

# THE EFFECTS OF SNORKELERS ON FISH BEHAVIOR

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**Abstract.** The impact of human presence on reef fish behavior is well documented in cases of harmful fishing practices, but less research has looked into the impact of the simple presence of humans in the water. This study looked at the impact of non-invasive tourist activities (swimming and snorkeling) on the behavior of four species of reef fish; *C. solandri*, *S. nigricans*, *R. aculeatus*, and *C. flavissima*. Fish shyness was assessed by studying two factors – how close humans were able to approach fish, and how long the fish took to reemerge after being scared into hiding. In the case of *R. aculeatus*, fish aggression was also studied, and all behaviors were compared in areas of high and low human impact. Three of the four species were found to be significantly less shy in areas of high human impact, and *R. aculeatus* showed elevated levels of aggression in areas where they regularly encounter humans.

**Key words:** *community ecology; tourism impact; reef fish; behavioral ecology; fish aggression*

## INTRODUCTION

Coral reefs are known for their rich diversity and sensitive nature which puts them increasingly at risk from a wide variety of factors. As the world begins to experience the impacts of global climate change, coral reefs are among the first casualties, a grim prognosis that has been documented continuously over the past decades. At the 7<sup>th</sup> International Coral Reef Conference (Guam, 1992), Wilkinson (1999) warned of the anthropogenic threats facing coral reefs and their inhabitants. Twelve years later, at the 10<sup>th</sup> International Coral Reef Conference (Japan, 2004), interviews of scientists conducted by Kleypas and Eakin (2007) showed continuing concern for the health of reefs due to overfishing, human population growth and coastal development, suggesting that in the intervening twelve years, there has been little progress on this level of conservation. Not only does climate change cause serious damage to coral through warming seas and increased CO<sub>2</sub> content in seawater, but increasing storms combined with coastal development create dangerous runoff that can be fatal to coral communities (Rogers 1990, Hoegh-Guldberg *et al.* 2007).

Aside from climate-related concerns, overfishing creates a critical imbalance in marine communities, and the more complex results of these practices are only beginning to be investigated. While coral reefs are highly studied ecosystems, it's only recently that the effects of overfishing practices have been connected to population booms of harmful species such as *Acanthaster* sp., and changes in

coral species composition, indicating that the effects of overfishing are much wider than was originally thought (Jackson *et al.* 2001).

The diversity and clear water that makes coral reefs unique is also one of the main attractants of tourists. With millions of people choosing snorkeling vacations, marine organisms are coming frequently into contact with humans in the water, with a variety of complications. A study in French Polynesia found increased shark aggression proportional with more people in the water (Clua *et al.* 2010), and Ku'ulei and Cox (2003) found a direct correlation between coral reef destruction and marine tourism. Likewise, the mere presence of humans in the water with marine mammals so drastically effects the animals' behavior that laws were imposed to keep people away from whales and dolphins (Constantine 1999). Given these studies, it seems likely that the behavior of smaller reef fish is also effected by human presence.

On the island of Moorea in French Polynesia, a barrier reef around the island creates an ideal area for snorkeling and swimming adjacent to white sand beaches. This causes humans to come frequently into contact with the reef fish which are themselves a draw for tourists looking for the quintessential tropical island experience. The present study analyzed four different species of reef fish in Moorea, all inhabiting the same reef ecosystem, and coming into contact with humans on a regular basis.

Reef fish can be roughly divided into territorial and transitory groups. Territorial species defend food or breeding grounds,

frequently fending off transitory neighbors, and encountering swimmers or snorkelers from their home range. Transitory fish move across the reef through a large range, foraging or preying on other fish.

The Picasso triggerfish (*Rhinecanthus aculeatus*, see Appendix) maintain large territories in sandy areas where they forage for food by routing in the sand for small particles. Their habitat consists of shallow sandy patches between reefs and they can be found in water as shallow as 10 cm (Randall 1986). Their tendency to make homes of smooth sandy slopes in shallow water puts them in frequent contact with humans in Polynesia where both fish and people take advantage of sandy beaches outside hotels and resorts. They are notoriously aggressive, especially at a new or full moon (Kuwamura 1997; Raick 2006), when the females are defending eggs laid on or under a thin covering of sand. They are some of the most commonly encountered reef fish in Moorea, and among the most ill-tempered.

