

Effects of predator kairomones and starvation on *Tegula tridentata* behavior in a Chilean
subtidal ecosystem

By Brooke Fitzwater

A thesis presented to the Honors College of Middle Tennessee State University in partial
fulfillment of the requirements for graduation from the University Honors College

October 2016

Effects of predator kairomones and starvation on *Tegula tridentata* behavior in a Chilean subtidal ecosystem

by

Brooke Fitzwater

APPROVED:

Dr. Dennis Mullen
Biology Department

Dr. Lyn Boyd
Biology Department Chair

Dr. Donald Snead
Elementary and Special Education
Honors Council Representative

Dr. Robert D. Sieg
Honors Scholar

Acknowledgements

There were several funds, grants, and scholarships that were so graciously provided to make this project a reality:

Middle Tennessee State University Undergraduate Research Experience and Creative Activity (URECA) Grant

Paul W. Martin, Sr., Scholarship

James R. Kemp Scholarship

John A. Patten Scholarship

Wayne Rosing Scholarship

Everyone who donated through the project's GoFundMe campaign

There are also several people to whom I have endless gratitude:

My Family – Thank you for putting up with me during this long process. Thank you for supporting me and for tolerating me when most of our conversations ended up being marine-related. Thank you for the encouragement and undying patience.

Drs. Anthony & Mary Farone and Dr. Robert “Drew” Sieg – Thank you for your endless support, encouragement, and words of advice. Thank you for believing in me and giving me the opportunity of a lifetime.

Dr. Steve Howard – Thank you for helping me to weed through the statistical analyses and for your input on the project. Thank you for making time to meet with me and for your support.

Dr. Benjamin Sawyer – Thank you for your invaluable input on grants and for your undying support throughout this project. Thank you for Skyping with me when I was halfway across the world, for continuing to encourage me, and for giving me new perspectives to think about.

The People of ECIM – Thank you for your generosity, your openness, and your warmth. Thank you for taking me places I've never been and for allowing me to work beside you. Thank you for encouraging and supporting me. Thank you for giving me the gift of learning another language and for teaching me about the sea and the world of research.

Rodrigo José Alarcón Ireland – Thank you for your patience, for your kindness, and for your willingness. Thank you for understanding that I was new into the world of research. Thank you for teaching me español. Thank you for encouraging me and for checking on me every morning. Thank you for helping me when snorkeling didn't go as planned. Thank you for being there when I needed you.

Dr. Evie Wieters – Thank you for your patience and for allowing such a young researcher with no experience to fly to another country and dive into the water headfirst. Thank you for working with me, for showing me new ways of doing research and new techniques, for your invaluable input on the project, and for entrusting me with your laboratory's resources. This project would not be where it is now without you. I promise, it was well worth my time.

Dr. Dennis Mullen – Thank you for sticking with me all this time. This project has been a long time in the making, and I appreciate your time, efforts, and input dearly. Thank you for taking a chance on me, for believing in me, for teaching me, and for encouraging me. Thank you for your continued interest and willingness to help make this project a reality. Your mentorship has had a tremendous impact on this project, and it would not have been the same without you.

Abstract

Gastropods have been shown to alter their behavior in response to both predators and starvation. *Tegula tridentata*, a marine subtidal gastropod in Chile, is an herbivore that is preyed upon by the crab *Homalaspis plana* and the sea star *Meyenaster gelatinosus*. The effects of kairomones (chemicals) from *H. plana*, *M. gelatinosus*, and crushed conspecifics as well as the effects of starvation were tested to see if the different treatments elicited behavioral responses by *T. tridentata*. Three experimental trials were conducted in which *T. tridentata* behavior was monitored continuously every hour for 24 hours and was then monitored at less continuous but regular intervals for up to 72 hours. Aquaria containing *T. tridentata* (one per aquarium) were connected to predator treatment aquaria via flow-through systems to allow for kairomones to flow from the treatment aquaria into the *T. tridentata* aquaria. Different starvation levels were also used alongside the presence of kairomones. *T. tridentata* behavior and location within the aquarium was recorded during each observation. There was a significant reduction in movement rates and behaviors when *T. tridentata* were exposed to kairomones from *H. plana* even when starved for 20 days. These results have potential economical implications as there is a high economic demand in Chile for both kelp that *T. tridentata* consume and *H. plana*.

