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Examining the factors shaping the population structure of Thalassoma bifasciatum in the Lemon keys, Guna Yala, Panama

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Introduction

Introduction to Guna Yala

Panama formed 3-3.5 million years ago from the convergence of the Cocos, Nazca, Caribbean and South American plates. The formation created an isthmus that separated the Atlantic and Pacific oceans (Clifton *et al.,* 1997), causing the divergence of species and changes in currents. The closure of the isthmus lead to the extinction of species as well as increased Pacific upwelling and a strengthening of the Gulf Stream in the Atlantic Ocean (Thacker 2017). The Caribbean region today is the largest diversity center for the Atlantic Ocean (Dominici-Arosemena and Wolff 2005).

Part of the eastern third of Caribbean Panama is known as San Blas or Guna Yala. It runs from Punta San Blas to Puerto Obaldia, including 480 km of coastline and 365 coralline islands. The region contains 320,600 ha of mainland forest and coastal waters (Guzman *et al.,* 2003, Figure 1).

Earlier research has shown that human influences have impacted the coral reefs of Guna Yala. Population growth has led to more waste being expelled into the water and the expansion of islands by coral mining (Clifton *et al.,* 1997). Overfishing is another major concern (Hoehn and Thapa, 2009), but Guna people have been working to develop conservation strategies (Hoehn and Thapa, 2009; Guzman *et al.,* 2003).

Natural factors have also impacted the reefs of San Blas. The 1983 mass mortality of *Diadema antillarum*, the black sea urchin, led to increases in algal cover, that outcompeted coral species (Lessios 2005). Regional bleaching events in 1983 and 1995 also decreased coral, and therefore fish abundance (Clifton *et al.,* 1997).

Factors that Affect Fish Populations

A clear taxonomic division between reef and non-reef fishes has not been found, as species can migrate between habitats (Roberton 1998). Therefore, it is important to examine reef fish abundance in other regions. Additionally, the edges of habitats are lacking in fish diversity research (Sagarin and Gaines 2002), so examining the reef-seagrass transition is useful.

Fish populations also vary based on local and regional factors (Rodríguez-Zaragoza *et al.,* 2011; Dominici-Arosemena and Wolff 2005). Regional factors, like the human impact, bleaching and mass mortality contribute to declines. For example, many ecological changes have occurred throughout the tropics (Hughes 2003), much of which is due to overexploitation of resources and degradation of habitats (Gardner 2003). Coverage of hard coral in the Caribbean decreased by 80% in just 30 years (Gardner 2003). Coral loss did not directly correspond with fish diversity decline, but has contributed, especially over the past decade (Paddack 2009).

The introduction of invasive species, such as the lionfish, *Pterois volitans,* has led to changes in density of fishes throughout the Pacific. Lionfish are natural predators, but native fish populations are at considerable disadvantage due to the lack of coevolution. Many reef fishes have thus been the unsuspecting prey of *P. volitans.* One of these species is *Thalassoma bifasciatum* whose population density increased by 75% after lionfish removal (Palmer *et al.,* 2016).

Additionally, local factors like levels of light penetration, substrate coverage and local biodiversity could lead to changes as well. This study will examine some local factors to see if they affect *Thalassoma bifasciatum* populations.

Studies examining the relationship between fish and their environments can be used to see how habitat changes affect fish populations. They can also be used to generate management strategies for coral reef conservation. Further studies with more regions, habitat types, and species are needed to have a better understanding of population and community structure (Jones & Syms, 1998).

Thalassoma bifasciatum Information and Current Research

Thalassoma bifasciatum is an important species that fills a niche in the coral reef communities of the Caribbean. One of the roles of the wrasse is to clean parasites from other fish. This mutualistic relationship allows the wrasse to gain food resources while the other fish benefits from reduced parasites. Additionally, *Thalassoma bifasciatum* is an important food resource for some picivorous carnivores, such as the spotted moray, graysby and the red hind (Darcy *et al.,* 1974).

Studies containing *Thalassoma bifasciatum* in the San Blas archipelago have been done, but none have reported the overall density and abundance of the bluehead wrasse. Studies have shown growth rates (Victor 1982) and recruitment patterns (Wilson 2001) of the species, but factors contributing to the population structure have yet to be researched in depth.

Similar studies have yet to be completed on *Thalassoma* populations in Guna Yala. However, diversity of reef fish including *Thalassoma* and correlations to habitat in the Bocas del Toro region have been conducted (Dominici-Arosemena and Wolff 2005). Bocas del Toro, although also located on Caribbean side of Panama, is still a very different environment than Guna Yala. Bocas del Toro lacks barrier reefs but has larger ocean swells, contributing to less coral diversity in the area (Clifton *et al.,* 1997). Although Labridae are still fairly common in the area, many other fish species have low or no populations present. Therefore, if diversity of other fish populations plays a role in bluehead wrasse abundance, then the results of this experiment should be different than those from Bocas del Toro (Clifton *et al.,* 1997). Additionally, *T. bifasciatum* was not the only focus of the paper, thus lacking the specificity of results that this paper provides (Dominici-Arosemena and Wolff 2005).

In addition, many reef fish studies only include information on coral reefs and possibly rocky substrate (Robertson 1998) but this study will also incorporate seagrasses to observe if this new environment will contain any *T. bifasciatum.* This study is unique because it examines multiple forms of nearby habitats in an understudied region of Panama to see how environmental factors contribute to the population structure of *Thalassoma bifasciatum*.

Research question

What is the population structure of *Thalassoma bifasciatum* in the Lemon Keys, Guna Yala, Panama?

Research objective
To examine size class structure of *Thalassoma bifasciatum* and how its abundance and density vary in relation to factors such as substrate, species diversity and depth.

Materials and Methods
Site Setup and Environmental Measurements

Two non-overlapping study sites were selected in the Lemon Keys of Guna Yala, Panama off the coast of the same island (Figure 2). The sites had a latitude of 9°32'33.75"N and a longitude of 78°54'14.47"W and remained separate to limit the migration of organisms between them. Collection was done on fringing reefs from June 21 to June 28, 2018, which is during the rainy season.

Each site had four 30m x 2m transects (Benfield *et al.*, 2008), three of which ran parallel to the shore and were 5-10 m apart. The fourth transect ran perpendicular to the other three and helped to normalize for the change in depth experienced between transects (Figure 2). The first site was in a shallower area that consisted of seagrass (Figure 3), rocks and some corals, and the second site was in a deeper area that was primarily reef based with some rocky substrate (Figure 4). The ends of each transect were marked with noticeable natural objects or with rebar stakes.

After the transects were placed, 1 m^2 quadrats (Rodríguez-Zaragoza *et al.,* 2011) were measured every five meters on each transect, for a total area of 480 m^2. These were used to get a more accurate estimate for the overall substrate of each site.

The average depth for each site was recorded (Rodríguez-Zaragoza *et al.,* 2011). Due to the generally shallow presence of coral reefs, surveys were only conducted in waters no more than a few meters deep (Benfield *et al.*, 2008). Daily factors like time, visibility, tides and conditions were noted to see if they affected numbers of *Thalassoma bifasciatum*.

