

THE SPATIAL ORIENTATION, HABITAT USE, AND RIGHTING ABILITY OF FUNGIIDS IN MO'OREA, FRENCH POLYNESIA

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Abstract. Fungiids (Scleractinia, Fungiidae) are free-living corals that can independently establish reef structures. These corals have the ability to move and may use locomotion to avoid competition with non-fungiids. Fungiids are able to right themselves through polyp expansion and contraction. This study had two primary goals: to explore the spatial orientation and habitat use of fungiids in Mo'orea, French Polynesia and to examine the righting ability of fungiids in the laboratory. First to characterize habitat use, standardized surveys for fungiid aggregations were conducted. Then, the distance from the center of a fungiid aggregation to the nearest coral head was measured and the substrate for 12 meters around an aggregation was recorded. The shelter use between two genera of fungiids (*Fungia* and *Herpolitha*) was compared. In the laboratory, differences in righting time between a solitary and aggregated *Fungia* were tested to explore a potential benefit of living in aggregations as inversion often obstructs their mouth. In the field it was determined that fungiid aggregations were unlikely to be in close enough proximity to non-fungiids to be in direct competition for light and space. Fungiid aggregations were surrounded mainly by algae covered rock. *Herpolitha* lived in areas with direct sunlight exposure whereas *Fungia* preferred sheltered environments. There was no clear difference in the righting time between a solitary and an aggregated *Fungia*. These results support previous work that fungiid locomotion may be useful in the future as climate change alters oceanic conditions as these corals could migrate to more suitable habitats and colonize areas where other coral larvae cannot settle.

Key words: *Mo'orea, French Polynesia; coral; Fungiidae; fungiid aggregation; spatial orientation; Fungia; Herpolitha; shelter use; righting time*

INTRODUCTION

Coral reef ecosystems benefit humans ecologically and economically through shore protection, tourism, food production, and supplying raw materials for medicinal and alternate purposes (Moberg and Folke 1999). Yet, anthropogenic influence, specifically the effects of climate change, continues to threaten coral reefs around the world (Hoegh-Guldberg 1999, Goldberg and Wilkinson 2004, Hoegh-Guldberg and Bruno 2010). The effects of increasing atmospheric carbon dioxide levels includes elevation of sea surface temperatures and lowering of oceanic pH (Hoegh-Guldberg *et al.* 2007). These effects can cause coral bleaching events to increase (Hoegh-Guldberg *et al.* 1999) and result in a decrease in the concentration of calcium carbonate ions available to reef-builders (Hoegh-Guldberg *et al.* 2007). Through migrating deeper, free-living fungiid corals (Scleractinia, Fungiidae) may be able to escape areas where corals are susceptible to bleaching (Hoeksema 1991). Understanding the life history and spatial orientation of these mobile corals is important

knowledge as many aspects of the ocean are unknown, and the ecosystem is continuously subjected to immense anthropogenic pressures.

The family Fungiidae consists of both solitary and colonial corals that live exclusively in the Indo-Pacific region (Vernon 2000). Most of the thirteen genera have symbiotic zooxanthellae. *Fungia* (Scleractinia, Fungiidae) are solitary corals that have a single mouth and are primarily free-living as adults (Vernon 2000). These organisms frequently live on unexposed portions of reefs. *Herpolitha* (Scleractinia, Fungiidae) are colonial corals that possess multiple mouths. One particular species, *Herpolitha limax*, often lives in environments similar to *Fungia* in lagoons and on reef slopes (Vernon 2000). Out of all scleractinians, stony corals, fungiids are the only mobile corals (Hoeksema 1989, Mondal and Raghunathan 2015). Chadwick-Furman and Loya (1992) observed that often small fungiids (0.5 to 6.0 cm in length) lived attached to a substrate and that larger individuals (1.5 to 55 cm in length) were benthically detached.

Certain fungiid species can locomote through tissue inflation (Chadwick 1988,

Chadwick-Furman and Loya 1992). Wave action may also move free-living corals and invert them (Hoeksema 1988). Once overturned on a substrate, this may impact their ability to feed, as this orientation is likely to obstruct their mouth which is on top of their body (Picture 1; Appendix C). Fungiids are able to self-right through polyp expansion and deflation (Hoeksema and Bongaerts 2016) or through aid from organisms such as crabs and through wave movement (Jokiel and Cowdin 1976).

In the Indo-Pacific, fungiids are often aggregated (Elahi 2008). An aggregation can either be conspecific (Elahi 2008) or heterospecific: consisting of multiple species of fungiids (Hoeksema and Benzoni 2013). Despite the neighboring species of fungiid, these aggregations do not appear to have a negative effect on each other (Sheppard 1979, Elahi 2008). Elahi (2008) showed that *Fungia paumotensis* and *Fungia concinna* had the ability to differentiate between the neighboring *Fungia*, as those in conspecific aggregations produced less mucus and movement. Even though *Fungia* aggregations have been shown to cause a reduction in calcification rates, these fungiid populations could be beneficial for reproduction (Elahi 2008).