Another aggressive fish found in Polynesia, the dusky farmerfish (*Stegastes nigricans*, see Appendix) is one of the most common reef fish and can be found in coral, rock crevasses, and algal ridges (Allen and Emery 1985). They are versatile in habitat, regardless of coral quality and water quality, as long as there are holes and caves for them to hide in. Farmerfish are algae farmers, carefully cultivating their preference of algae, and defending algal mats with nips and charges. Their defense is particularly ferocious when they encounter other algae-eating fish (Hamb 2011), though they will charge almost anything in their territory and will attack human feet and hands that are placed too close to their den, communicating aggression with a series of low grunts and rumbles. *S. nigricans* display a characteristic alert behavior when faced with an intruder, rising to the top of the reef and facing directly the offending party, usually retreating to safety at the last minute.

Far less aggressive, and very popular with snorkelers due to their bright yellow color and appealing blue rings around their eyes, the lemonpeel angelfish (*Centropyge flavissima*, see Appendix) is a shy transitory reef dweller, moving slowly across the reef feeding on algae on rocks and corals (Pyle 2001). They will inspect new additions to the area such as scientific equipment or other fish, but flee in the presence of humans, hiding in crevasses in the reef. They exhibit stereotypical shy behavior when threatened, facing intruders from far away before fleeing a short distance and

turning again to see if the intruder is following. They can often be seen in small groups of 2-4 and all individuals will watch intruders and flee simultaneously.

Another non-aggressive transitory fish, the spotted boxfish (*Canthigaster solandri*, see Appendix) move across the reef, frequently in pairs, eating algae (Myers 1991). Non-toxic and without physical defenses, the boxfish nonetheless appear unaffected by human presence, moving slowly around the bases of coral heads with a maneuverable tail propelling a square boxlike body giving the fish its name. They are found across areas of different reef quality in French Polynesia, in areas of high or low human interaction, but maintain their passive demeanor throughout all areas.

Though exhibiting different behavior, these fish have in common their exposure to humans in their reef habitat, (in some cases many humans) on a regular basis. The present study compared the behavior of populations of fish in sites with constant human contact compared with sites where the fish seldom or never encounter humans in the water. In particular, the goals were to: (1) analyze fish shyness by comparing how close fish allowed humans to approach, (2) see how long the fish were hiding after being disturbed by a snorkeler over their habitat, thereby taking time away from foraging and territory defense, and (3) analyze the areas where triggerfish were attacking swimmers to see if this increased territorial aggression could be a result of exposure to humans.

## METHODS

### Study site

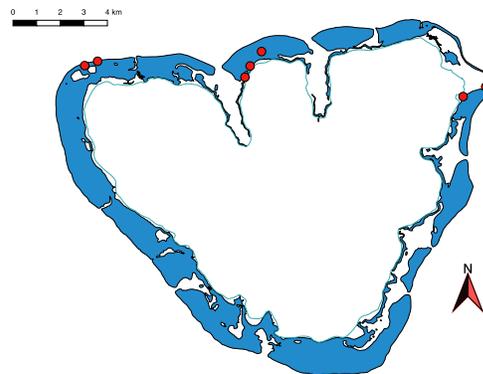


FIG. 1. Study sites on Moorea, French Polynesia.

This study was conducted on the island of Moorea in French Polynesia (17.5° S, 149.8° W), from 13 October to 7 November 2017. I selected three sites with varying high and low numbers of humans in the water, as observed during the course of the study. All sites contained an ecosystem of diverse coral species, both alive and dead, as well as areas of flat sand and algal mats. All of the four species of fish studied were present in all the areas. Each site was surveyed 2-4 times a week for human traffic and assigned a score of impact between 0 and 4, (0 = no people observed in the water for the duration of the study, 1 = under 5 people observed in the water, 2 = 5-10 people observed in the water, 3 = 10-20 people observed in the water, 4 = > 20 people observed in the water) and a score of high or low traffic (high = > 5 people observed in the water each time the site was visited, low = < 5 people observed in the water at any point).