Introduction

Predation is a phenomenon that carries high costs to prey. An attack by a predator could result in the death of the prey or may result in injury should the attack be unsuccessful (Kopecký, 2013). Predation can produce either a direct effect in which the interaction is fatal for the prey or an indirect effect in which the prey alters its behavior to avoid death or injury (Fortin *et al.* 2005). Due to the costs of predation, avoidance behaviors are critical to survival, causing many organisms to evolve advantageous anti-predator behaviors to ensure survival; for example, the marine whelk *Buccinum undatum* did not typically forage and instead exhibited hiding behaviors (burying itself underneath the substrate or hiding within its shell or behind a rock) when in the presence of nearby predators (Rochette, 1999).

Many aquatic species of prey have developed adaptations in response to predation that allow them to evade injury or death. Some prey species can detect nearby predators and behave in a manner that will best ensure survival; *Neolamprologus pulcher*, a species of social cichlid fish, reduces activity rate, increases time spent seeking shelter, and spends more time in the presence of conspecifics when a predator is visually detected

(O'Connor et al. 2015). Prey have also been shown to distinguish between different predator species and exhibit predator-specific behaviors. The cuttlefish *Sepia officinalis* exhibits different behaviors towards three different predators (Staudinger, et al. 2013). In some occasions, prey species have been shown to distinguish which of the nearby predator species poses the greatest risk and will therefore avoid it the most. The freshwater snail *Physella gyrina* exhibits stronger avoidance responses towards *Lepomis gibbosus* (pumpkinseed sunfish) than several species of crayfish (Turner, Shelley, & Bernot, 1999). A variety of different stimuli can be used to detect nearby predators, and chemical cues emitted by an organism (kairomones) are a common stimulus that is detected by prey at the disadvantage of the predator (Brown, Eisner & Whittaker, 1970). Prey may either detect kairomones emitted by the predator or chemical cues emitted by conspecifics that have been injured or consumed by predators. Some prey such as the snail *Pomacea canaliculata* use kairomones emitted by injured or deceased conspecifics to detect predators, leading to alarm responses and behavioral changes (such as burying themselves in order to hide from predators) (Aizaki & Yusa, 2008).

In many circumstances, predation risk can also have strong effects on foraging behavior. Nearby predators can cause prey to reduce foraging activity; caged *Carcinus maenas* (green crabs) near *Littorina littorea* (common periwinkle snails) cause the snails to consume 490% less algae than when they are not in the presence of green crabs. (Trussell, Ewanchuk, & Bertness 2002). Foraging is a necessary means of obtaining energy for metabolic processes, so prey species often assess the potential risk of predation against the potential benefit of foraging within close proximity to the predator; if the benefit outweighs the risk of predation, some prey will forage where both the

reward and the risk are high. *Semotilus atromaculatus* (creek chubs) are cannibalistic, placing juvenile creek chubs at risk for predation from adults. However, juvenile creek chubs will select regions with high predation risk from adult creek chubs when the benefit of the food within the same area outweighs the potential risk of predation (Gilliam & Fraser, 1987).

In a central Chilean coastal ecosystem, marine gastropods have been shown to detect nearby predators and use the risk-reward trade-off principle when faced with a predator and a desirable food source within the same habitat (Soto, Castilla & Bozinovic, 2005). *Tegula tridentata*, a common marine gastropod found in the subtidal zone that often occupies *Lessonia trabeculata* kelp fronds (Pereira *et al.* 2015), is preyed upon by the crab *Homalaspis plana* (Morales & Antezana, 1983) and the sea star *Meyenaster gelatinosus* (Vasquez & Buschmann, 1996). In this study, indirect effects of predation on *T. tridentata* by *H. plana* and *M. gelatinosus* and the effects of starvation on *T. tridentata* behavior were tested to determine if the snails could distinguish between different predators and if starvation levels affected how *T. tridentata* reacted towards predators. Since there is an economic demand for kelp in Chile for a variety of commercial purposes (Buschmann, Hernandez-Gonzalez & Varela, 2008), as well as an economic demand for seafood from the Chilean coast (Fernandez & Castilla, 1998), understanding the relationship between *T. tridentata*, its predators, and the kelp is essential for developing management practices and regulations for the Chilean kelp and seafood industries. This research presents a platform for understanding how a small-scale ecological interaction could have potential implications for both the ecosystem and the economy along the central Chilean coast.