Fungiids possess unique characteristics that allow them to compete with other organisms for resources in the environment. Fungiids are aggressive if they contact sessile corals (Shepard 1979, Chadwick 1988, Chadwick and Loya 1992). During human initiated field contacts, larger polyps of *Fungia scutaria* secreted deleterious mucus onto a non-fungiid coral while smaller polyps often moved away (Chadwick 1988). Fungiids may use their mobility to avoid competition for space (Maragos 1974, Sheppard 1979, Hoeksema 1988, Chadwick and Loya 1992), sponge toxicity (Hoeksema and De Voogd 2012), and to settle in areas where other corals cannot establish themselves (Hoeksema 1988, Chadwick and Loya 1992). After a fungiid migrates, asexual reproduction can assist in colonization of the coral (Hoeksema 1988). Fungiids may be able to build reef structures themselves by a mound reef of fungiids on soft substrate (Littler *et al.* 1997) as well as through offering a hard base for other coral to colonize (Shepard 1981). Since coral larvae can likely only settle on a hard substrate (Fadlallah 1983), colonization of soft substrate through movement is a distinctive ability of fungiids.

The first part of this study included the field observations and focused on the spatial

orientation and habitat use of fungiids. For spatial orientation, it was hypothesized that fungiid aggregations would not be in close proximity to larger sessile corals and instead would be mainly surrounded by algal matter. The shelter use between the fungiids in the genera *Fungia* and *Herpolitha* was compared. This section of the study served as an extension of Hart (2005) to determine whether multiple genera prefer shelter, or if that characteristic is unique to the genus *Fungia*. The hypothesis was that while *Fungia* tended to occupy areas with shelter, *Herpolitha* would not. The second part of the study tests a potential importance of fungiid aggregations in the laboratory. To do so, the difference in righting time between a solitary coral and an aggregated coral was tested.

METHODS

Study sites

This study took place on the island of Mo'orea, French Polynesia. Five sites were surveyed for fungiids on the north side of the island (Fig. 1) from October 8 to November 7, 2018. All of the sites consisted of a reef in or at the mouth of a bay that steeply dropped off at the reef edge.

The first site was located on the northeast side of Paopao Bay (S 17.489010°, W 149.818660°). The reef is approximately 40 m wide and is situated between two docks. The area is shallow (0-2 m) and mainly consists of rock overgrown with algae. The most prominent genera of algae are *Turbinaria* and *Padina*. There are a few large coral beds and heads with *Porites* as the most abundant genus.

The second site was Gump reef (S 17.489822°, W 149.825912°), situated near the UC Gump Research Station on the northwest edge of Paopao Bay (Ginsberg 2008). On this patch reef, there is little shelter available to the fungiids (Hart 2005, this study) and sand is the main substrate. Within the selected survey area of Gump Reef, the area was shallow (average water depth of 1 m) and the distance from the shore to the reef edge ranged from 5 to 100 m. *Padina*, *Turbinaria*, and *Porites* were abundant throughout this stretch of reef.

The east side of Opunohu Bay (S 17.507149°, W 149.852314°) was also surveyed. At this site, the distance from the shore to the edge of the reef is on average 20 m. The area is shallow (average water depth of 1.50 m). Large coral heads are rare, and the substrate mainly consists of algae, predominantly *Padina*.

The fourth site was a shallow fringing reef northeast of the mouth of Paopao Bay (S 17.482600°, W 149.815361°). From the shore, the reef spans about 120 m to the reef edge, and then the shallow reef (2 m) steeply drops off. Throughout the fringing reef, there are large corals heads and beds with *Millepora* and *Porites* as common genera. The algae, *Turbinaria*, is also abundant.

The fifth site was the back reef to the north of the fringing reef (S 17.481456°, W 149.818329°). A 100 m wide drop off separates the fringing reef from the back reef. In the surveyed area, the water depth ranged from 1.50- 2.30 m. The reef edge (3.50 m) quickly steepens. There are large rocks with algae and coral attached. *Pocillopora* and *Turbinaria* are prominent on the reef.

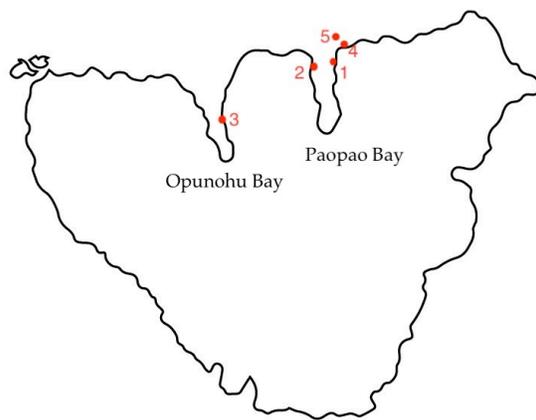


FIG. 1. Field sites in Mo'orea, French Polynesia.