Fish Data Collection

After these site measurements were conducted, an initial dive was used to get familiar with the area and with fish identification (Benfield *et al.*, 2008). Data was then collected for four days, two in the morning and two in the afternoon. Two surveys of each site were done each day and the time of collection was kept fairly standard between the two days. Therefore, there was a total of 4 different times (two in the morning and two in the afternoon) for each site, with one repetition. Each collection (for all eight transects) took about an hour and 20 minutes, for a total dive time of 2 hours and 40 minutes each day.

During collection, the quantity and length measurements (Dominici-Arosemena and Wolff 2006) of *Thalassoma bifasciatum* individuals were recorded per transect. Length measurements were done using a 1 meter PVC pipe with a sturdy ruler attached (Benfield *et al.*, 2008) and measured to the nearest centimeter. Their visible phase of life, juvenile (yellow and white with a black spot on the dorsal fin), intermediate (vertical banding, possibly retaining some yellow coloration) or terminal (characteristic blue-headed form), was also noted (Figure 5). Interactions between these fish and their environment were logged, primarily whether or not they were swimming with other individuals. Additionally, the number of fish families in the area was noted, as well as the total number of fish and the number of fish per family to compare diversity of other species to *T. bifasciatum*. Families like Gobidae and Blennidae were ignored, as they are so small that they are hard to quantify accurately (Benfield *et al.*, 2008).

Statistical Analysis

After data was collected, calculations and statistical analysis were completed. Substrate was examined and quantified for every 5 meters. T-tests and ANOVA were used to test significance between sites, transects and times while examining certain factors (Dominici-Arosemena and Wolff 2006; Benfield *et al.*, 2008). These tests were used to compare the significance of both total fish populations and specifically for *T. bifasciatum* to see if the differences between the sites and times were significant.

Ethics

While working on the reef, contact with organisms was limited as much as possible. The ends of transects were only placed into sandy or rocky areas, not directly into coral heads. I swam carefully as not to touch any coral, and only stood up in sandy areas. No plants or animals were intentionally injured, killed or otherwise harmed during these studies.

Results

Size Distribution and Schooling Behavior of *Thalassoma bifasciatum*

Size and stage of life were recorded for all the *T. bifasciatum* found per transect (Figure 5) . Initial phase measurements ranged from 1-9 cm with an average of 4.1 cm, intermediate phase ranged from 4-11 cm, with an average of 7.3 cm, and terminal phase ranged from 8-13 cm with an average of 10.2 cm.

For Site 1, initial phase individuals were mostly found where other *T. bifasciatum* were present, and composed 33.3% of the total number counted. Intermediate phase individuals were found on Transects 2 and 3 for both collections on June 23rd, just on transect 3 at 10:30 on June 25th and for transects 2,3, and 4 for the remaining times. 51.3% of individuals counted were in intermediate phase. Terminal phase individuals made up 25.3% of the population and were found on Transects 2, 3, and 4.

Site 2 had 32.7% in initial phase, 43.7% in intermediate phase and 23.6% in terminal phase. All phases were found for each transect at least a few times. Intermediate phase were found for all times at all transects except Transect 3 at 9:15 AM on June 27.

Occasionally, *T. bifasciatum* were seen actively swimming in pairs or slightly larger groups (Table III). For Site 1, 40 *T. bifasciatum* were swimming together. 47.5% of schooling individuals were initial phase, 51.2% were intermediate phase and none were terminal phase. For Site 2, a total of 52 *T. bifasciatum* were swimming together. 41.1% were initial phase, 33.3% were intermediate phase and 25.5% were in terminal phase. For Site 1, 0% of schooling individuals were on Transect 1, 70.0% on Transect 2, 25.0% on Transect 3 and 5.0% on Transect 4. For site 2, 31.4% of schooling individuals were on Transect 1, 27.5% on Transect 2, 21.6% on Transect 3 and 19.6% on Transect 4 (Table III).

Other Fish Populations and their Effects on *T. bifasciatum*

The fish families found were Scaridae, Chaetodonidae, Acanthuridae, Tetraondonidae, Pomacentridae, Haemulidae, Lutjanidae, Serranidae, Holocentridae, Synodonidae, Carangidae, Aulostomidae, Ostraciidae, Cyprinidae, Mullidae and other Labridae. This gives a total number of 16 different families, all of which were found at Site 2, but only 13 of which were found at Site 1 (no Mullidae, Holocentridae or Aulostomidae were seen) (Figure 8).

The average number of families found per transect and site ranged from 4.125 (Transect 1 of Site 1) to 8.5 (Transect 4 of Site 2) (Table I**)**. The number of families for Site 1 increased from Transect 1 to Transect 2, but decreased for the remaining transects. For site 2, The average number of families increased from Transects 1-4. The p value between the number of families per site was <0.0001, indicating significance.

Excluding *T. bifasciatum,* there were 2,885 fish counted on Site 1 and 3,457 fish counted on Site 2, giving a total number of 6,342 fish (Figure 7). The p value comparing the total number of fish between sites was 0.024, indicating significance. The ANOVA for the four times of day (9:15 AM, 10:30 AM, 2:15 PM and 3:30 PM) for Site 1 was 0.984 and was 0.0190 for Site 2. Therefore, the difference in fish abundance for Site 1 was not significant, but it was for Site 2.

The number of fish ranged for Site 1 ranged from 28 to 166 individuals per 60 m^2. Transect 1 had 409 fish, Transect 4 had 530, then 841 for Transect 3, and Transect 2 with 1105 fish. Site 2 had between 76-155 *T. bifasciatum* for 60 m^2. A total of 776 fish were found for Transect 1, 767 for Transect 2, 864 for Transect 3 and 1050 for Transect 4. The numbers for Site 2 were closer to each other than those of Site 1, having a standard deviation of 131 verses 314.

Scaridae was the most prevalent family for Site 1, with 1463 individuals, or 50.7% of the fish found at this site. Labridae was second with 25.9%, then Tetraodonidae (11.5%), Pomacentridae (6.93%), Acanthuridae (2.84%), Chaetodonidae (1.46%), Carangidae (0.21%), Synodonidae (0.14%), Lutjanidae (0.01%), Serranidae (0.07%), Ostraciidae (0.07%), Haemulidae (0.03%) and Cyprinidae (0.03%) (Figure 8).

For Site 2, Pomacentridae was the most abundant family, with 1281 individuals (37.1 %) and Scaridae was the second-most prevalent with 30.1%. Tetraodonidae (17.4%), Labridae (5.79%), Haemulidae (2.89%), Lutjanidae (2.66%), Acanthuridae(1.82%), Chaetodonidae (1.59%), Serranidae (1.10%), Holocentridae (0.35%), Carangidae (0.20%), Aulosomidae (0.12%), Ostraciidae (0.12%), Cyprinidae (0.06%), Mullidae (0.03%), and Synodonidae (0.03%) followed (Figure 8).