Methods

Collection, animal care, and general experimental design

All organisms (both kelp and animals) were collected in the field at Punta de Tralca, El Quisco, Chile. All experimental studies were conducted at Estación Costera de Investigaciones Marinas (ECIM) in Las Cruces, Chile, during the months of June and early July (austral winter) in 2016. Animals used in predator treatments (*H. plana* and *M. gelatinosus*) were housed in 20 liter aquaria that were attached to 1.4 liter aquaria that housed experimental *T. tridentata* by a tube. Water flowed from the treatment aquaria into the snail aquaria so that kairomones from predators could flow into snail aquaria (Figure 1). A low flow of water was used to ensure that kairomones were not immediately flushed out of snail aquaria before they could be detected. Water flow both in treatment aquaria and between treatment and snail aquaria was cut off and predators were fed at minimum 12 hours before an experimental trial to allow kairomones



Figure 1: Experimental setup showing the predator tanks (in this case with *M. gelatinosus*) attached to the snail aquaria.

to accumulate within the treatment aquaria and to ensure that *T. tridentata* behavior was analyzed directly upon introduction of kairomones. Predators used in all experimental trials were the same specimens excluding a few *M. gelatinosus* that were replaced due to a reduction in health and one new *H. plana* that was introduced in Trial 3, and these predators were randomly assigned to an aquarium during each trial. The *T. tridentata* used as experimental subjects during each trial were never reused as an experimental subject and were also randomly assigned to each treatment. Treatments were also randomly assigned and were housed on tables in an open laboratory under an opaque roof. All aquaria had access to natural daylight that allowed for a natural photoperiod which was roughly ten hours. Water circulating through aquaria was run through a quartz-filtered seawater that flowed through pipes from the adjacent coast. All treatment aquaria (20 liter aquaria), including control treatments, were constantly aerated. All snail aquaria were divided into three equal sections: a section containing food for *T. tridentata* (kelp), a section containing a shelter, and a section that was void of objects. For all treatments, the kelp *L. trabeculata* was used as the food choice for *T. tridentata*. Only healthy fronds were selected for use, and healthy kelp pieces that had no signs of stress or previous grazing were cut to the same size to be used as the source of food, and trials were only conducted up until the fronds had visually deteriorated to the point where they were no longer viable. Pieces of *L. trabeculata* from various fronds were randomly selected to ensure that treatments were receiving pieces from different fronds. A minimum of 12 hours before the start of each experimental trial, *T. tridentata* were randomly selected and placed in their respective aquaria to allow them to become acclimated to the aquarium before the shelters and *L. trabeculata* pieces were introduced.

At the start of each experimental trial, *L. trabeculata* pieces and the shelters were placed in the snail aquaria and *T. tridentata* were placed in the middle of the aquarium. For all experimental trials, behavior was monitored continuously for three hours straight and then once an hour until 24 hours total had elapsed.

Across all trials, location of *T. tridentata* within the aquarium and the behavior of the snail at the time of observation were noted. Location was either noted as “shelter,” “empty space,” or “kelp” in reference to the sections within the aquarium as detailed above. There were five different categories of behavior: “hiding” (*T. tridentata* was inside the shelter), “grazing” (foraging on *L. trabeculata*), “no movement” (stationary), “turning” (remaining in one location but moving body in a circle), “moving” (actively traveling from one location to another in the aquarium).

Trial 1

In Trial 1, three treatments were used: 8 *M. gelatinosus*, 6 *H. plana*, and 8 control treatments (treatments containing no predators). Shelters were made using plastic PVC pipes that were cut to 2 cm long, and *L. trabeculata* were cut to 2 cm on the shortest side so that they were similar in size to the shelter. *T. tridentata* were starved for four days prior to the start of the trial to ensure that they foraged on the *L. trabeculata* piece during the experiment. Predators were fed three *T. tridentata* each the night before the start of the trial and a new one was added after a snail was consumed. Observations of *T. tridentata* were conducted as described previously and hourly monitoring continued four hours after the first initial 24 hours had elapsed. Observations recommenced the next morning (8 hours later), and continued every two hours over a period of 14 hours. There were a total of 40 observations over a period of 56 hours.

