



Comparison of mortality and feeding behavior of the false cleanerfish *Aspidontus taeniatus* and the lance blenny *A. dussumieri* regarding the effects of mimicry

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Received: 14 June 2022 / Accepted: 31 October 2022
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Abstract

Many examples of mimicry have been reported in coral reef fishes of which the most well known is the mimicry of the blues-treak cleaner wrasse, *Labroides dimidiatus* by the false cleanerfish, *Aspidontus taeniatus*. To examine the effect of protective and aggressive mimicry of *A. taeniatus*, mortality and feeding behavior were compared with those of the non-mimic lance blenny, *Aspidontus dussumieri*, by field observations on the coral reefs of Miyako Island, Okinawa, southern Japan. Survival rate of *A. taeniatus* was more than twice higher than that of *A. dussumieri*, but the detected differences were not significant, and the effect of protective mimicry could not be determined. The benthic foods common to both species (the tubeworm, *Spirobranchus giganteus*, and the boring clam, *Tridacna crocea*) were very scarce in the study sites, and the feeding behavior of the two species was clearly different: *A. dussumieri* pecked at the bottom substrate, whereas *A. taeniatus* fed on fish fins and eggs of damselfish, regardless of body size. Our findings are the first documented evidence of the effect of aggressive mimicry on biting fish fins in relation to the availability of other foods not only in small but also in large *A. taeniatus*.

Keywords Aggressive mimicry · Fin biting · Food availability · *Labroides dimidiatus* · Protective mimicry

Introduction

Many examples of mimicry have been reported in coral reef fishes (Moland et al. 2005; Randall 2005; Robertson 2013). The false cleanerfish, *Aspidontus taeniatus* (Blenniidae) resembles the blues-treak cleaner wrasse, *Labroides dimidiatus* (Labridae) in shape and coloration, and is known as the most elaborate example of mimicry in vertebrates (Wickler 1968; Robertson 2013; Smith-Vaniz et al. 2020). This mimicry is thought to serve two functions: protective

and aggressive mimicry (Wickler 1968; Kuwamura 1983). Because the cleaner wrasse removes ectoparasites from reef fishes and has some immunity to predation (Losey 1987; Cheney et al. 2008), the mimic *A. taeniatus* is also thought to be less likely to be eaten (protective mimicry), and it can bite the fin of a deceived fish (aggressive mimicry). *Aspidontus taeniatus* feeds on not only fish fins but also the tentacles of the Christmas tree worm, *Spirobranchus giganteus* (Polychaeta, Serpulidae), the mantle of the boring clam, *Tridacna crocea* (Bivalvia, Cardiidae), and the demersal eggs of fishes, especially of damselfishes (Pomacentridae) (Kuwamura 1983, 2022; Cheney et al. 2014; Fujisawa et al. 2018; 2020; Sato et al. 2022).

For the aggressive mimicry of *A. taeniatus*, geographical variation has been reported in the frequency of biting fish fins (Cheney et al. 2014): the frequency was higher in French Polynesia than in the other study sites, and the frequency of juveniles was higher than that of adults in Indonesia. On the fringing reefs of Sesoko Island, Okinawa, southern Japan, where the benthic food items, *S. giganteus* and *T. crocea*, are abundant, they are eaten by both small and large *A. taeniatus*, while the frequency of biting fish fins is higher in smaller individuals (5–7 cm in total length: TL) and that

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of eating fish eggs is higher in larger ones (8–14 cm TL) (Fujisawa et al. 2018). In contrast, on the reefs of Ishigaki Island (approximately 440 km southwest of Sesoko Island), where *S. giganteus* and *T. crocea* are scarce, the frequency of biting fish fins in small *A. taeniatus* is much higher than that in Sesoko Island (Fujisawa et al. 2020). Thus, small *A. taeniatus* depend on aggressive mimicry when the benthic foods are scarce, whereas large individuals do not bite fish fins and seem to depend on fish eggs in the Ishigaki Island (Fujisawa et al. 2020).