Sites MT1, PP1, PP3 and TB1 were found to have a high traffic rating, while MT2, PP2 and TB2 were found to have low traffic. On a gradient, MT1 = 4, PP1 = 3, TB1 = 3, PP3 = 2, pp2 = 1, TB2 = 1, MT2 = 0.

#### Sites

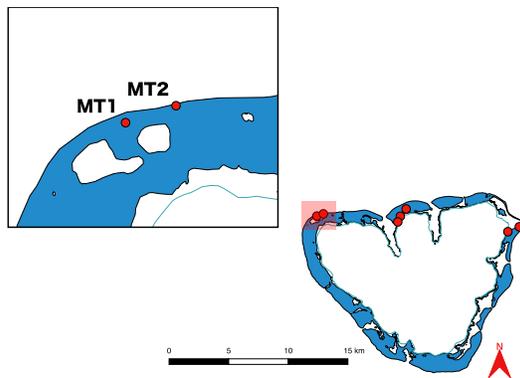


FIG. 2. Motu Tiahura map - high traffic (MT1) and low traffic (MT2) sites.

#### Motu Tiahura:

The low traffic site (MT2) at Motu Tiahura runs the length of the conglomerate platform on the north side of Motu Tiahura starting at the east most end of the conglomerate structure and ends at the channel at the west end of the conglomerate structure. The high traffic site (MT1) starts at the expansion of the channel entering the lagoon between Motu Tiahura and Motu Fareone and south runs the length of the lagoon between the two motus to the south side of Motu Tiahura.

MT1 and MT2 are on the northwest tip of the island of Moorea and boast a wide diversity of fish and coral. Proximity to several hotels and shark and ray-feeding areas bring many tourists to the MT1 site where protection between the two motus creates low waves and mild currents. This site is also the area where cruise ships send snorkeling excursions, leading to hundreds of people in the water at a time. In contrast, while MT2 has the same habitat, no swimmers or snorkelers were observed in this site likely due to the site being only accessible one of two ways – either by crossing the sharp rocks of the conglomerate structure to the west of the site or by swimming through the strong currents that move around the conglomerate to the east.

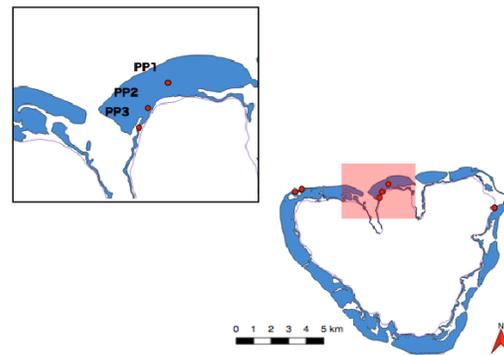


FIG. 3. Plage Publique map - high (PP1), low (PP2) and moderate (PP3) traffic.

#### Plage Publique:

The high-traffic Plage Publique site (PP1) starts at the overwater bungalows at the Hilton Hotel and ending at the Pension Fare Maheata. The overwater bungalows in PP1 provide direct access to the water, and the area frequently has many snorkelers and paddle boarders, but tourists visiting the hotel tend to restrict themselves to the small area by the bungalows. The low traffic site (PP2) runs from the Pension Fare Maheata to the beginning of the public swimming area at Plage Publique de Ta'ahiamanu. PP2 had few swimmers for the duration of the study due to a lack of access to the water from the shore. A third moderate traffic site (PP3) runs from the start of the Plage Publique de Ta'ahiamanu and ends at the end of this beach. The popularity of the public beach here brings many swimmers but few snorkelers.

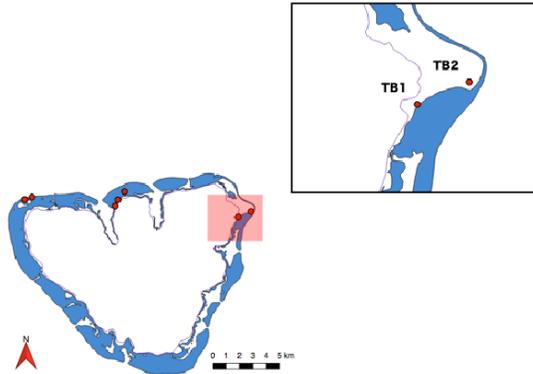


FIG. 4. Temae Beach map - high (TB1) and low (TB2) traffic.