Trial 2

Trial 2 was conducted in a similar manner as Trial 1 with a few exceptions. There were again three treatments used: 5 *M. gelatinosus*, 6 *H. plana*, and 8 controls. Since *T. tridentata* did not utilize shelters in Trial 1, new shelters were used to encourage them to utilize the shelters. A 5.83 cm x 5.83 cm ceramic tile was placed on top of the 2 cm PVC pipes that were used in the previous trial. These shelters were used for remaining trials and *L. trabeculata* were cut to the same size as the ceramic tiles. *T. tridentata* were starved for 20 days prior to the start of the trial. Due to a shortage of *T. tridentata* specimens available during this trial, predators were only fed one snail at the start of the trial. None of the predators consumed the snails that were offered during the trial. *T. tridentata* were monitored hourly for 10 hours after the initial 24 hour period had elapsed and were then monitored every three hours during the night (totaling three observations). Hourly monitoring was then conducted over a period of 16 hours, and then the same pattern of monitoring every three hours was conducted through the night. Due to rough sea conditions, the water flow into the aquaria shut off abruptly on three separate occasions, so data that was taken during these periods where no water was flowing were not used. The next morning, observations were conducted every two hours for a period of 6 hours. The trial was conducted over a period of 72 hours total. There were a total of 52 observations.

Trial 3

Trial 3 followed the same procedures as the previous trials with some exceptions. The purpose of this trial was to determine if *T. tridentata* were reacting to the kairomones emitted by the predator or if they were reacting to chemical cues that were emitted by

crushed conspecifics. Since *H. plana* elicited the strongest behavior response in the previous trials, it was used as the predator in this trial. Unlike the previous trials, two snail aquaria were attached to the treatment aquaria, one containing *T. tridentata* that had been starved for 30 days and one containing *T. tridentata* that had been obtained from the field the day before (0 days starved). Due to the lack of aquaria, a control was used, but only for the 30 days starved treatment, and thus during the statistical analysis, the control data was not able to be used. There were 5 replicates of each different treatment. *H. plana* were not fed during Trial 3, and *T. tridentata* (“crushed conspecifics”) were hand-crushed and placed in treatment tanks the night before the start of the trial. Only one crushed conspecific was used per experimental replicate to standardize to the previous trial. After the initial 24-hour continuous monitoring, observations were conducted each hour for a total of 8 hours. The remainder of Trial 3 was conducted in the same manner as Trial 2 in an effort to standardize the experimental trials even though there were no problems with the flow of seawater from the filter during Trial 3. Trial 3 was conducted over a total of 72 hours. There were a total of 56 observations.

Data Analysis

For Trials 1 and 2, total distance traveled (in centimeters) and the number of times that a specific *T. tridentata* replicate moved from one observation to the next (referred to as “position change”) were compared using a One-Way ANOVA in Excel 2016. Position change was converted to proportions (number of observations/total number of

observations conducted during the entire trial). Location within the snail aquaria and behavior during the time of observation were also converted to proportions and were compared using a Kruskal-Wallis Test with VassarStats (<http://vassarstats.net/>).

For Trial 3, total distance traveled and position change were compared using a Two-Way ANOVA in Excel 2016. Position change was also again converted into proportions in the same manner as Trial 1. Location within the snail aquaria and behavior during the time of observation were converted to proportions in the same manner as with Trials 1 and 2 and were compared using a Friedman's Test with VassarStats (<http://vassarstats.net/>).

Results

Trial 1

Under conditions in which *T. tridentata* were starved for 4 days prior to the start of the trial, snails across all treatments behaved in relatively similar manners. There was no significant difference between predator treatments for both total distance traveled and the total number of position changes (Figure 2.1, Table 1.1). There was a significant difference for location (Figure 2.2) within aquaria as well as behavior at the time of observation (Figure 2.3) across all treatments (Table 1.2), with *T. tridentata* favoring the empty space within each aquarium and remaining stationary during observations. Shelters were never utilized during the trial.

Table 1.1: Results of One-Way ANOVA for total distance traveled and position change during Trial 1. None of the values were significant during this experimental trial.