For the protective mimicry of *A. taeniatus*, no studies have been carried out so far to determine the effect of protective mimicry on survival rate. A non-mimic color variant of *A. taeniatus*, which was brownish instead of bluish (6.5 cm TL), found in Sesoko Island (Sato et al. 2020a) disappeared earlier than mimic color individuals of similar size inhabiting the same reef (Sato et al. 2020b).

Comparison with closely related species seems to be one of the effective means of understanding the relation between mimicry and food diversity in *A. taeniatus* (Kuwamura 1983). The lance blenny, *Aspidontus dussumieri*, is the only other species in the genus (Smith-Vaniz 1976; Smith-Vaniz et al. 2020), and its geographic distribution, body size, and shape are similar to those of *A. taeniatus*, but its body color is brownish, not resembling the bluestreak cleaner wrasse. *Aspidontus dussumieri* mainly feeds on filamentous algae by pecking at the bottom substrate and occasionally bites the tentacles of *S. giganteus* but never feeds on fish fins and fish eggs in Sesoko Island (Kuwamura 1983). As geographical variation in feeding behavior has been reported in *A. taeniatus* (Cheney et al. 2014; Fujisawa et al. 2020), similar variation may occur in *A. dussumieri*. Thus, observations on feeding behavior of *A. dussumieri* are needed in other localities than Sesoko Island.

We compared mortality and feeding behavior of *A. dussumieri* with those of *A. taeniatus* on the coral reefs of Miyako Island, approximately 350 km southwest of Sesoko Island. We chose study sites where both species occur and, unlike in Sesoko Island, *S. giganteus* and *T. crocea* are scarce. The sites with scarce benthic food items were chosen to determine whether *A. dussumieri* would change feeding behavior as did *A. taeniatus* in Ishigaki Island (Fujisawa et al. 2020). We compared their mortality and feeding behaviors to establish the effect of protective and aggressive mimicry, respectively.

Materials and methods

We conducted route censuses of *A. dussumieri* and *A. taeniatus*, and 30-min observations of their feeding behavior at two study sites on the south coast of Miyako Island from 2018 to 2021. Since no *A. dussumieri* were found at the

study sites of *A. taeniatus* in Ishigaki Island (Fujisawa et al. 2020), preliminary surveys were made by snorkeling on the coral reefs around Miyako Island, approximately 120 km northeast of Ishigaki Island, in August 2018. We chose an inner reef off Waiwai Beach on the south coast of Miyako Island as St. 1 (24°43'N, 125°20'E), where both species of *Aspidontus* occurred, and *S. giganteus* and *T. crocea* were scarce. Most area of the study site (< 5 m depth) was covered by the colonies of the branching coral, *Montipora digitata*, and massive coral *Porites* sp. A few *S. giganteus* and *T. crocea* were found on a few colonies of *Porites* sp. We performed a route census of approximately 700 m and made observations of feeding behavior for 30 min in January 2019. In May 2019, both species of *Aspidontus* disappeared from St. 1, so we added another inner reef as the study site St. 2 (24°43'N, 125°18'E), approximately 3 km west of St. 1. Along the census route of approximately 600 m in St. 2, the habitat was similar to St. 1: the colonies of *M. digitata* covered most of the area within a depth of 5 m, large massive coral *Porites* sp. were scattered, and *S. giganteus* and *T. crocea* were scarce. We repeated surveys at the two sites in August and December 2019, November 2020, and August, September, and December 2021 (Electronic Supplementary Material, Table S1). The survey scheduled for August 2020 could not be conducted due to the COVID-19 pandemic, and a temporary survey was conducted only in November of the same year.