Daily Environmental Conditions and Their Effects on *T. bifasciatum*

Because sampling occurred during Panama's rainy season, conditions and visibility were consistently affected by storms. The first day of sampling-June 23- had fairly strong waves, cloudy skies, and a visibility of 9.04 m. June 24th was measured soon after a thunderstorm but had smaller waves. There was a lot of dead, floating seagrass and many Ctenophora. June 25th was the first morning collection, and it followed a stormy night that led to choppy waves. Visibility was initially low but steadily increased during survey. No data was collected June 26th. June 27th had the lowest visibility of only 5.80 m and the water had a yellowish tinge. There was a lot of floating dead seagrass, trash, and sickly or dead pufferfish.

The morning measurements were around low tide and the tide got slightly higher for the afternoon. Site 1 had an average depth of about 0.8 m and Site 2 had an average depth of about 1.8 m.

An ANOVA test comparing the number of *T. bifasciatum* for the four days was 0.751. Test results comparing times of day were 0.88 for Site 1, 0.64 for Site 2 and 0.97 overall.

Substrate Composition and its Effects on *T. bifasciatum* Distribution

There were 151 *T. bifasciatum* found in Site 1 and 199 found in Site 2 (Figure 9), giving an overall abundance of 0.36 individuals per square meter. A t-test comparing the two sites gave a p-value of 0.037, indicating differences between sites are statistically significant.

Site 1 had three parallel transects: one of primarily seagrass, one on the seagrass-coral transition and one in a more coralline and rocky area. Transect 1 consisted primarily of seagrass, sand and rock-covered algae with some amounts of free-standing algae, sponges and massive coral. Sand was present throughout all of Transect 2, and algae, coral rubble, seagrass, and algae covered rocks were very common. Five quadrants had massive coral and 3 had encrusting coral, all found in small amounts. All quadrants except for 30 m contained dead hard coral, and the 5 m mark had almost 20%. Large percentages of fire coral were found for 5 and 10 meters, 55.6% and 30.9% respectively, but not on in the other quadrants (Figure 6).

Transect 3 had massive coral at 15, 25 and 30m. Some encrusting coral, fire coral and dead hard coral were found at 10, 20 and 25 meters. Algae and sand were fairly common throughout the transect. There were no algae covered rocks at 20 or 25 meters, but the other quadrants ranged from 32.1% to 67.9%, with 15 meters having the most. Transect 4 ran perpendicular to the previous three transects and contained 8/10 of the categories in the previous sites (no fire coral or sea urchins were present). There was only one urchin found at the other transects, but the fire coral was fairly prevalent in Transects 2 and 3, giving values of 14.4% and 11.3%, respectively. Otherwise, Transect 4 was fairly representative for the other sites.

For all eight surveys on Site 1, there were no *T. bifasciatum* found on the first transect. Transect 3 consistently had the greatest abundance, for a total of 0.15 *Thalassoma*/m^2. Transect 2 had an abundance of 0.12 *Thalassoma*/m^2 and Transect 4 had an abundance of 0.042 *Thalassoma*/m^2, for an overall abundance of 0.31 *Thalassoma*/m^2 for site 1.

Site 2 began slightly deeper on the reef, and consisted of more coral and no seagrass. Site 2 also contained leafy coral, branching coral and zoanthids not present in Site 1 and had a higher abundance of urchins. Transect 1 on Site 2 had massive coral on 4 quadrants and reached 48.1% at 15 m. Only 1.2% of coverage was leafy coral at both10 and 15 meters. Dead hard coral, sand and algae covered rocks were mostly present throughout. Fire coral was only found at 20 meters but made up 24.7% of the substrate coverage. Algae was only recorded at 20 and 25 meters. Coral rubble made up small percentages at 5, 20 and 30 meters but 27.2% at 25 meters.

Transect 2 had a similar percentage of coral cover (excluding fire coral) to Transect 1, but had less massive coral and more leafy and encrusting species. Soft coral was present at 5 meters and composed 32.1% of the total quadrant. A small percentage (2.5%) of fire coral was present at 20 meters but nowhere else. Zoanthids composed 1.2% of coverage at 5 and 20 meters. Algae covered rocks and dead hard coral were fairly common and one urchin was found at 25 meters.

Transect 3 had larger quantities of massive and leafy coral but less encrusting than Transect 2. Sand, algae covered rocks, and coral rubble were common at both transects. For Transect 3, Dead hard coral was found at 10, 15 and 25 meters. Zoanthids were found at 5, 15 and 25 meters. Algae was only recorded at 5 and 30 meters and did not compose much of each quadrant. Fire coral was also found at the same meter marks as algae, but composed a greater percentage (Figure 6).

As with site one, Transect 4 was fairly representative of the previous transects. It contained branching coral and sponges not recorded at previous sites but did not contain the soft coral recorded at Transect 2 (Figure 6).

Site 2 had an overall abundance of 0.41 *Thalassoma*/m^2. 0.12 *Thalassoma*/m^2 were found on Transect 1, 0.11 *Thalassoma*/m^2 were on Transect 2, 0.10 *Thalassoma*/m^2 on Transect 3 and 0.09 *Thalassoma*/m^2 on Transect 4, showing that Transect 1 had the highest abundance and Transect 4 had the lowest. The values for Site 2 were closer to each other than for Site 1, having a standard deviation of 0.013 *Thalassoma*/m^2 compared to 0.069.

Discussion

Size Distribution and Schooling Behavior of *Thalassoma bifasciatum*

There were a lower percentage of terminal phase *T. bifasciatum* found than the other phases, probably because fewer individuals are likely to make it to more advanced phases of life. However, more intermediate phase individuals were found than initial phase, which could be explained if there were problems producing the more recent generation or if there was an abundance produced at once for the intermediate phase. Additionally, if the initial phase lasts less time than the intermediate phase, this could offer another explanation.

About 26% of the *T. bifasciatum* found on each site were noted swimming in groups. Fish have been shown to school as a means to avoid being eaten by predators (Larsson 2012), so *T. bifasciatum* might value the extra protection of its neighbots. Larger individuals were more commonly spotted alone, possibly due to their enhanced ability to avoid predators.

Other Fish Populations and their Effects on *T. bifasciatum*

Thalassoma individuals, especially younger ones, were commonly seen interacting with schools of Scaridae and other Labridae such as *Halichoeres bivittatus* (Table II). These schools were mostly present in sandy areas in close proximity to corals or rocks. Individuals would commonly peck at rocks and algae, occasionally with *Thalassoma* joining in. Again, the presence of more non-predatory fish could help with protection for *T. bifasciatum.*

T. bifasciatum were not noted to interact with other families, even highly abundant ones like Pomacentridae. Pomacentridae were very commonly noted hiding in coral and rocky substrate and because *T. bifasciatum* were more free-swimming, they may not interact as often.

No lionfish were found during this study, so their influence on *T. bifasciatum* could not be quantified. However, they have been noted in the region (Harwell 2017) so lionfish populations still may affect fish in the area.

Daily Environmental Conditions and their Effects on *T. bifasciatum*

Depth could have played a role in the number of fish found, as there is more room for fish to swim. However, the perpendicular transect helped account for change in depth within sites and the change between the two sites was not very extensive.

Because the ANOVA values were larger than 0.05, changes between dates and times were not significant. This shows that light penetration, wave conditions, and tide fluctuations did not have a significant effect on the number of *T. bifasciatum* found. The daily changes did not seem to be very large, so this did not come as a surprise.