<u>Analysis</u>	<u>F</u>	<u>P</u>
Total Distance Traveled	1.1472	0.3386

Position Change

0.7807

0.4722

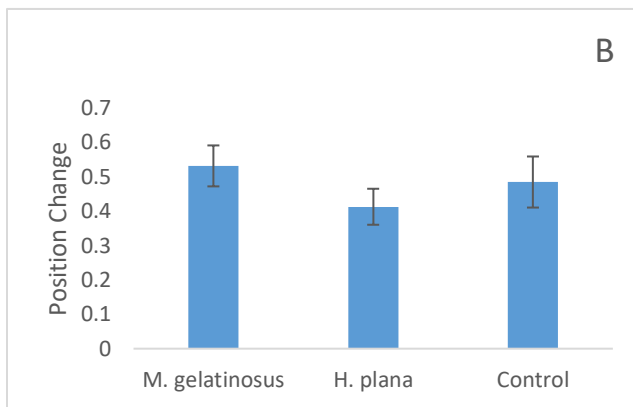
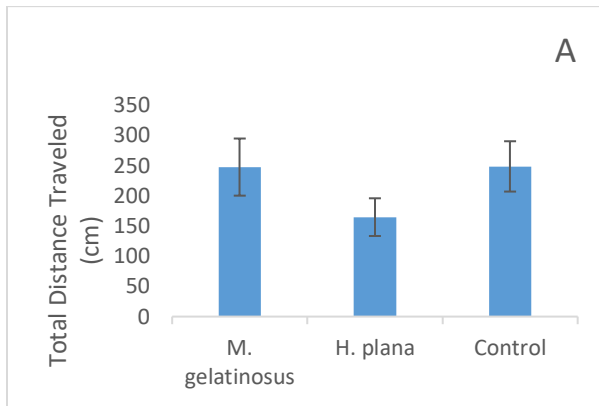


Figure 2.1: Mean distance traveled (A) and mean number of position changes (B) by *T. tridentata* for the three treatments over the 40 observations.

Table 1.2: Results of Kruskal-Wallis Analysis for location within aquaria and behavior during time of observation during Trial 1. All of the values were significant during this experimental trial.

<u>Analysis</u>	<u>H</u>	<u>P</u>
<i>M. gelatinosus</i> Location	16.08	0.0003
<i>H. plana</i> Location	11.37	0.0034
Control Location	15.68	0.0004
<i>M. gelatinosus</i> Behavior	24.29	<0.0001
<i>H. plana</i> Behavior	16.73	0.0022
Control Behavior	22.7	<0.0001

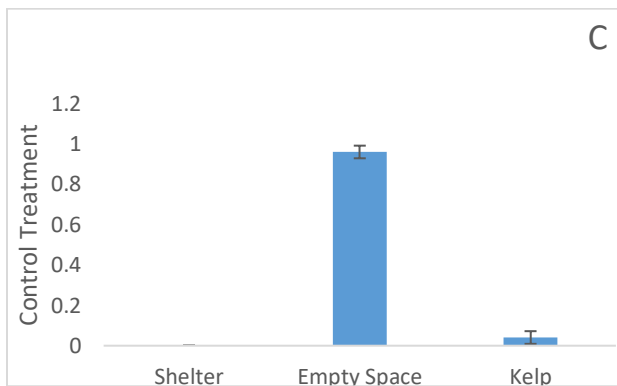
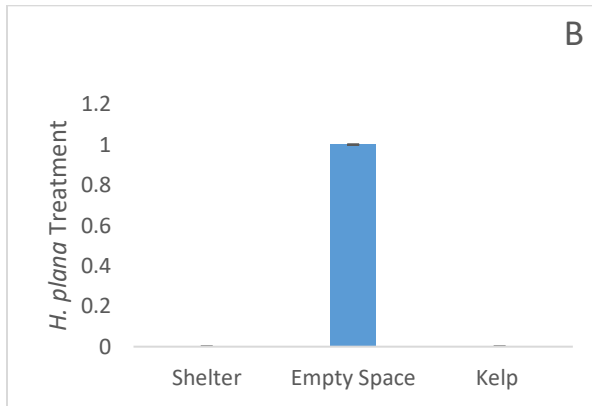
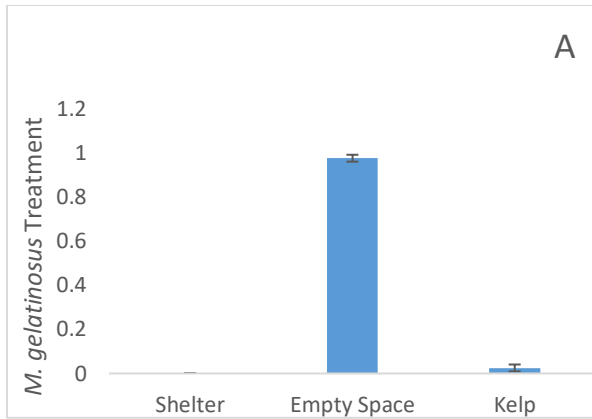


Figure 2.2: Mean values for location within aquaria for all three treatments over 40 observations.