All the observations were made by snorkeling and recorded on the waterproof sheet. During the route census, we recorded the number of individuals of *A. dussumieri* and *A. taeniatus* with their estimated TL (cm). Juveniles of these two species live a planktonic life until they grow to over 5 cm TL (Ohta and Tachihara 2004). Small individuals (6 cm and 5 cm TL of *A. dussumieri* and *A. taeniatus*, respectively) recruited into the study sites in August (Table S1), and no eggs were found in the nests of damselfishes in January. Therefore, mortality from August to December was compared between the two species. However, *A. dussumieri* disappeared from both sites since November 2020 (Table S1), so only the data collected in 2019 were available. The difference in survival rate between the two species was tested for significance by Fisher's exact test.

During the 30 min observations of feeding behavior, we recorded the following parameters and activities: estimated TL (cm) of the focal individual and the number of biting tentacles of *S. giganteus*, biting mantles of *T. crocea*, pecking at the bottom substrate, biting fins of fish with species name, and raiding the egg-guarding nest of fish with species name. These behavioral traits were occasionally captured by videos with an underwater camera (Tough TG-5 and TG-6, Olympus, Tokyo, Japan) to make species identification easier. A total of 13 and 34 times of 30 min observations were made for *A. dussumieri* (6–9 cm TL)

and *A. taeniatus* (5.5–10 cm TL), respectively. The difference in food items between the two species was tested for significance by the Mann–Whitney *U* test. The relation between body size and feeding frequency was analyzed by Spearman's rank correlation coefficient. All analyses were performed using the statistical software, R ver. 4.0.2 (R Core Team 2020).

In addition, three individuals of *A. dussumieri* (7–8 cm TL) were found in the study site of *A. taeniatus* in Sesoko Island (see Sato et al. 2020b, 2022) in August and September 2019, and 30-min observations of feeding behavior were made once for each individual. The data recorded were the same as mentioned above. No *A. dussumieri* was found in the study site of Sesoko Island in other years from 2014 to 2021.

Results

Mortality

Mortalities of *A. dussumieri* and *A. taeniatus* during the spawning season of damselfishes were estimated from the data obtained from August and December 2019 (Table S1). The total number of *A. dussumieri* individuals was 9 (6–8 cm TL) in August and 7 (6–9 cm) in December and that of *A. taeniatus* was 48 (5–12 cm) in August and 15 (8–12 cm) in December. We have no data on growth rate in the study sites. If we assume that individuals with TL larger than 8 cm (Assumption 1) or 9 cm (Assumption 2) were survivors in December, only one out of nine (11%) or none (0%) would have survived in *A. dussumieri*, and 13 out of 48 (27%) or 9 out of 48 (19%) in *A. taeniatus*. The survival rate of *A. taeniatus* was more than twice higher than that of *A. dussumieri*, but the difference was not significant under either assumption (Fisher's exact test, $P = 0.427$ and 0.328 , respectively; Table 1).

Table 1 Number of survivors of *Aspidontus dussumieri* and *A. taeniatus* in December out of all the individuals in August 2019

	<i>A. dussumieri</i>	<i>A. taeniatus</i>
Assumption 1		
Survivors > 8 cm	1	13
Not found	8	35
Assumption 2		
Survivors > 9 cm	0	9
Not found	9	39
Total in August	9	48

We assumed that individuals larger than 8 cm (Assumption 1) or 9 cm (Assumption 2) TL were survivors in December

Feeding behavior

The feeding behavior of each individual is shown in Table S2 and a comparison of the two species in Table 2. *Aspidontus dussumieri* ($N = 13$, 6–9 cm TL) frequently pecked at the bottom substrate (median = 87, range = 0–313 peckings per 30 min; Table 2) and did not feed on other foods such as fish fins and fish eggs. The substrate pecked was mostly rock or sand flat and occasionally *M. digitata* and calcareous algae (Table S2). In contrast, *A. taeniatus* ($N = 34$, 5.5–10 cm TL) usually fed on fish fins (median = 1, range = 0–11 peckings per 30 min; Table 2) and fish eggs (number of nest-raiding per 30 min: median = 1, range = 0–6) of small damselfishes (for the target species, see Table S2), and rarely fed on other foods (Table 2). The frequency of pecking at the substrate (median = 0, range = 0–1 peckings per 30 min; Table 2) was significantly lower than that of *A. dussumieri* (Mann–Whitney *U* test, $U = 18.5$, $P < 0.01$).