Substrate Composition and its Effects on *T. bifasciatum* Distribution

T. bifasciatum were shown to prefer coral reefs to seagrass beds, possibly due to the increased protection reefs provide. It has been noted that *T. bifasciatum* avoid picivorous carnivores while completing cleaning practices, including certain Serranidae (Darcy *et al.* 1974) seen during surveys. *T. bifasciatum* generally hide when known predators are present (Grorud-Colvert and Sponaugle 2006; Palmer *et al.,* 2016), but this behavior was not noted during this study. Although *T. bifasciatum* are prey fish, a species of blenny, *Hemiemblemaria simula,* displays their initial phase coloration, potentially still as a means for protection (Humann and Deloach 2014). Therefore, *T. bifasciatum* are not the most at risk species for predation on the reef, so protection may not be the only reason they prefer reefs to seagrasses.

T. bifasciatum might also prefer coral reefs to seagrasses because they have easier access to the zooplankton, mollusks, small crustaceans and parasites from other fish (Humann and Deloach 1999) that they consume.

Possible Sources of Error

Transects might not have been aligned exactly or pulled evenly across the substrate. Because of the more uneven nature of reefs, there was likely more error as coral cover increased. Quadrants could also easily be shifted by the waves. To help with accuracy, patience was heavily utilized and measurements were done in the calmest conditions possible.

The increased surface area of reefs could also allow more space for organisms to hide, potentially preventing some fish from being counted. Estimates were made as accurately as possible and cryptic species were excluded. Fish in larger schools were more likely to be miscounted and some fish may have been counted multiple times on the same transect.

Conclusion

In conclusion, *Thalassoma bifasciatum* are a fairly common reef fish that exhibited growth up to 13 cm in length. They made up 5.50% of the total fish population, for an abundance of 0.73 fish/m^2. Initial or juvenile phase individuals composed 32.86% of the population, 46.86% were in intermediate phase and 20.29% were in terminal phase.

The population structure of *T. bifasciatum* was affected by substrate coverage, slightly from population density of other fish, and not significantly affected by depth or daily fluctuations in environment. *T. bifasciatum* are not found on seagrass beds and their numbers increased as the substrate became more coralline. The largest school found on a transect was 6 individuals, but a larger school was spotted slightly off from the first site. *Thalassoma* were most commonly spotted alone or in groups of two, but they commonly associated with other members of Labridae and with Scaridae. There was no significant difference between the dates or time of collection, suggesting that changes in tide, visibility and other daily fluctuations did not affect populations.

These preliminary observations on this single species serve as a basis for future studies to comprehensibly asses the distribution of fish species by environmental factors and substrates.

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Appendix

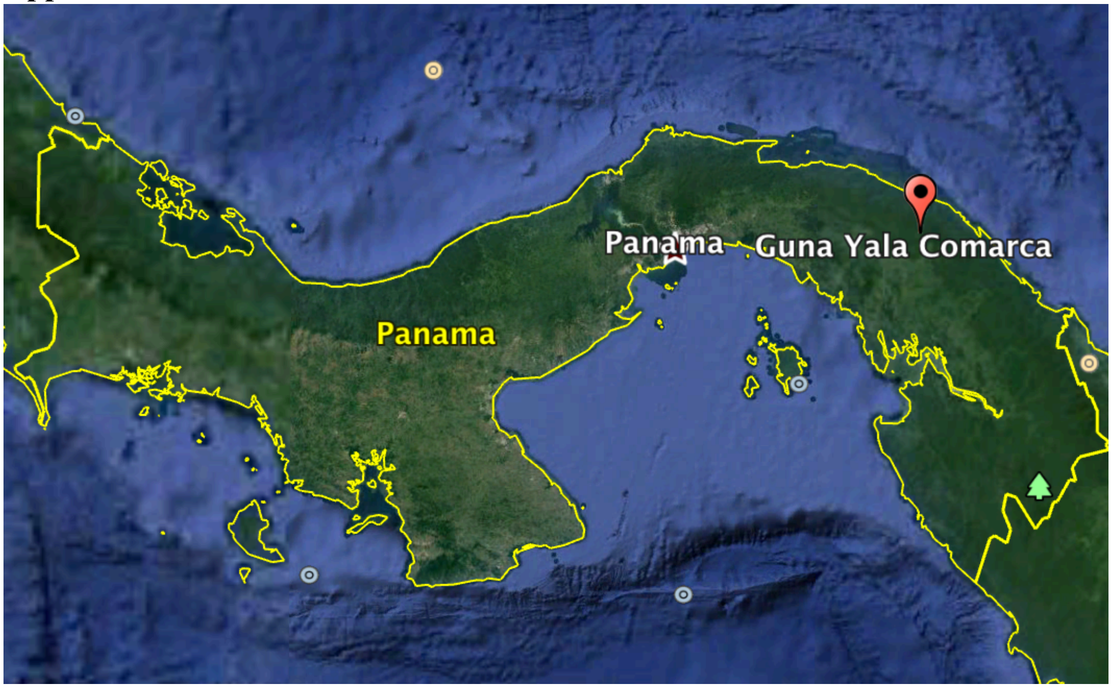


Figure 1 Map of Panama with the region of Guna Yala emphasized. Data was collected in the archipelago off the coast of the Guna Yala Comarca.