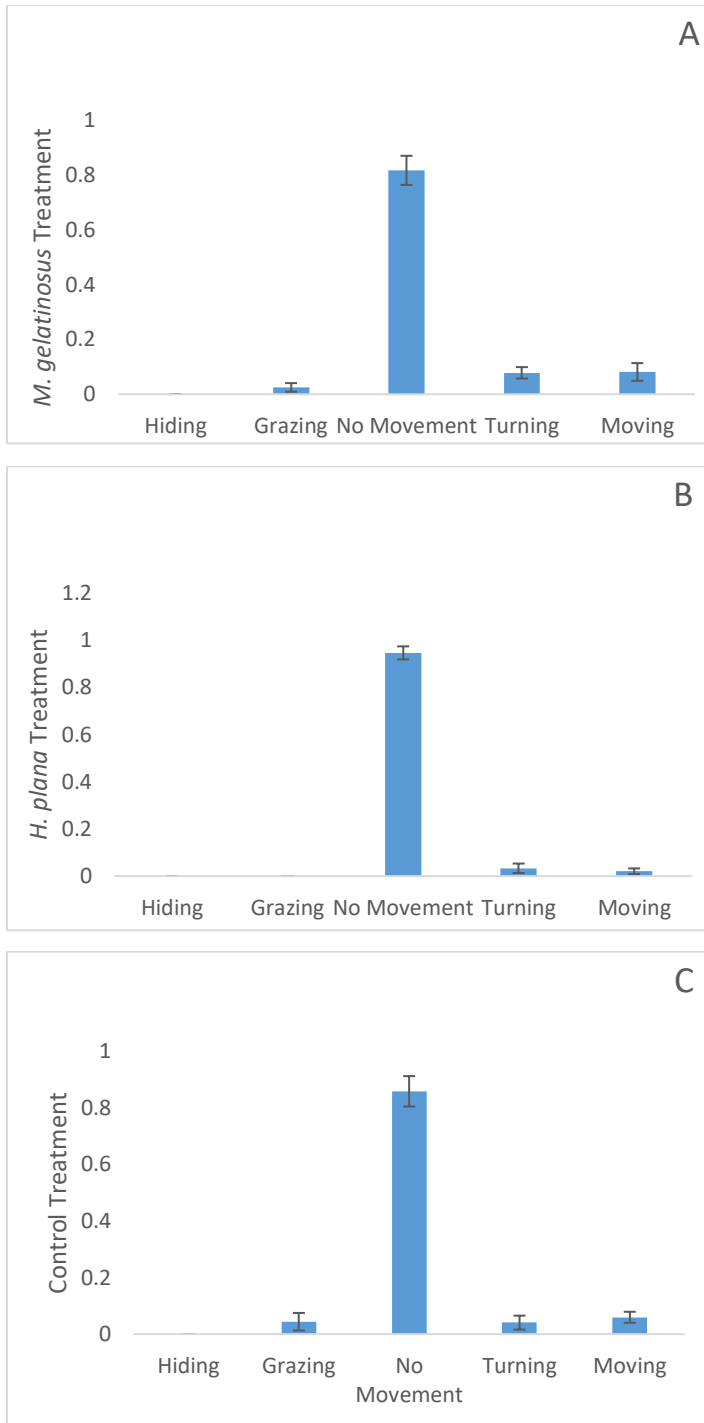


Figure 2.3: Mean values for behavior at time of observation across all three treatments in Trial 1 over 40 observations.

Trial 2

When subjected to a 20 day starvation period and presented with a larger shelter, *T. tridentata* responses to treatments were different across treatments. There was a significant difference between treatments for total distance traveled and total number of position changes, with *T. tridentata* in *H. plana* treatments moving and changing positions the least out of the three treatments (Table 2.1, Figure 3.1). There was a significant difference for all treatments for location within aquaria (Figure 3.2) and behavior at the time of observation (Figure 3.3) except for location within aquaria for the *H. plana* treatment (Table 2.2). *T. tridentata* in the *H. plana* treatment spent a considerable amount of time both in the empty space but also hiding underneath the shelter, indicating that *T. tridentata* elicited a stronger response to kairomones from *H. plana* even when starved for 20 days.

<u>Analysis</u>	<u>F</u>	<u>P</u>
Total Distance Traveled	6.4178	0.0090
Position Change	5.766	0.0130

Table 2.1: Results of One-Way ANOVA for total distance traveled and position change during Trial 2. Both analyses yielded significantly different results.