Both small and large *A. taeniatus* bit fish fins and raided the damselfish nest, and the frequencies were not correlated with body size (Spearman's rank correlation coefficient, $r_s = 0.045$ and -0.046 , respectively; Fig. 1). When targeting fish eggs, *A. taeniatus* frequently formed groups of up to 12 individuals, and one group was observed to change its aim to fish fins after failing to raid the damselfish nest (Video S1). However, fin biting was usually performed individually.

In addition, it was observed for the first time that *A. dussumieri* bit the mantle of *T. crocea* in Sesoko Island in August and September 2019: once per 30 min in each of three individuals of 7–8 cm TL. Two of them also bit the tentacles of *S. giganteus* once or twice per 30 min, but pecked at substrate much more frequently (14–25 times per 30 min).

Table 2 Frequency of feeding on each food item in *Aspidontus dussumieri* and *A. taeniatus*

	<i>A. dussumieri</i>	<i>A. taeniatus</i>
Food item	($N = 13$)	($N = 34$)
<i>Spirobranchus giganteus</i>	0 (0)	0 (0–3)
<i>Tridacna crocea</i>	0 (0)	0 (0–21*)
Substrate	87 (0–313)	0 (0–11)
Fish fin**	0 (0)	1 (0–11)
Fish egg***	0 (0)	1 (0–6)

Median and range (in parenthesis) of the number of feeding behavior per 30 min

*Nine of 21 are *Tridacna squamosa*

**For the target species, see Table S2

***Number of intruding into the damselfish nest; for the target species, see Table S2

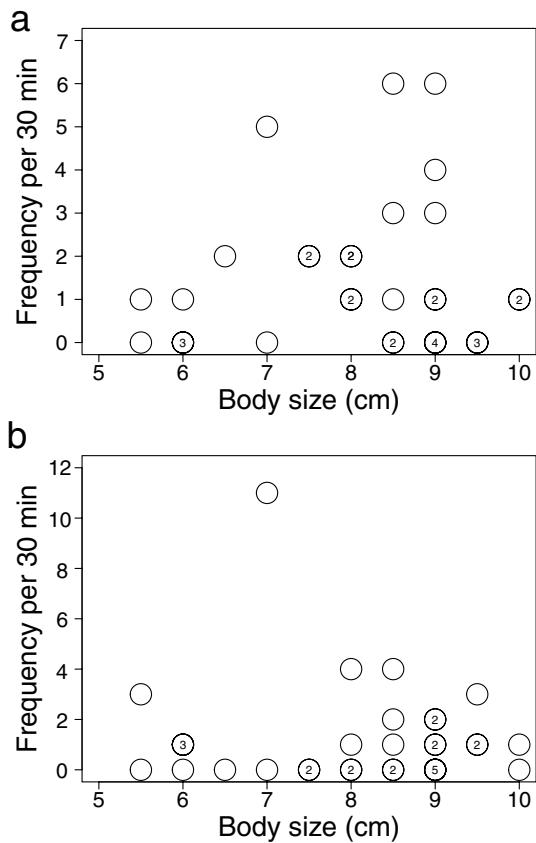


Fig. 1 Relationship between body size (total length) of *Aspidontus taeniatus* and frequency (/30 min) of **a** biting fish fins, and **b** raiding the damselfish nest to eat eggs. When there is overplotting, the number of overplotting samples is shown in the circle

Discussion

For the protective mimicry of *A. taeniatus*, we predicted that its survival rate would be higher than that of the non-mimic *A. dussumieri*. Our results indicate that the estimated survival rate from August to December 2019 was more than twice higher in *A. taeniatus*, but no significant difference was detected. However, it was difficult to exclude factors other than predation, such as migration and lack of food, as causes of their population decline. The disappearance of *A. dussumieri* from both study sites and the fact that it did not recruit in 2020 and 2021 suggest that environmental factors other than predation might also have affected its occurrence. Further studies are needed to determine the effect of protective mimicry in *A. taeniatus*.