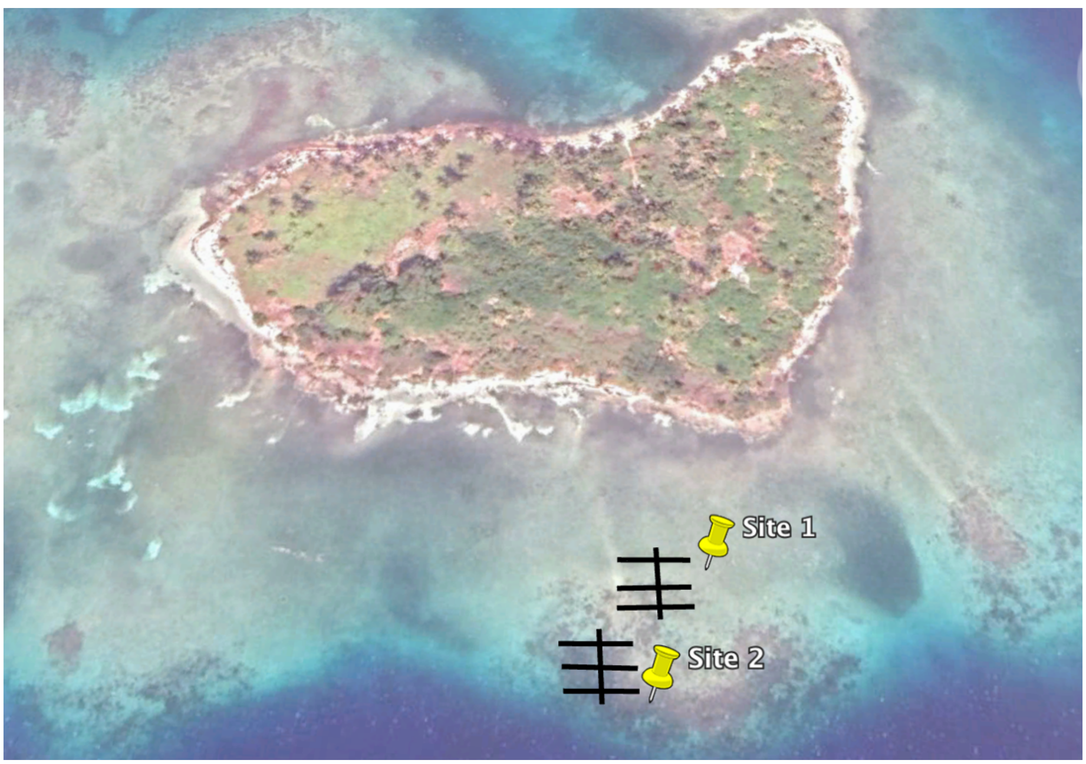


Figure 2 Map of both sites. Site 1 contained a seagrass bed, the seagrass-coral transition zone and a coralline area. Site 2 was deeper and primarily coral based. Transects for each site were numbered 1-4, with 1 being the closest to the shore, followed by 2 and three, and 4 was the perpendicular intersection.

Figure 3 Transect 1 of site 1, in the seagrass area.

Figure 4 Photo of Site 2, Transect 1 in a reef area.

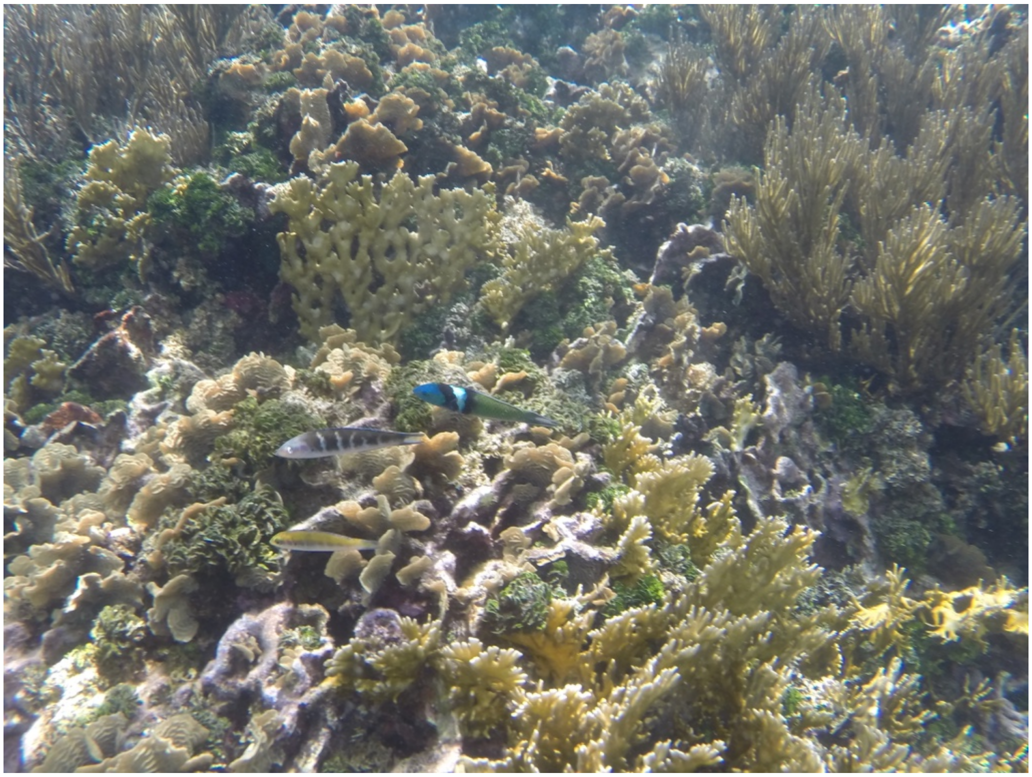


Figure 5 Photo containing all three phases (initial, intermediate and terminal) of *Thalassoma bifasciatum* swimming over the reef.

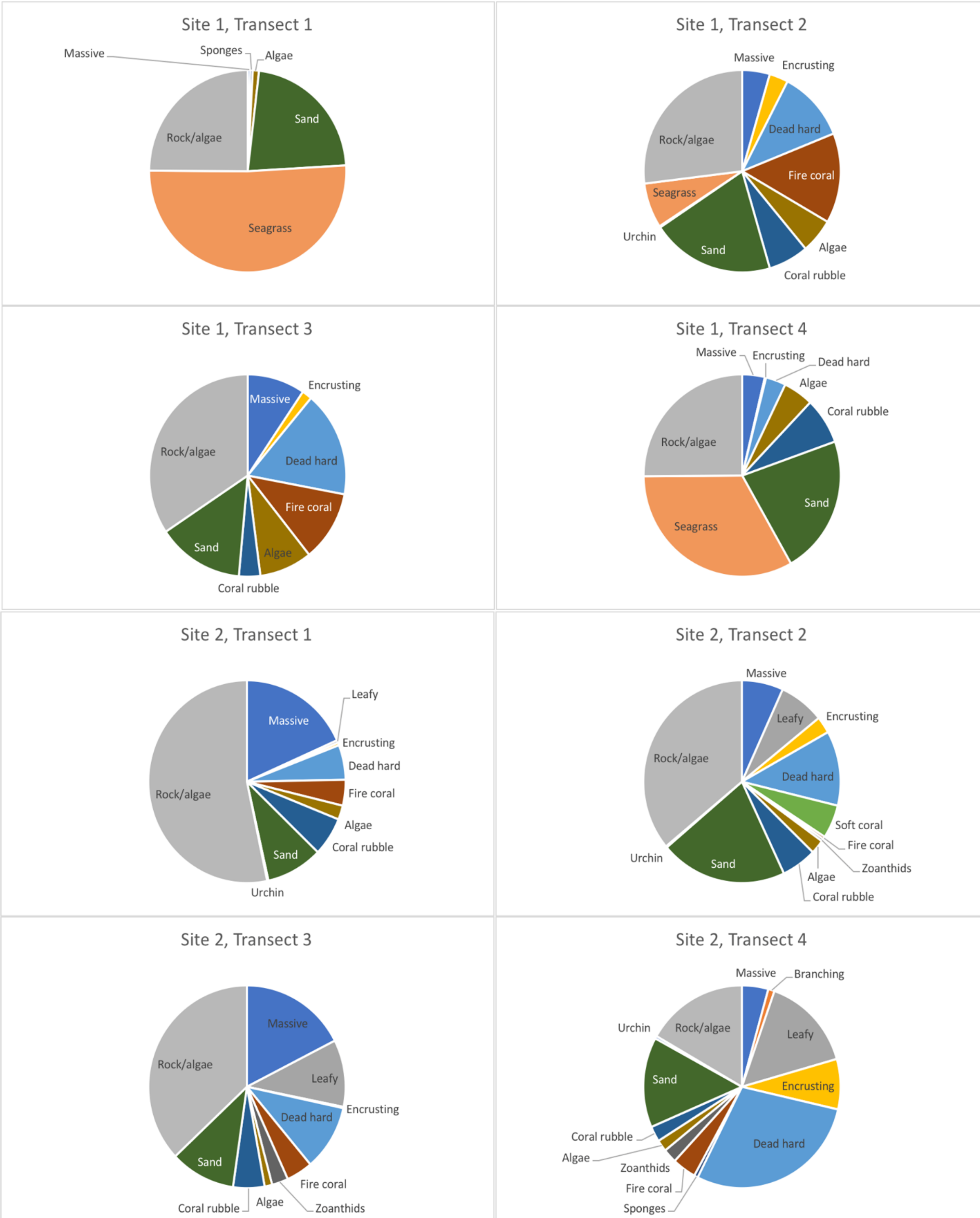


Figure 6 Percentage cover of various substrates for each site and transect. “Leafy”, “massive”, “branching” and “encrusting” refer to different coral morphologies. “Dead hard” refers to coral skeletons that still have recognizable morphologies and “Rock/algae” are unrecognizable.