**Temae Beach:**

The high traffic Temae site (TB1) runs from the overwater bungalows of the Hotel Sofitel Moorea to the southwest end of the public beach. Like at PP1, overwater bungalows at this site allow direct water access and natural and artificially augmented reef structures below and near the bungalows create a high traffic site with many snorkelers and swimmers.

The low traffic site (TB2) runs from the end of the public beach to the south point of the conglomerate platform. This site must be

accessed by walking along the private beaches north of the public beach, and high currents and large amounts of fire coral keep numbers of swimmers to a minimum, with only a few swimmers were ever observed in this area.

*Description of Behaviors*

Preliminary observation allowed me to develop an ethogram (Table 1.) for each behavior observed, as well as creating an exact point in time when a fish became alert, fled or attacked. Using this data, I was able to standardize behavior to be consistent across all fish species for use in measuring shyness and aggression.

*Analyses*

“Proximity to Diver”:

Each time a site was surveyed, the observer swam across the reef starting at one end of the study site and working in a zig-zag pattern to avoid resampling fish, observing each fish seen and alternating species. When a fish was seen, the observer would drop a marker (a weight with flagging tape attached) and continue swimming towards the fish at a regular pace. When the fish became alert to the

Type of behavior	Behavior	Description
Aggression	Posturing	Fish has dorsal fin raised, faces observer or other fish with both eyes forward.
	Charging	Fish makes a rapid lunge at observer or other fish without a connecting bite.
	Attacking	Fish makes a rapid lunge at observer or other fish with a connecting bite.
Shyness	Hiding	Fish makes a rapid retreat to a hiding spot (cave or hole in rock) using a burst of speed.
	Reemerging	Fish emerges from hiding spot.
	Fleeing	Fish swims rapidly away from observer or other fish.
	Alert	The fish stops to look at observer or other fish face or side on.

observer a second marker was dropped, a third dropped when the fish fled (or approached) and a fourth placed at the point where the fish was when it fled/ hid.

Once the fish had fled, a transect tape was used to measure the distances between markers starting at the point where the fish was seen. If the fish approached the observer, the measurements were taken after the fish had left. Each fish was observed once, with the observers moving away after measurements were taken. These measurements were assessed to calculate distance from observer when the fish became alert and how close the observer was to the fish when it fled. Ethogram behavior was noted to standardize “aggression” or “shyness” across all species.

“Time to Reemergence”:

The observers swam in a zig-zag pattern across each site starting at one end, taking data for each fish observed and alternating species to achieve the same numbers of fish at each site. An assistant swam towards the focus fish until the fish fled, hid, or attacked, upon which the assistant left the immediate area to the maximum distance where the reemergence of the fish could be observed but where the observer was far enough away to not influence fish behavior. A stopwatch held by the observer was started at the point where the fish fled or hid, and stopped when the fish reemerged or stopped fleeing.

Aggression Test:

The number of Picasso triggerfish (*R. aculeatus*) was counted by an observer swimming in a zig-zag pattern from one end of a site to the other. All fish seen were noted and the observer approached each fish head to assess “aggression” or “shyness”. Fish behavior was noted to see if the fish approached or attacked the observer, or fled. Each site was monitored three times, at different times of day and month. Notes also included observed pairs or juvenile *R. aculeatus*.

### Statistical Analysis

To analyze shyness, I separated data for each fish species and calculated the distance between the marker dropped when the fish fled or attacked, and the marker where the fish was when it exhibited this behavior. This allowed me to calculate how close the observer was to the fish before the fish reacted. Using R, I ran

an ANOVA on “Proximity to Diver” data by high and low traffic site for each fish, as well as analyzing “Proximity to Diver” data for traffic on a gradient from 0-4. For this gradient traffic, I ran a Tukey HSD post-hoc test to separate significance for each species. I also separated “Time to Reemergence” data for each species and ran an ANOVA by traffic in high and low areas, as well as on a gradient.

