

THE VISUAL CUES USED BY THE LEMON PEEL ANGELFISH (*CENTROPYGE FLAVISSIMA*) TO DETERMINE THREAT

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Abstract. Visual cues can be used by fish to assess threat, and tell them when it is important to hide. Three visual cues, size, shape, and pattern, were presented to the fish *Centropyge flavissima* (Cuvier 1831) on the reefs of Mo'orea, French Polynesia, to determine which ones were important in assessing threat. Multiple cues were combined to see if fish behavior changes when cues are combined. Size and shape are most important in assessing threat, and when combined the fish's response to size changes.

Key words: *visual cues; determining threat; hierarchical cues; Centropyge flavissima; lemon peel angelfish*

INTRODUCTION

All living things use their senses to gather information from the world around them. This information is used to assess threat, find food, determine friend from foe, as well as carry out many other functions essential to survival. At times the cues an animal receives from its environment may be conflicting, and the animal will need to determine which of the cues is the more important to act on in a given situation (Hazlett and McLay 2000). At other times, multiple cues could add together, causing the animal to react in a way that may be different from if the cues were presented individually (Hazlett 1996). For some, or possibly all animals, there may be a hierarchy of cues that are used to assess threat (Hazlett 1996).

After sensing a potential predator, either by using visual, auditory, or chemical cues; a common defense is for the prey to hide. Prey typically accomplishes this by using camouflage to blend into their surroundings or hiding in shelter created by the environment, such as: caves, crevices in coral, burrows in the ground, or hollows in trees. There are several costs involved with hiding, as the time spent hiding takes away from available time to do other essential things such as: feeding, finding a mate, or defending a territory from intruders (Jennions et al. 2003). Because of these trade-offs, potential prey would want to minimize the amount of time spent hiding.

Angelfish use hiding to escape predation (Randall 2005). This is true of the species *Centropyge flavissima* (Cuvier 1831), the Lemon peel Angelfish, which is a territorial reef fish (Stratton 1990) found throughout the Indo-Pacific reefs (Randall 2005). *Centropyge*

flavissima feeds on algae and uses the coral crevices for shelter (Randall 2005). This species does not stray far from shelter (Randall 2005) and there may be evolutionary pressures for them to settle in areas with abundant shelter (Steele 1999). These fish live in a harem style social group with one male and one to several females (Randall 2005).

This study, conducted in Mo'orea, French Polynesia, looked at the visual cues *C. flavissima* uses to determine threat. Another goal of this study was to determine if behavior changes when multiple cues are presented at once and if there is a hierarchy of visual cues that *C. flavissima* uses when determining threat. To accomplish this, the re-emergence time after hiding was recorded for different fish after models of various sizes, shapes, and patterns were presented to the fish. The three cues were tested individually first to see what effect the cues had when presented individually and to see which ones were more important. Then the cues were combined to test if behavior changed when multiple cues were presented at once. The null hypothesis was that if the different cues had the same effect then there would be no difference in re-emergence time for the individual or combined cues, and if the cues have no effect, the fish would not hide at all. Alternatively, combined, the cues could have a different effect than the individually presented cues, similar to what Hazlett (1996) found in his study on hermit crabs.

METHODS

Study sites

The study site for this project was on the northwest side of Cook's Bay off the Gump

Research Station in Mo'orea, French Polynesia. The site started at the Gump Research Station (17.49047°S, 149.82574°W) and followed the edge of the fringing reef to the green channel marker buoy (17.48676°S, 149.82489°W). Nine areas were selected along the coral shelf of the fringing reef where at least one *Centropyge flavissima* was present. The number of fish at each area ranged from one to four. Each area had a number of holes in the coral for *C. flavissima* to take refuge in, and the coral had algae growing on it for *C. flavissima* to feed on (Randall 2005). The sites were no more than 1.5 m deep; though there were areas that were deeper, no data was collected in these areas as the fish were rarely found there.

Making models

Models were made for each test that was conducted for this study. The models for the size and pattern tests were cut out from cereal boxes then taped with duct tape to make them more durable and water resistant. The duct tape was painted with Testors gloss enamel oil based black paint. For the shape and combined cues tests shapes were cut out of plastic and painted black using SintoPeinture oil based spray paint. Fishing line was attached to all models using duct tape. Metal washers were attached to the fishing line below the model to make the model sink in the water.