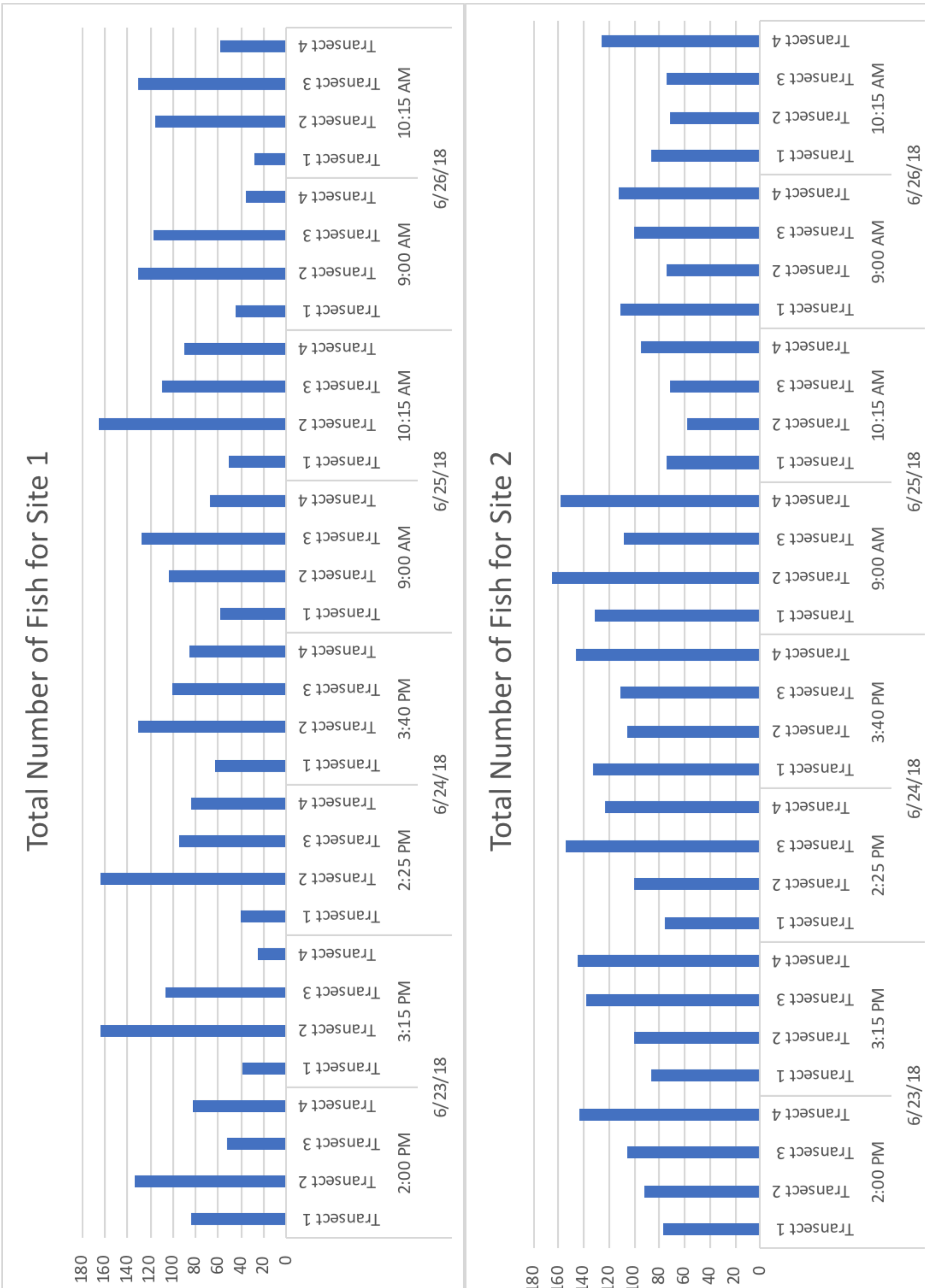
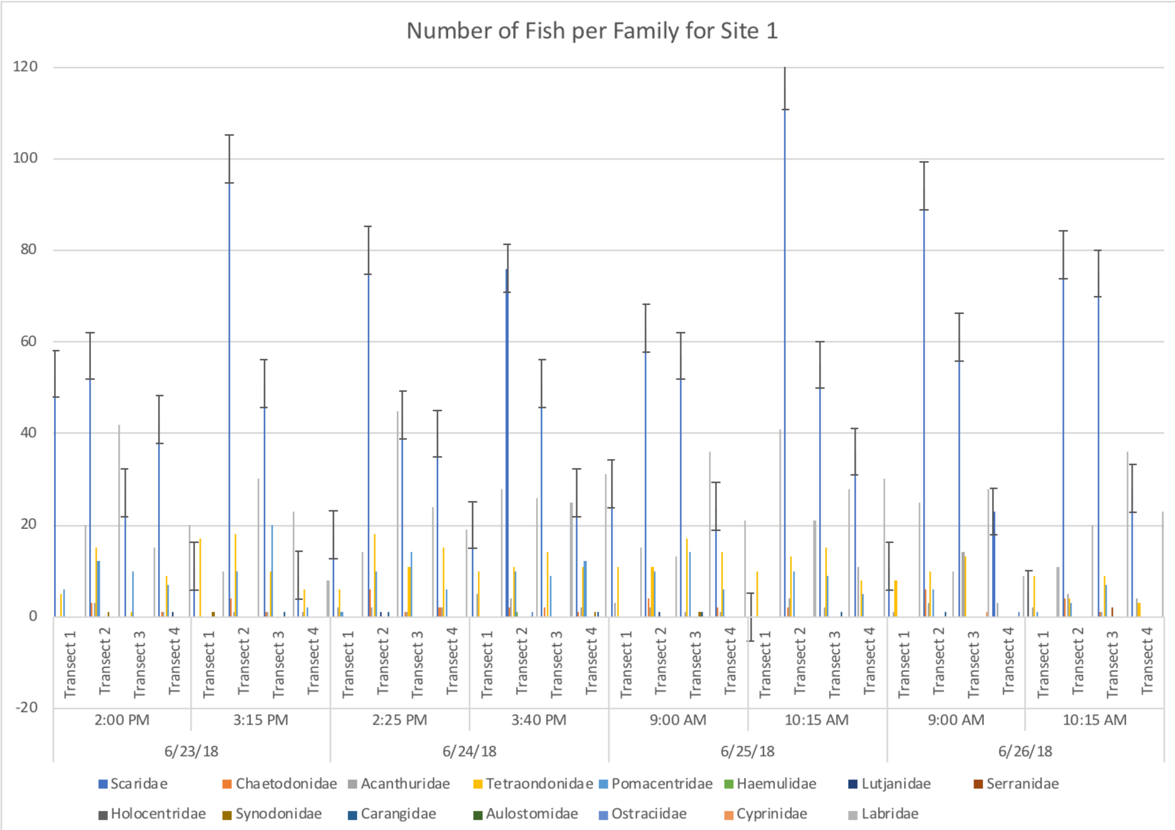


Figure 7 Total number of fish (excluding *T. bifasciatum*) present at each site for each transect, time and date.