For triggerfish attack data, I calculated attack numbers by site and by high and low traffic sites.

## RESULTS

### Fish shyness by “Proximity to Diver”

Results for “Proximity to Diver” analysis in high and low traffic (Fig. 5.), showed that three of four species, (*R. aculeatus*, *C. flavissima*, and *S. nigricans*) fled when swimmers were much closer than fish of the same species in low-traffic areas ( $F_{1,39}=18.28$ ,  $p<0.0001$ ;  $F_{1,102}=51.33$ ,  $p<0.0001$ ;  $F_{1,121}=57.35$ ,  $p<0.0001$ ). The exception was *C. solandri*, which behaved the exact same way in all habitats and did not flee or hide at the approach of humans.

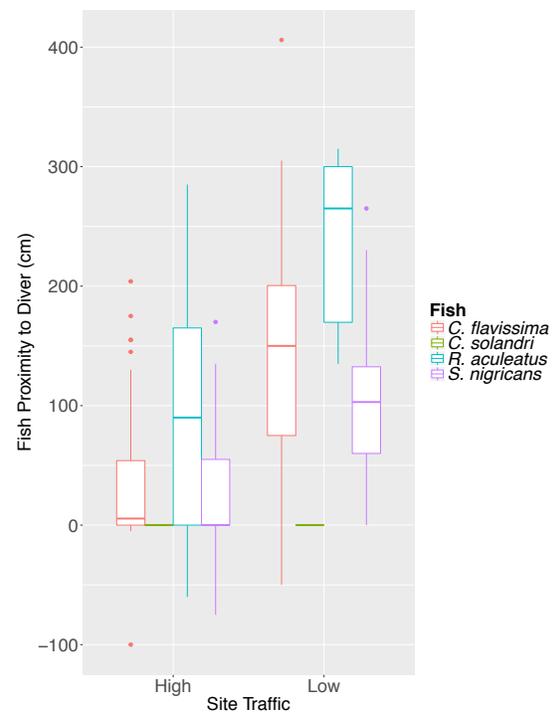


FIG. 5. “Proximity to Diver” in sites with high or low traffic.

Results for “Proximity to Diver” were also analyzed on a gradient of no traffic (0) to constant traffic (4) (Fig. 6). Similar to the high and low traffic results, results on a gradient indicated that *R. aculeatus*, *C. flavissima*, and *S. nigricans* were less shy in high traffic area proportional to the traffic score ( $F_{4,36}=4.75$ ,  $p<0.004$ ;  $F_{4,99}=14.40$ ,  $p<0.0001$ ;  $F_{4,118}=16.57$ ,  $p<0.0001$ ) in the high/ low results, *C. solandri* did not flee in any of these sites.

Results for the Tukey HSD post-hoc test (Fig. 6.) showed statistically significant differences between gradient sites.

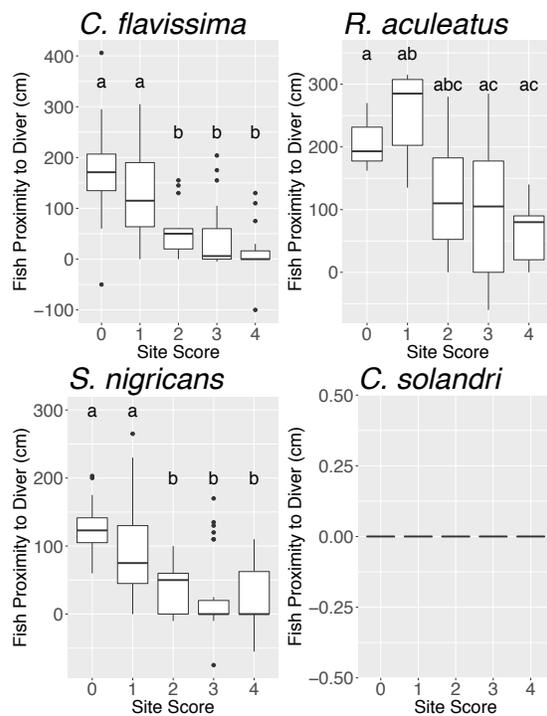


FIG. 6. “Proximity to Diver” in sites from 0-4 traffic score. Results of the Tukey HSD test show statistically similar data in letter form.