Spatial orientation of aggregations

Due to the patchiness of fungiid aggregations along a reef, an opportunistic method was used to characterize the area surrounding these populations. Before going into the field, polygons in Google Earth Pro (V 7.3) (Google Earth 2018) were created to delineate a set search area of 5,000 (± 100) m² or 10,000 (± 100) m² for each of the sites, depending on the size of the site. I surveyed one area at each site, except for Gump reef, where I surveyed two parts due to its larger area and scarcity of aggregations. If the coordinates of an area were not clearly distinguishable by landmarks or the edge of the reef, a GPS was used in the field to outline the search area. Each survey consisted of two snorkelers searching the designated areas of 5,000 m² for thirty minutes and areas of 10,000 m² for 60 minutes. If three aggregations of fungiids (I defined one

aggregation as at least three fungiid individuals) were encountered before the time limit expired, the search was terminated. Each site varied in reef composition as certain sites had more coral (sites 4, 5), algae (sites 1, 3), or sand (site 2) present. Therefore, I attempted to ensure an accurate representation of the distance from an aggregation to a coral head by limiting the amount of aggregations measured per site.

A prior study by Ginsberg (2008) in Moorea, French Polynesia determined that a fungiid aggregation contained individuals that were less than or equal to 1.23 m apart. This nearest neighbor distance was used in this study to identify aggregated fungiids. Once an aggregation was encountered, the stopwatch was paused and the genus, substrate, size (longest diameter) and the nearest fungiid neighbor distance were recorded. Fungiids were identified to the genus level using identification guidelines established by Hoeksema (1989) and Vernon (2000). A GPS point (GPS coordinates Table 1; Appendix A) and a photograph of each aggregation were taken. Then, at sites 1-5, the distance from the center of an aggregation to the nearest large non-fungiid coral was recorded. The part of the aggregation where the most individuals were located was determined. Then, to find the physical center of the aggregation, the maximum length from the end of one fungiid to the end of another was measured and divided by two. The minimum height of a large non-fungiid coral had to be at least 10 cm and the minimum circumference was 80 cm. At least half of the coral head had to be living and not covered in algae to be included in the study. These restrictions were included to ensure that the coral head was taking up both light (height) and space (circumference, living coral).

Once those measurements were taken, I further examined the habitat surrounding an aggregation. To do so, a 3 m transect from the center of an aggregation was set out facing north, east, south and west. At each 0.20 m interval along the transect, the substrate was recorded. The substrate was classified as algae covered rock (ACR), algae (AG), fouled coral rubble (FCR), large coral above the size requirements (LC), sand (S), and small coral that was below the requirements. ACR was defined as turf algae whereas AG consisted of algae such as *Turbinaria* and *Padina*. These data were used to determine the habitat conditions in the vicinity of each fungiid aggregation. Then, a separate random transect was set out to

determine the substrate available to explore selectivity. For each random transect, a random number generator was used to select which edge of the search area (polygon) to start at, the direction of travel (1-north, 2-east, 3-south, 4-west), and for what time period. The last two steps of this process were repeated to determine the start point of the random transect. Then, I repeated the same methods as described above to characterize the substrates available to the fungiids. Due to logistical reasons, transects were only set out from the first 10 aggregations (sites 1-4).

Shelter use between two fungiid genera

I explored the shelter use between fungiids in the genera *Fungia* and *Herpolitha* (see Appendix B for genus identification), focusing on Gump reef as the survey area. The same polygons and search time used in the previous Gump reef observations were employed. Once a fungiid of either genus was encountered, the stopwatch was paused and the genus, presence or absence of shelter, and its size were recorded. An organism was considered sheltered (presence of shelter) if it was shielded from direct sunlight (Hart 2005).

In order to assess the amount of shelter available on Gump reef, four random transects separated by 100 m were set out. These extended from the edge of the polygon closest to shore to the edge of the reef (GPS coordinates Table 2; Appendix A). Every 1 m, the presence or absence of shelter was recorded. For these transects, the presence of shelter implied that the substrate would protect an organism from direct sunlight. Shelter was absent on the reef when the substrate would subject an organism to direct sun exposure.

