to 5 minutes and total fish lengths (TL) ranged from four to ten centimeters. Most species were carnivores and territorial omnivores (Table 1).

Species from genus *Halichoeres* are known for their opportunistic behavior (Roede 1972; Coyer 1995; Jones 2002). In fact, any movement on the substrate (stones revolved, broken sea urchins or artificial feeding by divers) attracts their attention (authors' pers. obs.). This is also confirmed by previous studies where these species were recorded in association with other reef organisms, such as octopuses, sea turtles (Sazima et al. 2007), and eels, including *M. ocellatus* (Sazima et al. 2007; Araujo et al. 2009), indicating a frequent involvement in multi-species associations.

Spp	N	T.L (cm)	Time	Trophic
Acanthurus bahianus	1	4	40 sec.	Herb.
Halichoeres poeyi	5	4 – 10	50 sec. / 1min.	Omn.
Labrisomus nuchippinis	4	6	3 min. / 5 min.	Carn.
Labrisomus cricota	2	5 – 8	40 sec. / 2 min.	Carn.
Stegastes fuscus	4	5	30 sec. / 1 min.	Terri. Omn.
Stegastes variabilis	2	5	30 sec. / 3 min.	Terri. Omn.

Table 1 – List of species involved on "Ephemeral foraging interaction" events. **N occur.– Occurrences** = Number of occurrences; **T.L** = Total Length**.**

In some cases, the feeding nuclear species can be negatively affected by the association, when competition with the attendant takes place (Lukoschek and McCormick 2000; Craig and Erisman 2010). Indeed, just after few minutes an adult individual of *M. ocellatus* (60 cm TL) foraged, an exposed small crab (Brachyura: Ocypodidae, TL = 5 cm), stimulated the approach of 10 individuals of *Halichoeres poeyi* (Fig. 2). The crab had its carapace broken into pieces by the frenzy *H. poeyi*, as the meal was taken away from *M. ocellatus*. A similar event was observed at Cabras Island – Southeastern Brazil, where the species behaved the same way (J. P. Krajewski, pers. comm.).

Another event presented five adult *H. poeyi* next to the head of a *M. ocellatus* individual (50 cm TL) by a relatively short period of time (~2 min.), while the eel foraged. During observation, several individuals were also attracted, including three juvenile *Acanthurus bahianus* (TL = 4 cm) and one juvenile *Stegastes variabilis* (TL = 5 cm). An adult of *Stegastes fuscus* (TL = 10 cm) was also recorded associating with *M. ocellatus* during its foraging, but this association lasted only for a brief period (< 2 min.) while the eel moved throughout its territory.

In two other occasions, *M. ocellatus* attracted the attention of an individual of *Labrisomus cricota* (TL = 5 cm), which remained close to the eel, performing brief swimming movements close to its head. Interactions involving opportunistic fishes such *Labrisomus nuchippinis, Halichoeres bivittatus* and *Stegastes dorsopunicans* with the cephalopod *Octopus vulgaris* were previously recorded (Mather 1992). These associations are usually brief and come with the benefit of a new food source. Sampaio et al.

(2007) also observed the hairy blenny *L. nuchipinnis* following closely a foraging hermit crab of the genus *Paguristes* (Diogenidae). These species clearly follow the same trend in relation to multi-species association.

Figure 2 – Ephemeral foraging associations between *Myrichthys ocellatus* and other reef fishes. **A** - *Halichoeres poeyi* and *Labrisomus nuchipinnis*, **B** - *Stegastes fuscus*, **C** - *Halichoeres poeyi.*

Species sharing less-complex interactions are observed in several studies (Lukoschek and McCormick 2000; Sazima and Grossman 2005), and are considered to fall within the scope of nuclear-follower behavior category. However, these fish behave as the opportunity is shown, perceiving a clear chance to feed on easy preys. The triggering factor for attracting opportunistic fish is mainly the bottom disturbance (Krajewski 2009). This is particularly true for fishes with distinctive diets from the nuclear species, such as herbivores and omnivores. Short-term associations are observed with the nuclear species and the approach consists on substrate disturbance, which enhance the probability of any resource disclosure. Species as the damselfish *Stegastes variabilis* and *Stegastes fuscus* are recognized by their territorial behavior (Ferreira et al. 1998; Osório et al. 2006) and do not swim large distances away from their territory, except while chasing 'intruders' away. They commonly explore other available resources while their territory "gardens" are safe, i.e. when the opportunity occurs inside or within the vicinities of their territories. Regardless of their territoriality, damselfish observed did not attack the Goldspotted eel. This "friendly behavior" could be a result of small overlapping diets among them (Randall 1967; Ferreira et al. 1998), except for juveniles, which are known to incorporate supplementary animal protein on their diet (Ferreira et al. 1998; Feitosa et al., in press).

Based on such factors as the way the associations are triggered, time spent on the association and territoriality of attendants, these interactions may be separated into a different category among known attendant associations (Fig. 3), named ephemeral foraging association (EFA). The proposal of a novel kind of feeding association discloses its biologic value, as generalist and opportunistic. It does not judge the definition of the following behavior per se as defined by Fricke (1975), but clarify the meaning of the interaction. This fact implicates that, as follower, species do not only interact, but also accompany the nuclear species during a determined period of time, which would confer different levels of interaction complexity.

The interactions presented herein were briefly compared to the nominal following behavior reported in other studies, as the opportunist species approached *M. ocellatus* during its feeding, motivated by bottom disturbance only. During following behavior, interactions last longer and the nuclear species is followed for great distances.