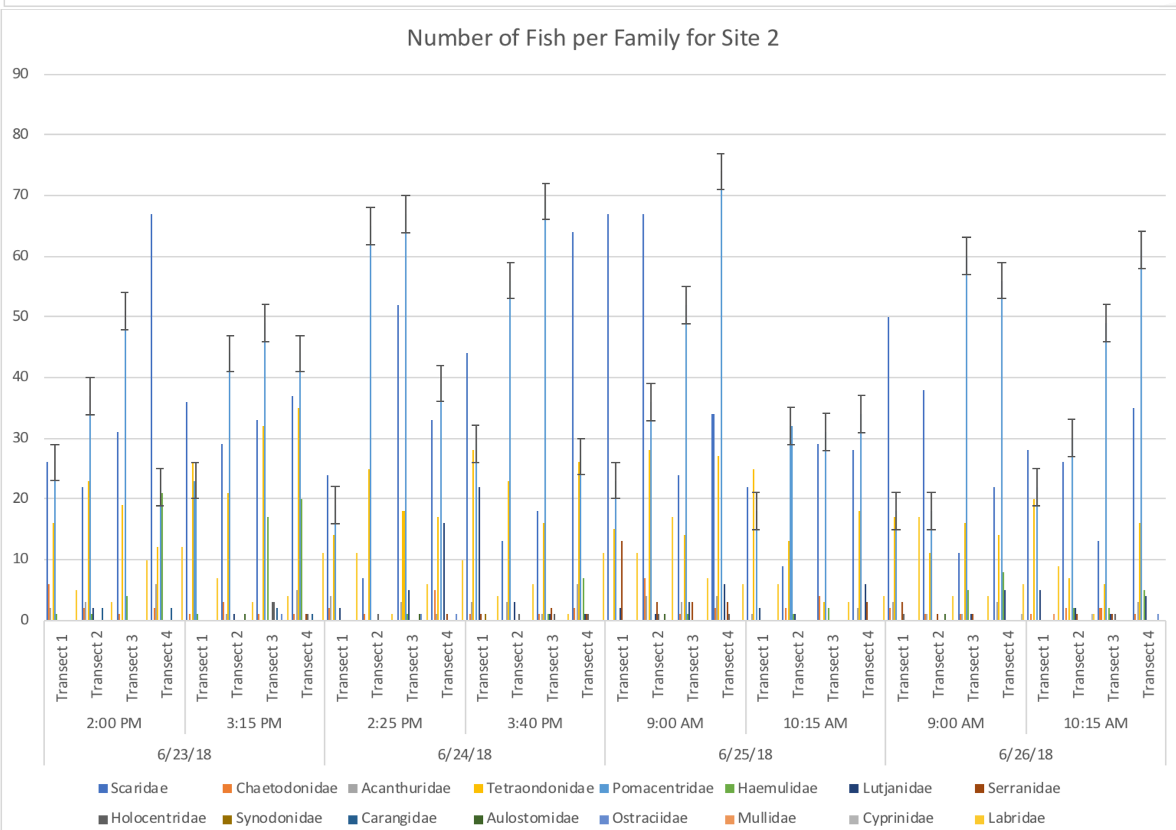


Figure 8 The number of fish per each family at sites 1 and 2 per transect, date, and time.

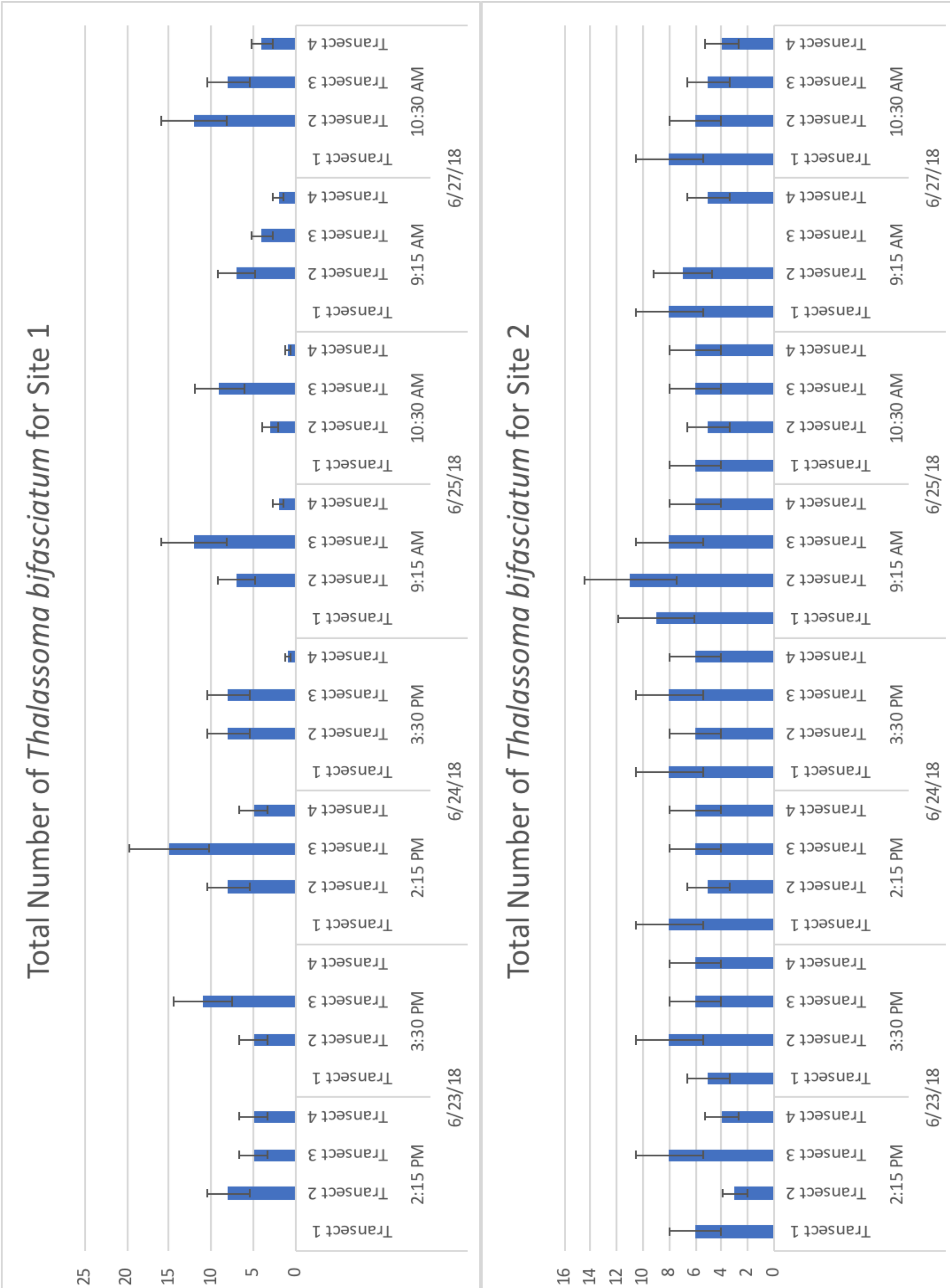


Figure 9 Graphs displaying the total number of *T. bifasciatum* per site, transect, time and da

