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Octopus mimicking its follower reef fish

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We describe a possible example of social mimicry between *Octopus insularis* and the small grouper *Cephalopholis fulva*, which frequently associate during foraging at Fernando de Noronha Archipelago, Brazil. The octopus, when swimming backwards, jet-propelled, becomes similar in colour and shape to accompanying *C. fulva* individuals and is therefore less conspicuous within the fish group. We regard this as an instance of social mimicry, a form of protection against visually-oriented predators in which different species similar in shape and colour mingle for the advantage of grouping. Even when swimming backwards alone, *O. insularis* may become similar to foraging *C. fulva* individuals, another putatively protective behaviour. We suggest that the feeding association commonly found between *O. insularis* and *C. fulva* minimized the evolutionary costs for the origin of mimicking by the octopus.

Keywords: social mimicry; *Octopus insularis*; *Cephalopholis fulva*; foraging association; Fernando de Noronha Archipelago

Introduction

The plasticity of body shape, ability to change colour, and good visual perception of contrasts, brightness and shapes allow octopuses to match several kinds of patterns and textures and so become well camouflaged, even if cephalopods seem colour blind (Mäthger et al. 2006). Most octopus species have a high capacity for camouflage against their background and, indeed, crypsis is regarded as a common defensive tactic of cephalopods against visually-oriented predators (Hanlon and Messenger 1996; Hanlon 2007). However, despite this plasticity of body shape and colours, mimicry as a defensive tactic is reported for very few octopus species, among them *Thaumoctopus mimicus* and *Wunderpus photogenicus* that dwell on sandy bottoms in Indonesia and adopt a superficial resemblance to venomous or poisonous animals, including fish and sea snakes (Norman et al. 2001; Hochberg et al. 2006; Hanlon et al. 2008).

Here, we have recorded a putative example of mimicry between the octopus *Octopus insularis* and the coney *Cephalopholis fulva*, a mid-sized grouper abundant in the shallow reefs of Fernando de Noronha Archipelago, off Brazil, tropical west

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Atlantic. *Octopus insularis* is a common species in the archipelago (Leite et al. 2008) and while foraging it is usually followed by several *C. fulva* individuals that prey on the small fish and invertebrates exposed by the substratum-disturbing activities of the octopus (Sazima et al. 2007).

Material and methods

About 100 h of scuba diving and snorkelling sessions distributed over five consecutive years (from 2000 to 2005) were undertaken in shallow reefs (1–15 m depth) at Fernando de Noronha Archipelago (03°50′S; 32°25′W), about 350 km off the coast of northeast Brazil, tropical west Atlantic. During the observations, we recorded the behaviour of octopuses and accompanying fish using plastic slates, photographs and video.

We quantified the colour pattern of five octopus individuals that were followed by coneys by randomly selecting 30 still frames from a 1- to 10-min video sequence for each octopus individual. Frames were extracted from the videos, saved as figures and viewed on a computer monitor. When moving close to the bottom, octopuses were classified as conspicuous, moderately cryptic or highly cryptic in each frame, following a methodology developed by Hanlon et al. (1999). In those frames in which the octopuses were swimming backwards, jet-propelled, in the water column, we classified them as not similar, moderately similar or highly similar to the accompanying coneys (modified from Hanlon et al. 1999). The octopuses in the frames were judged according to the following criteria: brightness, colour, pattern and shape (see Hanlon et al. 1999 for detailed methodology). Colours and contrast were assessed by human observation. Several other studies describe mimicry from the same perspective and some of these cases were experimentally confirmed to enhance protection of the mimic species against visually-oriented predatory fish (see reviews in Moland et al. 2005 and Randall 2005). The frames were analysed by the same observer to standardize the procedure.

Results

We recorded 39 individuals of *O. insularis* followed by one to 14 grouper individuals (Figure 1A). Most of these octopus individuals (33) were followed by at least five fish and they always remained in the centre of the fish group. All octopuses followed by fish remained mostly camouflaged against the bottom. However, when swimming backwards, about 40 cm above the bottom, all octopuses followed by *C. fulva* individuals became similar in shape and colour to the accompanying fish (Figure 1B).

In the frames analysed from videos, octopuses were recorded moving close to the bottom in 77.7% of the frames and swimming backwards in 22.3%. While followed by *C. fulva* and moving close to the bottom, octopuses spent most time (72.1% of the frames) highly cryptic against the bottom. On the other hand, when swimming backwards, all recorded octopuses changed their colour/contrast pattern and became similar (15.1% of the frames) or highly similar (84.8% of the frames) to the accompanying *C. fulva* (Figure 1B,C). This colour change rendered the octopus inconspicuous within the fish group (Figure 1B).