The time and distance spent on the association between the nuclear and the attendant species is not often mentioned on previous works addressing this subject. This fact is also highlighted by Strand (1988) as well, which suggests the analysis of these parameters to better explain the role of species in the interaction. For the studies that actually mention these parameters, Karplus (1978) observed the feeding association between the grouper *Epinephelus fasciatus* and the moray eel *Gymnothorax griseus*, which lasted from several minutes to over half an hour. Strand (1988) recorded the nuclear-following behavior between moray eels and other reef fish within a long time span (from18.5 and up to 80 minutes) with *Mycteroperca rosacea* as the attendant. On a more recent work, Gerhardinger et al. (2006) observed the association between *Myrichthys ocellatus* and *Epinephelus marginatus*, when it lasted for two minutes. However, the authors asserted it could have been longer, as they were not aware of interaction start point.

Species of families Serranidae and Epinephelidae are the most frequently recorded interacting with *M. ocellatus* (Maia-Nogueira et al. 2008; Araujo et. al 2009) and other Ophichthids (Sazima et al. 2007; Strand 1988; Diamant and Shpigel 1985). Time span and distances travelled during association for these records are greater and more complex interactions are

observed. For such reasons, these species are considered typical followers and maintained in the "Nuclear-Following behavior" category.

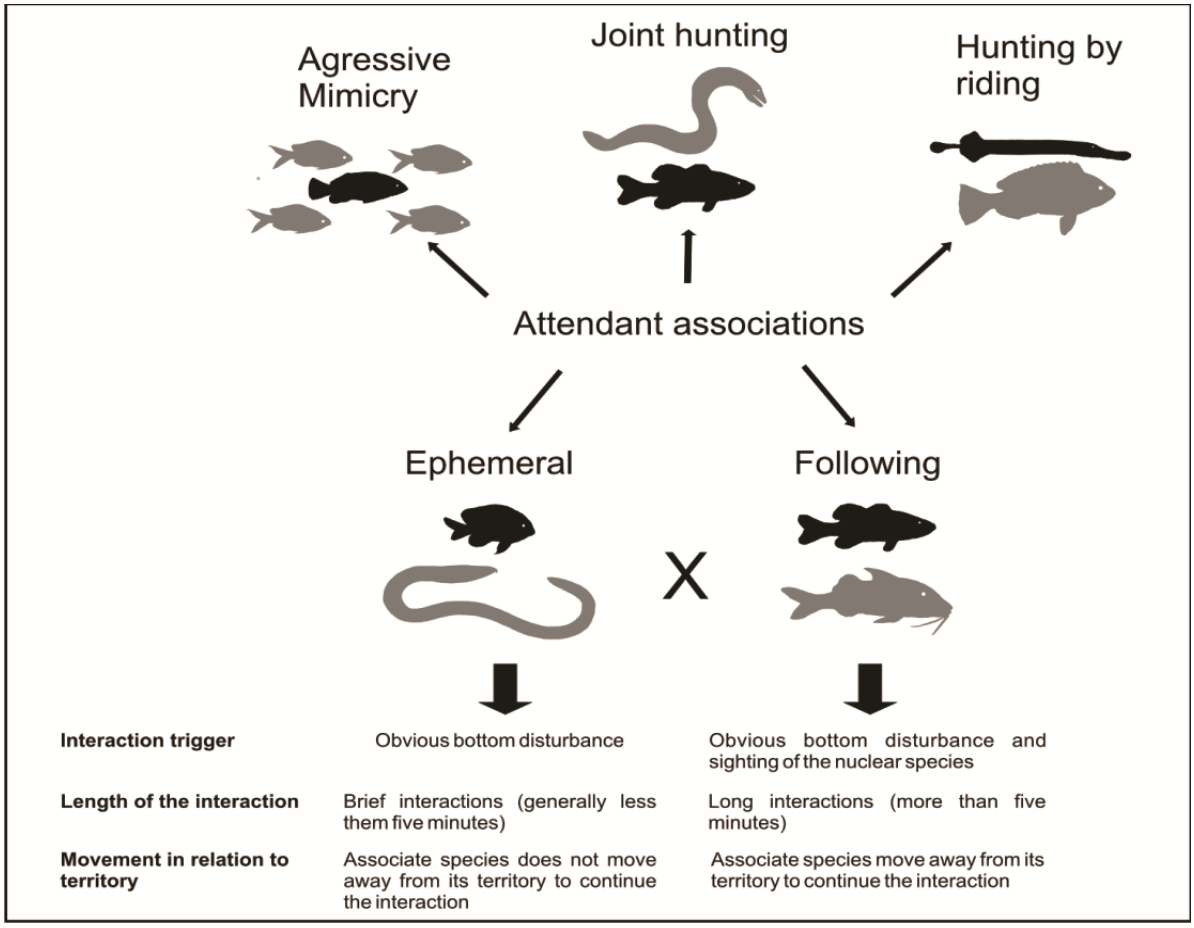

Figure 3 – Diagram showing the types of attendant foraging associations (sensu Lukoschek and McCormick 2000) with the proposed category ephemeral foraging association. Differences between *Ephemeral* and *Nuclear-Follower* associations are emphasized

Attendants are usually inquisitive (Gerhardinger et al. 2006), and this is a peculiar attribute of their behavior and social treats. These species are not attracted only by bottom disturbance, and it is also proved that the interactions are nonrandom (Bshary et al. 2006), for somehow they have a cognitive capacity related to *M. ocellatus*, as some signals could indicate a higher chance to obtain benefits (Bshary et al. 2006). The amount of cognitive response of species is a subject of discussion (Braithwaite and de Perera 2006; Bajer et al. 2010) and should be addressed in further studies encompassing *in situ* or aquaria experiments to elucidate any other possible mechanisms triggering these associations.

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