Laboratory experiment

I observed the righting time of *Fungia* in various positions to examine a potential importance of aggregations. Twelve *Fungia* were collected from the first site on the northeast side of Paopao Bay at a water depth of 1.70 meters. Six of the corals were small (5.50 to 7.20 cm in length) and six of the corals were large (8.90 to 12.90 cm in length). Within twenty minutes, they were transported to large, shaded outdoor tanks at the UC Gump Research Station. The corals were then placed on the tank's plastic bottom and acclimated for two days in a water depth of 0.60 m. Next, the corals were split into groups of three, including individuals that were similarly sized, and each

coral was assigned a unique number. Using a random number generator and each coral's unique identification number, the positions of each coral were determined. Position 1 was an upright *Fungia* on top of and surrounded by coral rubble (coral 1) and position 2 was a *Fungia* inverted directly on top of *Fungia* 1 (coral 2). The first two positions simulated aggregated *Fungia* if one *Fungia* was overturned onto the other *in situ*. Position 3 was the solitary *Fungia* that was inverted onto coral rubble (coral 3). After acclimation, coral 1 was placed on and fully surrounded by coral rubble. Then, coral 2 was inverted onto coral 1, fully blocking both of their mouths. Immediately after to start the trial, coral 3 was directly inverted onto and was surrounded by coral rubble.

From 08:00 to 22:00 hours from October 31 to November 14, 2018, observations on the position of coral 2 and 3 (inverted or upright) were recorded every three hours. If both coral 2 and 3 righted themselves in less than five days, the trial was terminated. The righting time was recorded as the number of full days it took for the organism to turn over. If an individual did not turn over after five full days, its righting time was recorded as six full days. When the same group of three organisms went through another trial, the positions of coral 2 and 3 were switched. This was done to eliminate the possibility of individual fitness (quicker righting time) in a certain position within a trial. At the end of the experiment, corals in positions 2 and 3 were weighed through dry weight. They were taken out of the tank, shook five times to remove water, and placed into a weigh bucket on an electrical scale. Length (largest diameter) and height (maximum height) measurements were taken for all individuals. All measurements were recorded to determine if length, height, and weight were correlated with righting time.

Data analysis

All statistical tests were conducted in Past (V 3.21) (Hammer *et al.* 2001). All figures were generated using the RStudio (V 1.1.453) (R Core Team 2018) package ggplot2 (Wickham 2016). The Shapiro-Wilk test was used to test for normality to determine which statistical tests were appropriate. For each statistical test, an alpha of 0.05 was used.

This study aimed to define the area around fungiid aggregations. No statistical tests were used to analyze the distance from an aggregation to a coral head. For the transects, a

Mann-Whitney U test was used to compare the majority of the substrates around fungiid aggregations with substrate availability at sites. ACR and LC were the only exceptions. Since the data for algae covered rock was normally distributed, a t Test for samples of equal variance was used instead. Since there was a lack of large coral found around aggregations and at sites, no statistical test was used to determine selectivity.

The shelter use on Gump reef of fungiids in the genera *Herpolitha* and *Fungia* was compared. Fisher's exact test was used to compare the *Herpolitha* utilizing shelter and exposed to direct sunlight. The same test was used for *Fungia* shelter use. Due to a larger sample size, a Chi-square goodness of fit was used to analyze shelter availability on Gump reef. As the size data of the genera was normally distributed, a t test for unequal variance was used to test for a difference in the average size of *Herpolitha* and *Fungia*.

For the laboratory experiment, the righting time between corals in different positions was analyzed. The data was only normally distributed for the righting time of corals in position 2. Therefore, a simple linear regression was used to see if the height and length of coral 1 (*Fungia* on bottom) was correlated with the righting time of coral 2. Since the data for position 3 did not follow a normal distribution, a Spearman's rank correlation was used to see if length, weight, or height were correlated with righting time of corals in both positions 2 and 3. A Mann-Whitney U test was used to test for differences in righting time based only based off of position.

RESULTS

Spatial orientation of aggregations

The distance from the center of 14 fungiid aggregations to the nearest large coral head ranged from 0.54 m to 10.81 m. Six out of fourteen aggregations were within 2 meters of a large coral (Fig. 2). The average distance was 3.49 m and the median distance was 2.94 m. The standard deviation was 2.92 m and the standard error was 0.92.

When comparing the substrate presence of algae covered rock around fungiid aggregations to the availability at the study sites, there was a statistically significant difference (t test, 18 df, t value= 3.950, $p < .001$). Even though 41% ACR (± 19 SD) made up the substrate available at sites, the majority of aggregations were surrounded by this