We also recorded 12 octopus individuals not followed by any fish. All these individuals remained mostly camouflaged in the bottom, but turned into a bicolour pale and dark pattern when they started to swim jet-propelled backwards. This colour

Figure 1. (A) *Octopus insularis* (centre) followed by 10 *Cephalopholis fulva*. (B) While moving backwards jet-propelled, the octopus (centre) matches the bicolour contrasting pattern of the accompanying *C. fulva*, becoming inconspicuous within the fish group (taken from a video frame). (C) Detail of another fish–octopus group, showing the octopus matching another colour pattern (uniform brown) of *C. fulva*.

pattern is similar to the colours displayed by foraging *C. fulva* individuals. (Figure 2A,B).

Discussion

Octopus insularis remains mostly camouflaged against the bottom, as other octopus species do (Hanlon et al. 1999). However, when swimming in the water column *O. insularis* became very similar to the accompanying *C. fulva*, a behaviour that probably renders it inconspicuous to visually-oriented predators. Additionally, when seen from close to the bottom, a view that most benthic predatory fish (e.g. morays, snappers and grunts) have, the octopuses recorded here were even more inconspicuous because they were always in the centre of a group of fish with similar

Figure 2. (A) When moving alone, the octopus *Octopus insularis* adopts the bicolour pattern (taken from a video frame) similar to that of *Cephalopholis fulva* (B).

colour/contrast and shape to themselves. No other mimicking octopus species is reported to adopt such behaviour in the presence of a follower fish group (e.g. Norman et al. 2001; Hochberg et al. 2006; Hanlon et al. 2008).

This resemblance of the octopus to *C. fulva* while in groups may be regarded as an instance of social mimicry, a behaviour that has been well documented for birds and reef fish, in which two or more species similar in shape and colour gather in groups (Moynihan 1968, Randall 2005). The term 'school-oriented mimicry' (Dafni

and Diamant 1984) was initially used to describe an association in which a solitary fish joins schools of a similar species for the advantage of schooling. However, Randall and McCosker (1993) proposed that this term be replaced with "social mimicry" because this term was already in use for mixed flocks of birds (Moynihan 1968). In social mimicry, individuals presumably gain protection against visually-oriented predators as the result of the visual confusion created by the presence of several similar individuals (Moynihan 1968; Randall and McCosker 1993; Krajewski et al. 2004; Moland et al. 2005; Randall 2005).

Cephalopholis fulva can display several colour/contrast patterns (e.g. bicolour pale and dark, uniform reddish, reddish with yellow sides) and is able to change its pattern rapidly (Nemtzov 1993). *Octopus insularis* individuals were recorded as matching several of these patterns and so becoming similar to the accompanying fish. *Octopus insularis* is able to change its colour to match the follower fish, acting as a facultative mimic. To our knowledge, only three cases of facultative mimicry have been recorded, two for octopus species in the Indo-Pacific (Norman et al. 2001; Hochberg et al. 2006; Hanlon et al. 2008) and one for a reef fish, the bluestriped fangblenny, an aggressive mimic of the cleaner fish *Labroides dimidiatus* (Cheney et al. 2008). The case of *O. insularis* is probably the fourth case of facultative mimicry and reinforces the top heavy occurrence of octopuses in this kind of mimicry (three out of four).

The bicolour pattern displayed by *O. insularis* when swimming alone is also exhibited by other octopus species (Hanlon and Messenger 1996; Hanlon et al. 1999). *Octopus cyanea* in the Pacific is believed to protect itself from predators while displaying a bicolour contrasting pattern because it does not look like an octopus at all in such a situation and so may be ignored by predators (Hanlon et al. 1999). In the present study, the bicolour pattern displayed by *O. insularis* is similar to the pattern of some *C. fulva* individuals. However, we have no evidence that *C. fulva* is noxious or harmful to predators, so Batesian mimicry (Moland et al. 2005; Randall 2005) can be ruled out. Hence, the most probable function of the contrasting bicolour pattern of *O. insularis* while moving alone is also to render it a "non-octopus" to potential predators, as already suggested for *O. cyanea* in the Pacific (Hanlon et al. 1999).

As *C. fulva* and some octopus species similar to *O. insularis* (e.g. *O. vulgaris*) are widely distributed in the west Atlantic (Humann and Deloach 2002a,b; Leite et al. 2008), it is possible that they group during foraging and show additional instances of social mimicry elsewhere. Following behaviour by opportunistic reef fishes and the outstanding ability of octopuses to change their colour and shape may have been one important initial step for the origin of the social mimicry instance recorded here.

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