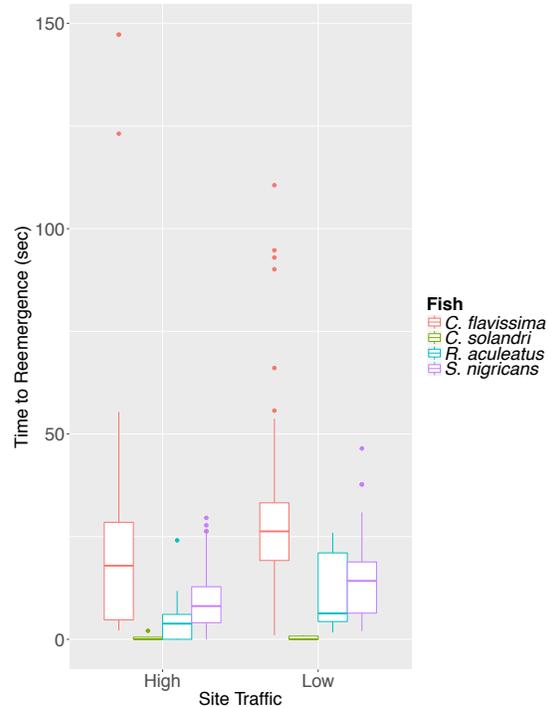


FIG. 7. “Time to Reemergence” in high and low traffic sites.

#### Fish shyness by “Time to Reemergence”

“Time to Reemergence” tests in high or low traffic (Fig. 7.) showed no statistical significance for *C. flavissima*, *C. solandri*, and *R. aculeatus* ( $p>0.05$ ) but showed statistically significant results for *S. nigricans* ( $F_{4,88}=2.40$ ,  $<0.05$ ), with *S. nigricans* reemerging in less time in areas of high traffic. Results were also analyzed on a gradient of 0-4 (Fig. 8), with no statistical significance. A power test run on each fish indicated that the minimum number of samples for each fish were attained.

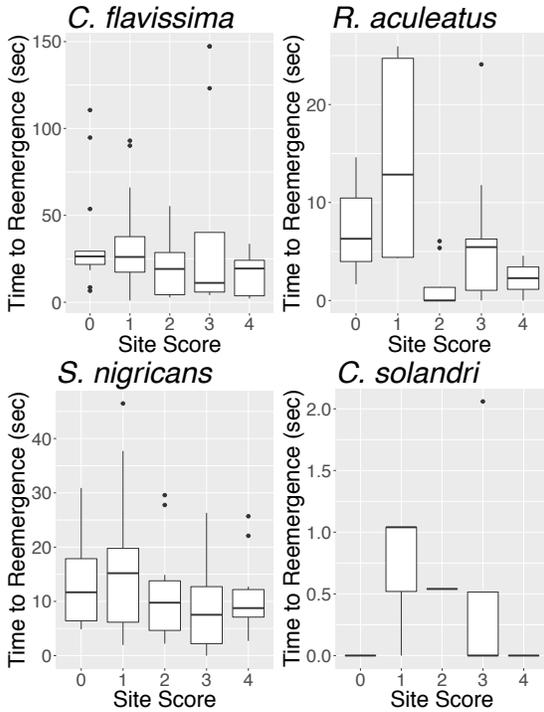


FIG. 8. "Time to Reemergence" in sites from 0-4 traffic score.