substrate ($76\% \pm 21$ SD) (Fig. 3). The area around aggregations consisted of 58% ACR on Gump reef, yet ACR made up only 18% of the available substrate. A Mann-Whitney U test showed that there was less algae surrounding fungiid aggregations than was available on the reefs ($U= 21$, $p < 0.05$). The mean percent of AG at the sites was 14% (± 16 SD) and only 2% AG (± 3 SD) was within the vicinity of aggregations. There was no statistically significant difference between the amount of fouled coral rubble, sand, and small coral around aggregations and randomly sampled at the sites (Mann-Whitney U, $U= 48.0$ for FCR, $U= 39.5$ for S, $U= 38.5$ for SC, $p > 0.05$ for all). 21% of the sampled substrate at sites was S (± 29 SD), yet only 6% of the total substrate neighboring aggregations was S (± 9 SD). No statistical test was used on large coral, as it was not commonly encountered on the reef. Only 0.2% (± 0.60 SD) of the area around fungiids consisted of LC and large coral was the available substrate 6% of the time. The one LC found near a fungiid aggregation through transects was 2.0 m away from the center of the aggregation. LC made up 25% of the substrate available on the fringing reef (site 4), yet none of the area around aggregations contained large coral. The standard deviation in the text and the standard error on the graph may be less powerful with the substrates whose data did not follow a normal distribution (AG, FCR, LC, S, and SC).

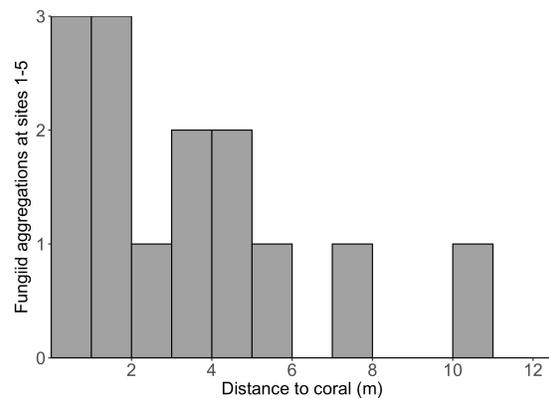


FIG. 2. Distance from 14 fungiid aggregations to the nearest coral that met the specified size requirements at sites 1-5.

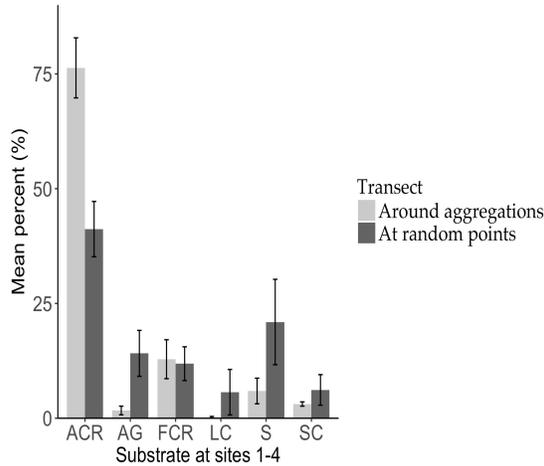


FIG. 3. Relative abundance of substrates available at sites 1-4 (n= 597) and the substrate surrounding fungiid aggregations 1-10 (n= 599).

Shelter use between two fungiid genera

A Chi-squared test showed that there was a difference in the presence and absence of shelter on Gump reef (1 df, Chi-sq = 105.98, $p < 0.001$). This reef had little shelter available (absence of shelter) as most of the reef was exposed to direct sunlight. Only 18% of the reef was sheltered (n=260 shelter data points) (Fig. 4).

Herpolitha often lived in areas that were subjected to direct sunlight (Fisher's exact test, $p < 0.05$), whereas *Fungia* preferred sheltered environments (Fisher's exact test, $p < 0.01$). 8% of *Herpolitha* (n=13) and 80% of *Fungia* (n=38) were living under shelter (Fig. 4). 92% of *Herpolitha* and 20% of *Fungia* were found exposed to direct sunlight. *Herpolitha* had a mean length (22 cm \pm 9 SD) that was nearly 3 times larger than that of *Fungia* (8 cm \pm 4 SD). A t Test for unequal variance revealed that there was a statistically significant difference in the average size of these two genera (49 df, t value= 5.705, p value < 0.001).

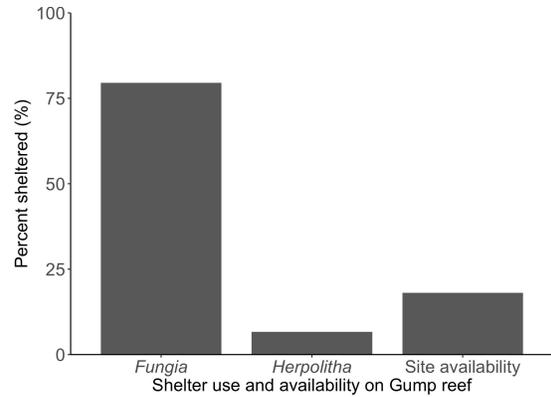


FIG. 4. Shelter use of *Herpolitha* and *Fungia* and the shelter availability on Gump reef.