Testing size

Size was tested as potential predators would likely be bigger than *C. flavissima* (Scharf 2000). This test was designed to see if this species has a greater response to bigger sizes than smaller sizes, as would be expected if predators were larger than the species on average. Three models of three different sizes were made. All models were circular in shape. The medium model was made to be approximately the size of *C. flavissima*, 10 cm (Stratton 1990). The small model was intended to be smaller than *C. flavissima*, and the large model was intended to be larger than *C. flavissima*. The small model was 5 cm in diameter. The medium model was 10 cm in diameter. The large model was 15 cm in diameter. All were a solid black in color.

Testing pattern

Three different models were made to test the effect of pattern on fish behavior. All were

circular in shape and the same size as the medium model from the size test, 10 cm in diameter. All models were painted with a base coat of black. Two were then painted with patterns. One was spotted; the other had vertical stripes (Fig. 2). The patterns were made using Testors gloss enamel white paint on the black base.



Fig. 2. Pattern models: Spotted on the left, striped on the right.

Testing shape

Two different shape models were tested to see what effect the shapes had on fish behavior. Two models were made (Fig. 3) with approximately the same area, the area of the medium circular model (81 cm²). One model was a predatory shape (Randall 2005), a barracuda, with an area of 80 cm². The other model was a non-predatory shape, a butterfly fish, with an area of 80 cm². Both were painted black.

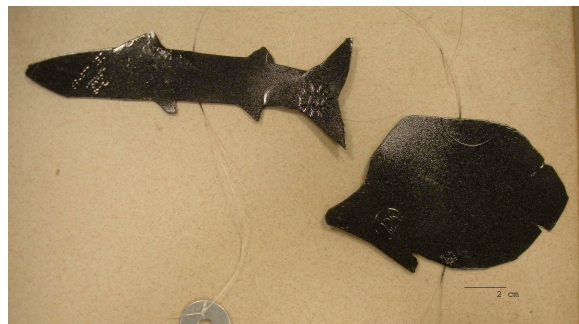


Fig. 3. Shape models: Barracuda on the left, butterfly fish on the right.

Combining visual cues

After the cues were tested individually, they were combined to see if there was a stronger response than when the cues were tested individually. The two shape models were combined with the small and large sizes. Since preliminary analyses indicated that pattern had little effect, solid models were

used. The small shape models had the following areas: the barracuda was 21 cm², and the butterfly fish was 20 cm². The large shape models had the following areas: the barracuda was 183 cm², and the butterfly fish was 183 cm². The original small and large size models had areas 20 cm² and 182 cm² respectively.

Presenting models

When the models for each test were complete they were presented to the fish. Once spotted from a distance, each *C. flavissima* was approached slowly on snorkel, to within a horizontal meter of the fish. The snorkeler hovered in the water for five minutes, only moving slightly if fish started swimming to a different part of the site, to allow the fish to acclimatize to human presence. After the acclimatization time, a model was slowly lowered through the water column to the level of the fish. Within each category the order of presentation was randomized for each fish. Each model was only presented once to each fish. When the fish noticed and/or reacted to the model, the model was removed. Time to re-emergence after hiding from the model was recorded. Hiding was defined as quickly swimming to and taking refuge in shelter. Emergence was defined as coming fully out of hiding, that is the whole body was out and visible to the observer. Data was recorded for 24 fish.

Statistics

All data were analyzed using the JMP Version 9 statistical package. A Wilcoxon/Kruskal-Wallis test and a matched pairs one sided t-test were used to analyze the size, pattern, shape, and combined cues data for significance. A Wilcoxon/Kruskal-Wallis test was used to test across sites and fish for significant variance in the data. A matched pairs t-test was used to determine if model presentation order had an effect on fish behavior.

RESULTS

Size test

Centropyge flavissima had a greater emergence time to larger than to smaller size models (Fig. 4). The emergence times for the small, medium, and large models were 2.25±4.46 seconds, 11.96±9.47 seconds, and

17.92±15.15 seconds respectively (mean±SD). The emergence times for both the medium and large sized models were greater than for the small model (Wilcoxon/Kruskal-Wallis test, $\chi^2=33.0591$, DF=2, $p < 0.0001$). The emergence time for the large model was greater than for the medium model (one-tailed t-test, $t_{23}=1.80$, $p=0.0421$). There was no significant difference in emergence times across areas in the site or between fish. No significant difference was found between emergence times based on the order of presentation.