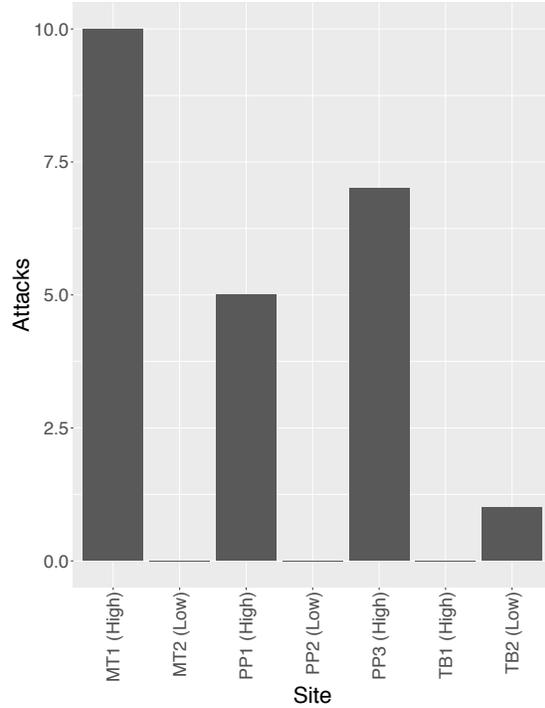


FIG. 10. Triggerfish aggression by site. Note high and low traffic score accompanying site.

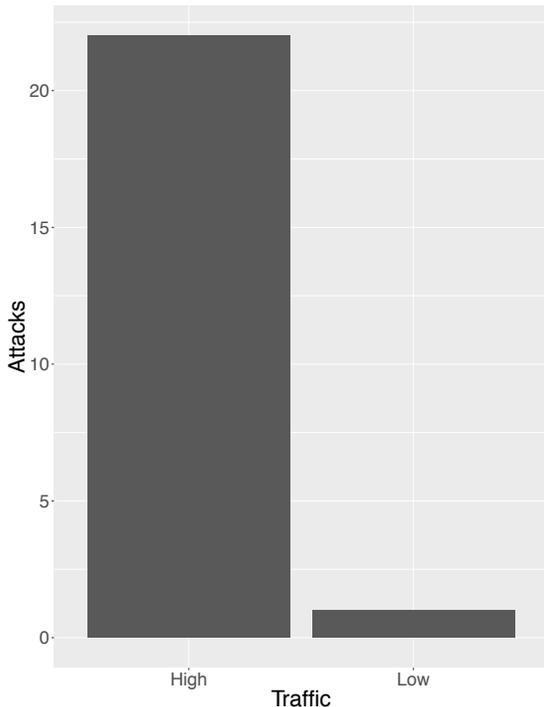


FIG. 9. Triggerfish aggression by high and low traffic score.

### Triggerfish aggression

Triggerfish (*R. aculeatus*) aggression yielded unexpected results, in that aggression was more extreme in areas with high numbers of humans, but not in all high traffic areas. Specifically, the high traffic area at Temae Beach (TB1) had no attacks ever recorded, despite high populations of both fish and people. Fish were also observed to be aggressive month-long, contrary to previous research into this behavior. Aggression was higher in areas with high human density (Fig. 9.), but did not appear to be correlated with density of fish. Analysis of attacks by area (Fig. 10.) showed high attacks in some high traffic areas, and the same fish attacking regardless of time of day or month.

### DISCUSSION

#### Fish shyness by "Proximity to Diver"

The results of the "Proximity to Diver" test showed a significant change in fish behavior in the presence of humans, but that fish were also adapting to human interactions, allowing them to be less affected by regular human contact. This indicated that snorkeling and swimming, especially in areas with lots of

people, was not causing a negative impact on fish behavior. This is important to note, because it indicated that humans in this context were not having a serious impact on the daily lives of reef fish, good news for the tourism industry, because it showed that we can share habitat with these animals without causing them undo stress.

This study also showed that different fish were effected by humans in different ways. The small and cryptically-colored *C. solandri* was unaffected by human presence, likely because its small size and dark color make it less of an object of interest to snorkelers than the brightly-colored *C. flavissima*. Brighter, more charismatic fish, (*C. flavissima*, *R. aculeatus*) were more inclined to flee upon the approach of humans (except in the case of aggression on the part of *R. aculeatus*), possibly because these are the fish snorkelers are more likely to follow or chase. This suggested that while human presence was not causing undo stress on fish, the behavior of humans and the context of human interactions with fish does make a difference. It is important in these areas of high tourism to educate swimmers and snorkelers on ways that their behavior can help the stress levels of both fish and people.