There was no overlap in feeding behavior between *A. dussumieri* and *A. taeniatus* in the study sites in Miyako Island. *Aspidontus dussumieri* frequently pecked at the bottom substrate and did not feed on other food items, whereas *A. taeniatus* mainly fed on fish fins and eggs of small damselfishes. In Sesoko Island, *A. dussumieri*

occasionally fed on *S. giganteus* (Kuwamura 1983; current study) and *T. crocea* (current study), which are a common food item of *A. taeniatus*. These results indicate that mimicry of *A. taeniatus* is not related to biting *S. giganteus* and *T. crocea*, but may have evolved in relation to fin biting and/or egg eating. The relation between fin biting and aggressive mimicry has been confirmed in small *A. taeniatus* (Fujisawa et al. 2018; 2020), but mimicry seems to have no effect in egg eating because egg-guarding parents always show severe attacks against *A. taeniatus* (Fujisawa et al. 2018; Sato et al. 2022).

In this study, we found no correlation between body size of *A. taeniatus* and the frequency of feeding on fish fins and fish eggs, indicating that both small and large individuals fed on these prey. This is the first time to demonstrate by field observations that aggressive mimicry is effective not only in small but also in large *A. taeniatus*, when benthic foods are scarce, although it was suggested by observations made by Wickler (1968) in aquarium where no food other than fish fins was available. In Ishigaki Island, where *S. giganteus* and *T. crocea* are as scarce as in the study sites of Miyako Island, small individuals frequently bite fish fins but not fish eggs, whereas large individuals feed on fish eggs but not fish fins, although the sample size of large individuals was small ($N=3$) (Fujisawa et al. 2020). In the study sites at Miyako Island, many small damselfishes such as *Cheilop- rion labiatus* (Table S2) inhabit the colonies of *M. digitata*, and attacks of small damselfish are not as severe as those of larger ones, which may allow even small *A. taeniatus* to raid their nests. On the other hand, the eggs in the nests of smaller damselfishes are fewer than those of larger ones, so the larger *A. taeniatus* cannot always get enough eggs and will bite fish fins in such situations (e.g., Video S1). In Sesoko Island, where *S. giganteus* and *T. crocea* are abundant, *A. taeniatus* can feed on these benthic organisms when their preferred food (fish fins for small individuals and fish eggs for large ones) are not sufficient (Fujisawa et al. 2018). When benthic food is not available, as in the Miyako Island study sites, both small and large *A. taeniatus* utilize both fish fins and fish eggs. Thus, *A. taeniatus* can change its feeding tactics depending on the availability of each food item, and aggressive mimicry can be very effective when no food other than fish fins is available.

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10164-022-00769-8>.

Acknowledgements We thank Azusa Endo for help in the field and Enago (www.enago.jp) for the English language review. This work was supported by JSPS KAKENHI Grant Number 19K06845 to T. Kuwamura. All procedures performed in this study were in accordance with the Guideline for Ethological Studies by the Japan Ethological Society, the Guidelines for the Use of Fishes in Research by the Ichthyological Society of Japan, and the ASAB/ABS Guidelines for the Use of Animals in Research.

Author contributions TK designed the study. TK and HS collected the data. TK, HS and YS prepared the manuscript.

Funding This work was supported by JSPS KAKENHI Grant Number 19K06845 to TK.

Data availability All data generated or analyzed during this study are included in the Electronic Supplementary Materials.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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