		Average Number of Families Present	
Site 1	Transect 1	4.125	
	Transect 2	6.875	
	Transect 3	5.875	
	Transect 4	5.625	
Site 2	Transect 1	6.875	
	Transect 2	7.625	
	Transect 3	8.25	
	Transect 4	8.5	

Table I Table displaying the average number of fish families found for each of the transects on both sites.

	6/23/18								6/24/18							
	2:15 PM				3:30 PM				2:15 PM				3:30 PM			
Transect	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site 1	Large schools of Scaridae that pecked at algae. Pomacentridae joined them.	Tetraodonidae peck at algae, large schools of Scaridae and Labridae at 10 and 15 meters.			Blennidae hiding under rock at 5 meters. Large wave hit at 10 m. Left a lot of sand and no fish		Sea cucumber at 10 meters.	Sand blown by waves at 5 meters. No fish around 10 m. Schools of Scaridae at 25 meters.	No fish for first 5 meters. Moon jelly present at 20 meters.	Large schools around 10 meters. Labridae, Scaridae and Acanthuridae in schools at 20 meters.		Only Tetraodonidae for first few meters. Schools of Labridae and Scaridae at 20 meters.	No *T. bifasciatum* . Lots of dead floating seagrass.	Large school of Scaridae and Labridae at 10 meters.		No fish for first 5 meters.
Site 2	Pomacentridae found close to coral heads. Chaetodonidae and Acanthurdae found alone or paired. Initial phase *T. bifasciatum* swimming together at 25 meters		Shrimp at 5 meters. Intermediate phase *T. bifasciatum* swimming together at 20 meters.				Large school at 30 meters.		Fish hiding in coral. Small Gobidae seen around 30 meters.	Fish hiding in reef. *T. bifasciatum* with Pomacentridae and Tetraodonidae at 10 meters.	Scaridae and Labridae at beginning, large school at 20 meters.	Much floating seagrass.	Large school of Acanthuridae, Labridae and Scaridae		Large school of Scaridae at 5 meters	Scaridae and Labridae eat algae. Large school of tiny juvenile fish that were not counted.

	6/25/18								6/26/18							
	9:15 AM				10:30 AM				9:15 AM				10:30 AM			
Transect	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Site 1	Lots of sand washed up at 10 meters	Intermediate phase *T. bifasciatum* at beginning. School of *T. bifasciatum,* other Labridae and Scaridae at 15 meters.	Large *T. bifasciatum* at the beginning of transect.	Squid around 10 meters					No fish for first few meters			Fast-swimming *T. bifasciatum* at the transition between rock/coral and seagrass.				
Site 2	*T. bifasciatum* swimming with Scaridae	Small *T. bifasciatum* cleaning a Serranidae.														

Table II Tables of extra substrate and fish family information noted in the field per site, transect and date.

SITE 1																																
	6/23/18								6/24/18								6/25/18								6/27/18							
	2:15 PM				3:30 PM				2:15 PM				3:30 PM				9:15 AM				10:30 AM				9:15 AM				10:30 AM			
Transect #	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
T. Bifasciatum Phase																																
Initial (cm)		4	4	5		4	**3**			**4**	5	3		3	4			**5**	4	3		**9**	3	2						*5*	4	**5**
		5	4	4			**3**			**5**	5				3			**4**	*3*			**6**	**5**							*7*	4	**7**
				5			3			**4**	4				3			5	*6*			**5**	**4**							**4**		
							4			4	7				4			6														
											5																					
											2																					
Intermediate (cm)		8	8			7	4			**7**	9	6		**7**	6	8		6	5	5			8			**9**	9	8		*10*	**7**	7
		8	8			6	5			7	6	8		**8**	5				8				6			**8**	7			*10*	**9**	
		7	7				7			8	6	6		**6**	4				5				8			**7**	8			**6**	5	
							8				5	7		**5**	7				**6**				6			**9**	7			**6**	7	
											6			**5**					**6**				8			7				**7**	10	
											8								6							9				**8**		
											6								6											**6**		
											6								8													
											5																					
Terminal (cm)		11		9		8	9			10				10				11	10				12			9		11		11	12	11
		9		10		8	9							9				8								10				10		
		9					11																									

SITE 2																																
	6/23/18								6/24/18								6/25/18								6/27/18							
	2:15 PM				3:30 PM				2:15 PM				3:30 PM				9:15 AM				10:30 AM				9:15 AM				10:30 AM			
Transect #	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
T. Bifasciatum Phase																																
Initial (cm)	**3**		6	4	4	4		4	4	6	6	4	4	**2**	4	4	4	**2**	4	7	**6**		**5**	3	*3*	**4**		*1*	**3**		5	
	3					3		4	4	4	3		4	**2**			*5*	**2**	4		4		*2*	4	*3*	**4**		*2*	5			
	3							5	2		5		4	**3**			*4*	5			4		*3*		5	**4**			4			
									2		4						4	5											4			
											5						4	5														
Intermediate (cm)	6	7	8	8	7	5	8	6	7	9	6	9	6	5	5	9	**6**	5	8	9	6	6	**8**	10	**7**	10		**7**	**7**	7	**8**	**9**
	8	7	7	7	8	7	8	7	9	6		8	7		7	6	**9**	7	8		**7**	8		10	**10**	9		**8**	10	**7**	**9**	
			8		6	7	8	7	5			9	7		8	7	9	7	**10**		7				7				9	**8**	10	
			7									5	6		8	8			8											11	8	
															6															*8*		
															10															*7*		
Terminal (cm)	9	11	**10**	9	10	10	8		11	12		11	10	11	10	11	**11**	12	11	**9**		**9**	**10**	9	**11**	12		12	11			**10**
			9			11	8							10				9	**13**	**11**		**11**	10	10	10	11						**12**
			10			12	9											10		**11**		10										12
																				11												

Table III Size distribution to the nearest centimeter of *T. bifasciatum* per life stage for each site, transect, date and time. Bolded numbers were individuals spotted swimming together during survey. Underlined or underlined and italic numbers were also seen swimming together and were used in cases in which the transect had more than group of *T. bifasciatum.* The two initial phase individuals for site 2 that are bolded and underlined were seen actively cleaning another fish.