#### *Fish shyness by "Time to Reemergence"*

It is important to understand how long fish are hiding after being scared away by humans, but this study yielded statistically insignificant results for three of the four species, and no clear correlation could be drawn between presence of humans and fish reemergence times. The exception was *S. nigricans*, likely because its strong territorial behavior allowed its reemergence to be easily observed. Results of a power test indicated that enough fish were sampled to observe any correlation, but the nature of the experiment had several errors that likely made results insignificant. The experiment was based on the observer being able to see the fish from far enough away that the fish would feel comfortable reemerging. This was not always effective due to the nature of the coral substrate; sometimes the fish reemerged on the other side of a rock by using unseen tunnels in the coral. Specifically, in the case of *C. flavissima*, the behavior of the fish to hide unseen in a hole in the rock and watch the observer from there likely led to inconclusive results.

#### *Triggerfish Aggression*

Current research suggests that triggerfish are most aggressive during breeding times (Ziadi-Künzli and Tachihara 2016) and in the case of the Moorea population this would suggest high aggression in areas where their breeding ground is impacted by people walking in the water. However, the fact that triggerfish were aggressive in the same areas during the non-breeding periods of the month opens new questions for study. This phenomenon is further complicated by the complete lack of aggression in the high traffic area of Temae Beach. There are several possible results explaining these unexpected inconsistencies in behavior. First, while the presence of juvenile *R. aculeatus* and the presence of breeding pairs of adults in Temae suggest the fish are breeding there, it is possible that some unknown factor in this site is causing the fish to be less aggressive, or possibly not to breed at all. The water off this beach is deeper in places, possibly allowing the fish to breed deeper with less impact from people.

A second possibility is that the fish in areas where the attack numbers are high are observing other fish attacking humans and seeing that this is an effective deterrent to protect territory. During data collection, we observed numerous tourists being attacked by triggerfish, resulting in the tourists exiting the water immediately after the attack. We also observed fish from several different territories attacking people simultaneously. The concept of observational learning in fish has been studied previously (Arai *et al.* 2007), but most results are contained to just freshwater fish and little research exists to indicate this behavior in marine fish. This would, however, explain the occasional attack in areas of low human traffic where fish don't encounter people on a regular enough basis to see other fish attacking and to observe that the human recipient of their aggression does not retaliate. This is a very preliminary observation, however, and much more study would be needed to assess the reason for these inconsistencies in aggression in Moorea triggerfish.

#### *Further Research*

Overall, these results indicated that humans and fish can coexist without severe impact to either. However, a better understanding of behavior of these animals could improve interactions and reduce the stressful impact on both fish and people. The aggression of *R. aculeatus* suggested that breeding grounds were being impacted by

people walking in the water and care should be taken during breeding times to lessen the number of people in the water. Due to the fact that triggerfish eggs only take 12 hours to hatch, a better understanding of these fish could lessen the stress on the fish and on tourists during these times.

The human impact on fish behavior is an area that still requires a great deal of study, particularly the phenomenon of triggerfish attacks on people. A larger study needs to examine where these fish are breeding, and why they choose the sites they do, so as to lessen the negative interactions with people. A better understanding of the interactions of these fish could improve the experience of both fish and snorkeler, as well as inspiring conservation efforts worldwide.

#### ACKNOWLEDGMENTS

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## APPENDIX – Study Fish



PHOTO 1. *C. flavissima*



PHOTO 2. *C. flavissima* displays "alert" behavior facing observer before retreating.



PHOTO 3. *R. aculeatus*



PHOTO 4. *R. aculeatus* displays "alert" behavior, stopping before attacking or fleeing from an observer.



PHOTO 5. *C. solandri*



PHOTO 6. *C. solandri* are typically found in pairs, which does not affect their lack of reaction to human presence.



PHOTO 7. *S. nigricans* displays aggressive posturing behavior towards an intruding fish.



PHOTO 8. *S. nigricans* "alert" behavior facing observer.