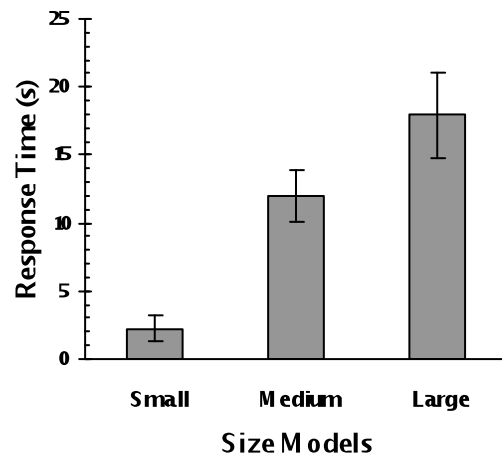


Fig. 4. Response time for *Centropyge flavissima* to size models in Mo'orea, French Polynesia. Graph shows mean ± SE for each size (n=24).

Pattern test

Centropyge flavissima had a similar response to all three pattern models (Fig. 5). There was no statistical difference in fish emergence times between the solid, spotted, and striped models (Wilcoxon/Kruskal-Wallis test, $\chi^2=1.40$, DF=2, $p=0.4974$). The emergence times for the solid, spotted, and striped models were 12.41±10.97 seconds, 21.21±29.55 seconds, and 16.33±17.22 seconds respectively (mean±SD). There was also no difference between response times for the order of presentation of the models. There was a difference across areas in the site (Wilcoxon/Kruskal-Wallis test, $\chi^2=21.99$, DF=8, $p=0.0049$) and between fish (Wilcoxon/Kruskal-Wallis test, $\chi^2=37.86$, DF=23, $p=0.0264$).

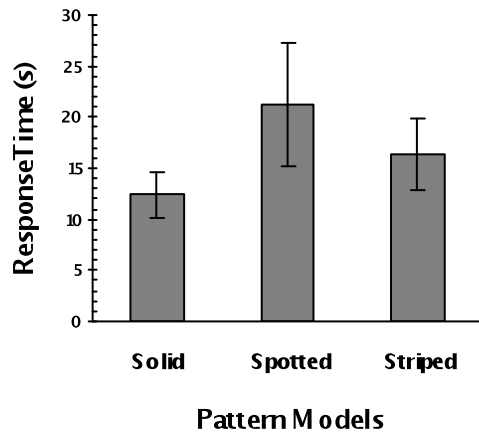


Fig. 5. Response time for *Centropyge flavissima* to pattern models in Mo'orea, French Polynesia. Graph shows mean \pm SE for each pattern (n=24).

Shape test

Centropyge flavissima had a greater emergence time to the predatory, barracuda model than to the non-predatory, butterfly fish model (Fig. 6). The emergence time for the barracuda model was 13.25 ± 15.25 seconds, and the emergence time for the butterfly fish models was 1.54 ± 2.98 seconds (mean \pm SD). The emergence times for the barracuda model were significantly greater than for the butterfly fish model (Wilcoxon/Kruskal-Wallis test, $\chi^2=25.40$, DF=1, $p < 0.0001$). There was no significant difference in emergence times between fish or across areas in the site. There was no significant difference between response times based on the order of presentation of the models.

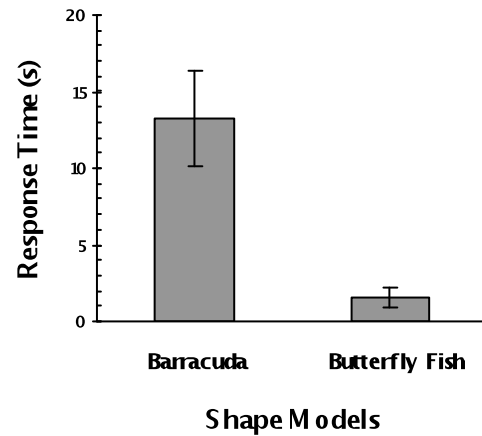


Fig. 6. Response time for *Centropyge flavissima* to shape models in Mo'orea, French Polynesia. Graph shows mean \pm SE for each shape (n=24).

Combined Cues Test

Centropyge flavissima responded more to the predatory barracuda model than to the non-predatory butterfly fish model. There was also a greater response to the bigger models than to the smaller models (Fig. 7). The emergence times for the small, medium, and large barracuda models were 8.00 ± 6.47 seconds, 13.25 ± 15.25 seconds, and 20.25 ± 22.87 seconds respectively (mean \pm SD). The emergence times for the small, medium, and large butterfly fish models were 0.71 ± 1.46 seconds, 1.54 ± 2.98 seconds, and 3.58 ± 6.04 seconds respectively (mean \pm SD). The emergence times for the barracuda models were significantly greater than for the butterfly fish models, and the emergence times for the large models were greater than for the small models (Wilcoxon/Kruskal-Wallis test, $\chi^2=78.69$, DF=5, $p < 0.0001$). For the same shape, the emergence time for the large model was significantly greater than for the small model (barracuda: one-tailed t-test, $t_{23}=2.89$, $p=0.0042$; butterfly fish: one-tailed t-test, $t_{23}=2.34$, $p=0.0141$). There was no statistical difference between the medium size and the small size for the same shape, nor was there a statistical difference between the large size and medium size for the same shape. There was no significant difference between fish or across areas in the site. No significant difference was found in response times for the order of presentation of the models.