Laboratory experiment

A Mann-Whitney U test showed that there was no statistically significant difference in the righting time when one *Fungia* was placed on top of another *Fungia* (position 2) or placed on coral rubble (position 3) (U= 20.0, $p > 0.05$). The righting time for coral 2 varied from 0 to 5 days (Fig. 5) and ranged from 0 to 6 days for coral 3 (Fig. 6). A Spearman's rank correlation showed that length ($r_s = 0.232$, $p > 0.05$), weight ($r_s = -0.088$, $p > 0.05$) (Fig. 7), and height ($r_s = 0.232$, $p > 0.05$) were not correlated with righting time (n=13 *Fungia*). A Simple Linear Regression showed no correlation between the righting time of coral 2 to the height ($R = 0.316$, $p > 0.05$) or length of coral 1 ($R = 0.336$, $p > 0.05$). 86% of the corals in position 2 were completely off coral 1 in less than 24 hours.

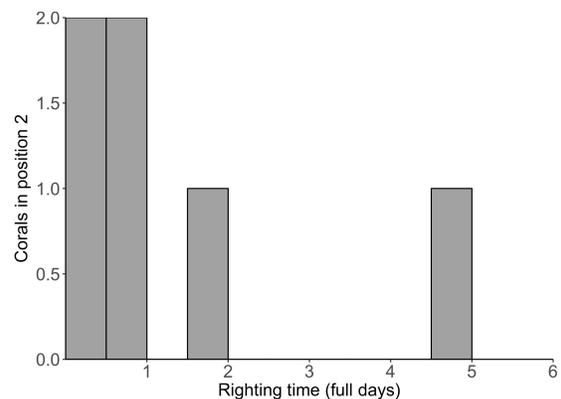


FIG. 5. Righting time of coral 2 (n= 6) in full days in the laboratory. Coral 2 was the *Fungia* inverted on top of another *Fungia* (coral 1) in order to simulate an aggregation.

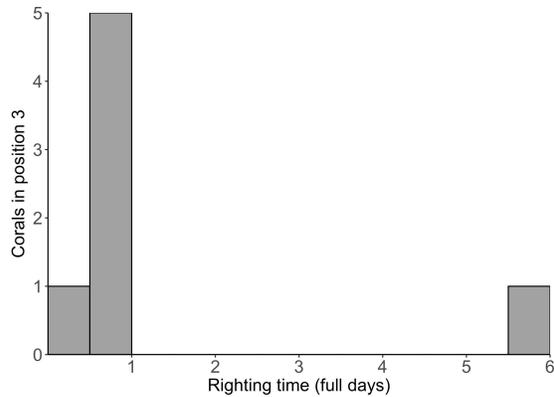


FIG. 6. Righting time of coral 3 (n=7) in full days in the laboratory. Coral 3 was the solitary *Fungia* that was inverted onto coral rubble.

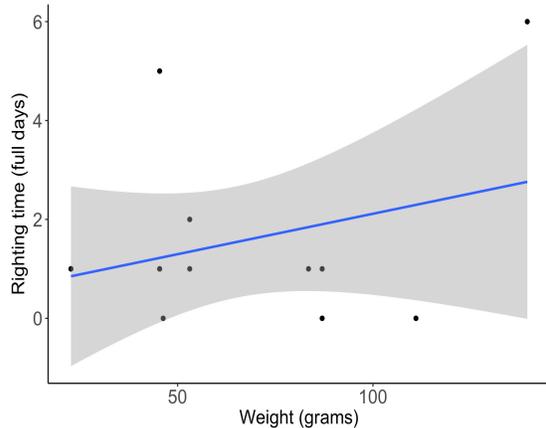


FIG. 7. There was no correlation between the righting time of coral 2 and 3 with *Fungia* weight. Here a line was fitted to the data to help with visualization though a Spearman's Rank Correlation was used for the analysis.

DISCUSSION

The purpose of the field study was to describe the habitat around aggregated fungiids and the shelter use of two fungiid genera in two bays in Mo'orea, French Polynesia. I found that fungiid aggregations were not directly located near large coral. Instead, algae covered rock was the main substrate observed for 12 meters around these fungiid coral populations. Moreover, I found a difference in shelter preference between two genera of fungiids (*Herpolitha* and *Fungia*). The laboratory component showed no clear difference in righting time when *Fungia* were in placed in different initial positions.