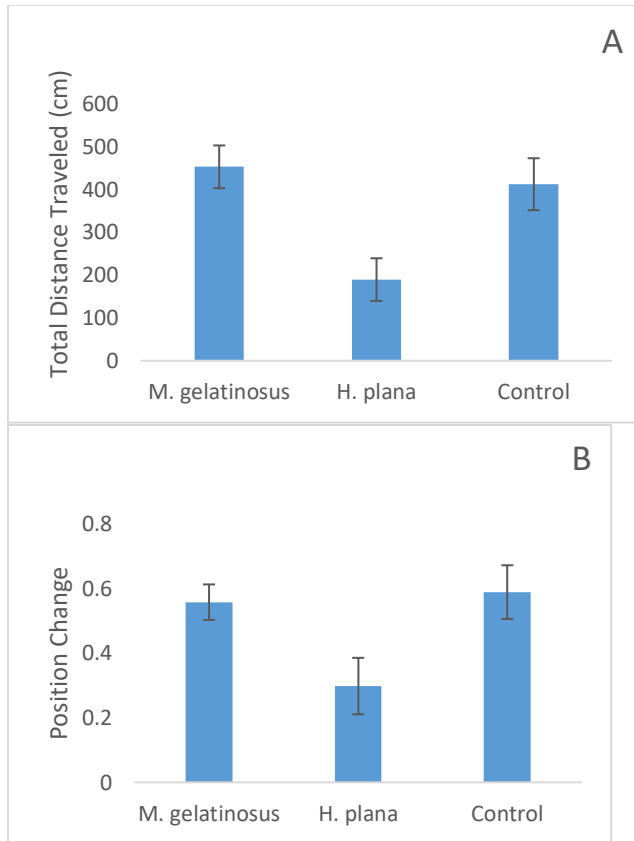


Figure 3.1: Mean distance traveled (A) and mean number of position changes (B) by *T. tridentata* for the three treatments over the 52 observations.

Table 2.2: Results of Kruskal-Wallis Analysis for location within aquaria and behavior during time of observation during Trial 2. All of the values were significant during this experimental trial except for *H. plana* location within the aquaria.

Analysis	<i>H</i>	<i>P</i>
<i>M. gelatinosus</i> Location	10.22	0.0060
<i>H. plana</i> Location	4.23	0.1206
Control Location	16.08	0.0003
<i>M. gelatinosus</i> Behavior	16.33	0.0026
<i>H. plana</i> Behavior	12.99	0.0113
Control Behavior	25.08	<0.0001

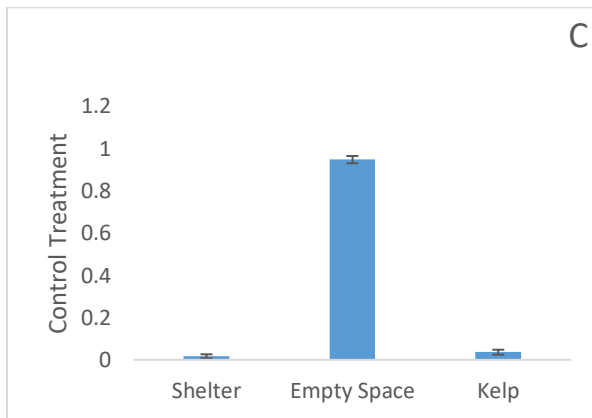
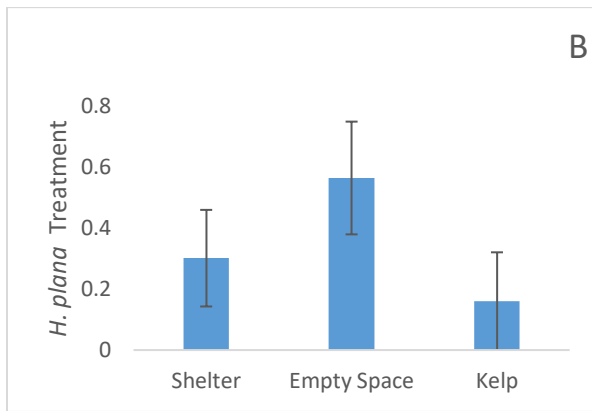
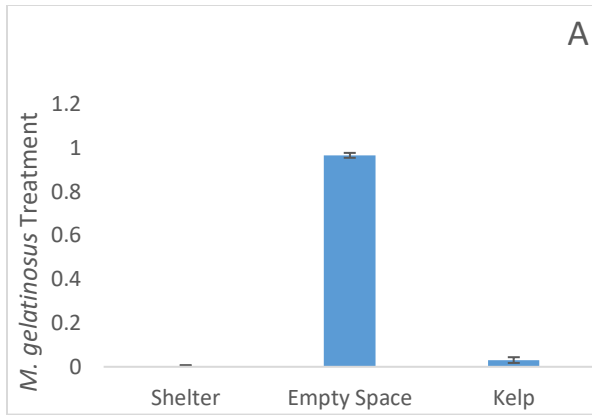


Figure 3.2: Mean values for location within aquaria across all three treatments in Trial 2 over 52 observations.