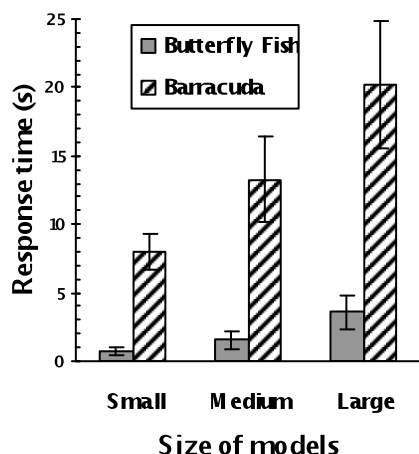


Fig. 7. Response time for *Centropyge flavissima* to combined shape and size models in Mo'orea, French Polynesia. Graph shows mean \pm SE for each size and shape (n=24).

DISCUSSION

Hiding can be very costly as it takes away from valuable time that would be spent feeding, finding a mate, or defending a territory from intruders (Jennions et al. 2003). Because of the potential risks involved with hiding, prey would want to minimize the time spent hiding. Visual and chemical cues are very important in the water for determining threat (Coleman and Rosenthal 2006), and whether or not it is necessary to hide. Three visual cues were tested in this study to see which ones are important for *Centropyge flavissima* in determining threat.

There was a difference in fish emergence times between the small model and the two larger models. The range of prey sizes eaten by a predator tends to increase as predator size increases (Scharf 2000, Arnold 1984). The results seen here agree with this pattern as the larger sizes are seen as more of a threat. There was only a small difference between the medium and large sizes, which could be because *C. flavissima* only recognizes bigger sizes as a threat, and how much bigger is not as important.

The pattern data showed that there was no difference in fish emergence times between the different pattern models. This could be because pattern is commonly used as background matching camouflage to blend in with the light and dark patterns of a complex habitat as is seen in coral reefs (Allen et al. 2011, Pellissier et al. 2011) and so would not be seen as an indicator of threat for *C. flavissima*.

It is also possible that fish with these patterns seek out complex habitats, such as in the coral shelf where *C. flavissima* was found, in order to camouflage themselves, but at other times, for example, when they are not threatened, being in these complex habitats may not be as important and so these fish would be visible in the water column (Zylinski et al. 2011). Though a survey of neighboring fish was not taken in this study, it is possible that all the neighboring fish with similar patterns to those tested were not predatory or threatening fish which would be another reason *C. flavissima* would not show a difference in emergence times for the different patterns.

Centropyge flavissima hid longer when presented with a predatory shape model than when presented with the non-predatory shape model. Similar results were seen in Gomez-Laplaza's (2002) study using a different species of angelfish and in Coleman and Rosenthal's (2006) study looking at swordtail fry. In both studies there was a greater anti-predatory reaction to predatory visual cues that were presented to the fish. Even if the barracuda is not *C. flavissima*'s natural predator it is possible that the fish have a similar response to all threatening shapes (Dunlop-Hayden and Rehage 2011).

Based on the results from the combined cues test, shape is more important than size in determining threat for *C. flavissima*. When combined, size was only different between the small and large sized models for the same shape. There was always a difference between the barracuda and butterfly fish shape models. Hazlett (1996) found that combining cues had a different effect on the organism than the individual cues. This was also true in the results of this study, as the fish's response to size changed when it was combined with shape.

It would be interesting to continue this and look at pattern and size combined as well as pattern and shape and all three combined, to see if there is a difference between the different combinations and the individual cues. Due to time constraints it was not possible to do all the combinations for this study, but would be an area for future research. Along with combining shape and pattern, patterns should be matched to the fish shapes on which they are found in the reef community.

As hiding can be very costly for a fish (Jennions et al. 2003), it is important for fish to use sensory cues to assess the potential threat of what is around them. Multiple cues can be

conflicting (Hazlett and McLay 2000) or additive (Hazlett 1996). It is even possible that combined cues have different effect than the individual cues (Hazlett 1996). The results of this study found that for *C. flavissima* size and shape were the important visual cues in determining threat. Pattern was not as important. When combined, shape was more important than size, and the fish's response to size changed as compared to when size alone was tested. There is a hierarchy of these visual cues for *C. flavissima*: shape is more important than size which is more important than pattern.

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