Fungiids are aggressive and directly compete with non-fungiids once they contact

each other (Shepard 1979, Chadwick 1988, Chadwick and Loya 1992). These results propose that aggregated fungiids should be located at a distance from non-fungiid corals. In support of this prediction, I found no aggregated fungiids contacting non-fungiids. This suggests that sessile corals and fungiids were unlikely to be in close enough proximity for immediate competition for light and space. Large coral was often observed at most of the sites, even though few large coral were randomly sampled through transects. to the low sample size of large coral on a reef, it may be more beneficial to examine the distance from the center of an aggregation to the nearest large coral instead. Fungiids could have been generally located away from large sessile corals (mean distance= 3.49 m) for several reasons. For example, Sheppard (1979) seldom found *Fungia* contacting sessile corals and suggested that fungiids may locomote to evade conflict. Two other studies, Maragos (1974) and Chadwick (1988), suggested that fungiids might actively avoid direct contact with large colonial corals (Maragos 1974, Chadwick 1988). Wave action can also be responsible for passive fungiid movement (Chadwick 1988, Hoeksema 1988, Chadwick-Furman and Loya 1992), and fungiids can aggregate in a certain place due to gravity (Hoeksema, personal communication 2018). Therefore, fungiids could have been aggregated away from large corals by chance. Finally, fungiid aggregations can potentially prevent the intrusion and colonization of other organisms (Jackson 1977). As aggregations observed in the present study often consisted of a few individuals (median number= 7), and fungiid aggregations can consist of 100 individuals (Elahi 2008), this possibility may not be as likely in the context of the current study.

Despite the availability of algae covered rock (turf algae) at a site, it was the main substrate that surrounded aggregations. Ginsberg (2008) observed that aggregated fungiids often lived in branching coral in Mo'orea. The field site Ginsberg (2008) surveyed had more branching coral than any of the sites used in this study (personal observation) rendering direct comparisons of the results between the current study and Ginsberg (2008) unfeasible. Hart (2005) showed that most *Fungia* in Mo'orea live on algae covering dead coral. This part of my study extends on the results of Hart (2005) by showing that not only do fungiids often live on algae covering a substrate, but that also the area around aggregations consists of mainly

algae covered rock. Through locomotion, fungiids can migrate to and colonize soft substrates (Chadwick-Furman and Loya 1992). In this study 73% (n= 105) of aggregated fungiids were found on soft substrate (86% on turf algae and 14% on sand). It is difficult for coral larvae to settle on turf algae and on sediment (Harrington *et al.* 2004). When turf algae trap sediment, larval settlement is inhibited to an even greater extent (Birrell *et al.* 2005).

Overall, turf algae consisted of 19% to 57% of the substrate available at the four sites in or at the edge of Paopao and Opunohu Bay, suggesting this was a common potential habitat for the fungiids. Agricultural and land development causes runoff and sedimentation in both of these bays (London and Tucker 1992). Therefore, when turf algae potentially trap the sediment that runs off into these bays, it could reduce coral larvae settlement, or the success of the larvae that do settle. Diaz- Pulido and McCook (2002) found that algal turf settled on corals that had died due to bleaching. Therefore, if coral bleaching events continue, there may be more turf algae on a reef. Once fungiids detach from their substrate, they can establish themselves on algae covered rock (turf algae) through locomotion. Since non-fungiids in the order Scleractinia are immobile, they will likely not be able to colonize turf algae if their larvae cannot settle on the soft substrate. Fungiids are able to remove sediment from their polyp (Ginsberg 2008, Bongaerts *et al.* 2012). This is an essential ability as excess sedimentation is a threat to corals (Wilkinson 2004). Therefore, if turf algae trap sediment, water motion moves sediment on top of fungiids, or they migrate to an area with high sediment influx, they have the ability to remove it.

Another method used to research habitat use and spatial orientation of fungiids was to analyze the shelter preference of two genera of fungiids. Gump reef and corals in the genus *Herpolitha* were primarily unsheltered, whereas *Fungia* were found living under shelter. The data collected on *Fungia* shelter use complements the observations of Hart (2005) who also found that most *Fungia* on Gump reef were sheltered. My study expands on previous work by exhibiting a difference in shelter use between two genera of fungiids. Even within a genus and between species, fungiids differ in their habitat use (Goffredo and Chadwick-Furman 2000). These two genera may vary in their shelter preference on Gump reef potentially due to differences in size and

bleaching susceptibility. *Herpolitha* were almost three times the size (largest diameter) of *Fungia*. Chadwick-Furman and Loya (1992) found that in reef cavities, sheltered, detached individuals moved slower as they were obstructed. The *Fungia* observed often barely fit under the shelter available on Gump reef. The shelter on Gump reef consisted mainly of rock overhang and reef cavities. Due to the larger length of *Herpolitha* and the small shelter size observed on Gump reef, this genus may not have been sheltered due to lack of appropriately sized shelters. All of the fungiids inhabited shallow water (on average 1 m); therefore, if unsheltered they would be exposed to similar sun exposure. Corals can have various UV tolerances (Siebeck 1988), corals in the same family can possess different zooxanthellae strains (Rowan and Powers 1991), and these strains can vary in their temperature tolerance (Kinzie *et al.* 2001). No *Herpolitha* showed any signs of bleaching, and the majority of the bleached *Fungia* were not sheltered. Hoeksema (1991) found that the smallest, normally sheltered fungiids were the least likely to be bleached. It may be possible that *Fungia* on Gump reef utilized shelter more, as they were more susceptible to bleaching from UV light than *Herpolitha*.

Part of this study focused on the spatial orientation of fungiid aggregations, which are common in Mo'orea, French Polynesia (Ginsberg 2008). The laboratory component aimed to determine if there was a quicker righting time within aggregated fungiids, which would have revealed a potential importance of living within these populations. It was found that righting ability was not accelerated within aggregated *Fungia* (coral 1 and 2). There was no correlation between height, length, or weight to righting time in corals in position 2 (*Fungia* inverted onto coral 1) or 3 (*Fungia* inverted onto coral rubble). The results on the relationship between coral size and movement differ from conclusions from previous studies. For example, Gittenberger and Hoeksema (2013) found that smaller corals have a higher chance of being turned over than heavier corals. Also, Hoeksema and Bongaerts (2016) found that larger fungiids may exhibit less movement. A potential explanation for the discrepancy in the laboratory results is that due to time and collection limitations, the experiment had a small sample size (n=4 treatment groups) and a small number of trials (7). Another potential source of error is that certain *Fungia*, through nocturnal expansion, moved coral rubble. As a result, part of the

coral's body was off the coral rubble and on the plastic tank bottom, altering the "initial" conditions. In future studies exploring this question, I would recommend a larger sample size and to ensure that a coral cannot land on the bottom of the tank by placing more coral rubble at the start of the trial.

An interesting observation in the laboratory was that within 24 hours, coral 2 was always off coral 1 (*Fungia* on bottom). At this stage, coral 2 was now either inverted on coral rubble or had already righted itself. This behavior implies that either coral 2 moved off of coral 1, coral 1 pushed coral 2 off as its mouth was obstructed, or the response was a combination of both actions. The two corals in position 2 that were inverted onto the tallest corals in position 1 (3.1 and 4.4 cm height), turned over in less than 24 hours. Before fully losing contact, part of coral 2 was often on coral rubble and the other part was resting at an angle on coral 1 (Picture 2; Appendix C). The higher the height of coral 1, the greater the angle coral 2 was at and this may explain the quicker turnover rate of coral 2. Potentially due to a low sample size, no significant positive correlation between the height of coral 1 and the righting ability of coral 2 was found. But, maybe the taller coral 1 is, the easier coral 2 can right itself as its body is at an angle when it is both on coral rubble and resting on coral 1.

This study explored the spatial orientation and habitat use of fungiids in Mo'orea, French Polynesia. In support of previous studies, I found that fungiid corals' unique locomotion ability may be useful for selecting particular micro-habitats and establishing in areas where other coral larvae may not be able to settle. Their movement may be beneficial in the future as ocean chemistry changes as it suggests that fungiids may be able to disperse to areas where conditions are more favorable. If coral bleaching events become more common, and turf algae covers dead corals, fungiids may be able to colonize this soft substrate and establish a new reef structure.

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APPENDIX A

GPS LOCATIONS

Table 1. Location of Aggregated Fungiids.

Aggregation number	GPS coordinate	GPS used
1	S 17.48901°, W 149.81866°	Garmin GPS 73
2	S 17.48985°, W 149.81865°	Garmin GPS 73
3	S 17.49081°, W 149.82613°	Garmin GPS 73
4	S 17.48943°, W 149.82570°	Garmin GPS 73
5	S 17.48816°, W 149.82532°	Garmin etrex 20
6	S 17.50703°, W149.85234°	Garmin GPS 73
7	S 17.50719°, W149.85222°	Garmin GPS 73
8	S 17.50714°, W 149.85233°	Garmin etrex 20
9	S 17.48247°, W 149.81482°	Garmin etrex 20
10	S 17.48244°, W 149.81482°	Garmin etrex 20
11	S 17.48248°, W 149.81479°	Garmin etrex 20
12	S 17.48149°, W 149.81837°	Garmin etrex 20
13	S 17.48143°, W 149.81834°	Garmin etrex 20
14	S 17.48142°, W 149.81837°	Garmin etrex 20

Table 2. Location of Gump reef transects that assessed substrate availability.

Transect number	GPS coordinate	GPS used
1	S 17.490778°, W 149.826144°	Garmin etrex 20
2	S 17.490092°, W 149.826182°	Garmin etrex 20
3	S 17.489216°, W 149.826400°	Garmin etrex 20
4	S 17.488360°, W 149.826259°	Garmin etrex 20

APPENDIX B

GENUS IDENTIFICATION

Picture 1. *Fungia* individuals.



Picture 2. *Herpolitha* individual.



APPENDIX C

VISUAL AIDS

Picture 1. The mouth of fungiids is on top of their body. It is shown here by the small opening in the center of their body.



Picture 2. Coral 2 is partially on coral rubble and partially at an angle on coral 1.