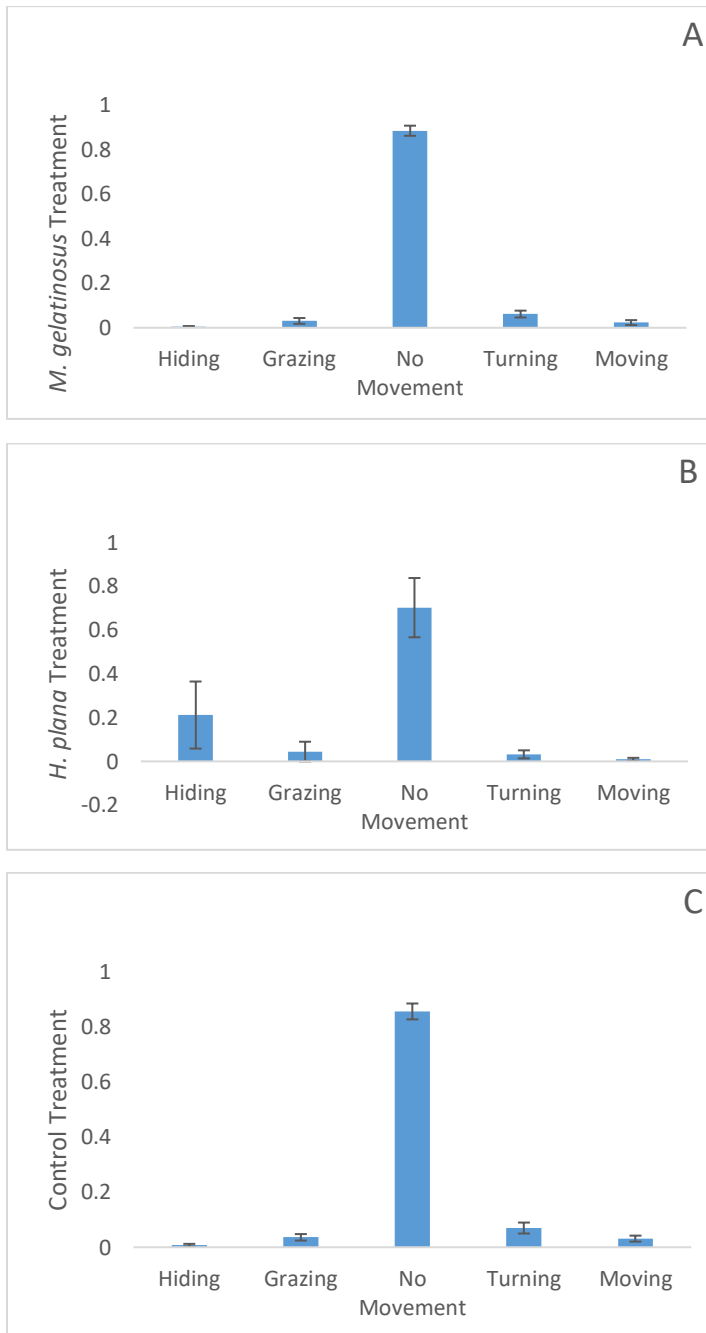


Figure 3.3: Mean values for behavior at time of observation across all three treatments in Trial 2 over 52 observations.

Trial 3

T. tridentata in both *H. plana* and crushed conspecific treatments behaved similarly across treatments. There was no significant difference between treatments for both total distance traveled and total number of position changes, with each treatment seeming to affect *T. tridentata* similarly (Table 3.1, Figure 4.1). There were no significant differences between the different locations (Figure 4.2) and behavior types (Table 3.2, Figure 4.3). This could possibly indicate that *T. tridentata* are affected by both kairomones emitted by *H. plana* as well as kairomones emitted by crushed conspecifics, but due to the lack of control replicates and the absence of a control during analysis, this is only speculative and more tests would be necessary.

Table 1.1: Results of Two-Way ANOVA for total distance traveled and position change during Trial 3. None of the values were significant during this experimental trial.

<u>Analysis</u>	<u>F</u>	<u>P</u>
Total Distance Traveled	0.9308	0.3490
Position Change	1.3459	0.2630

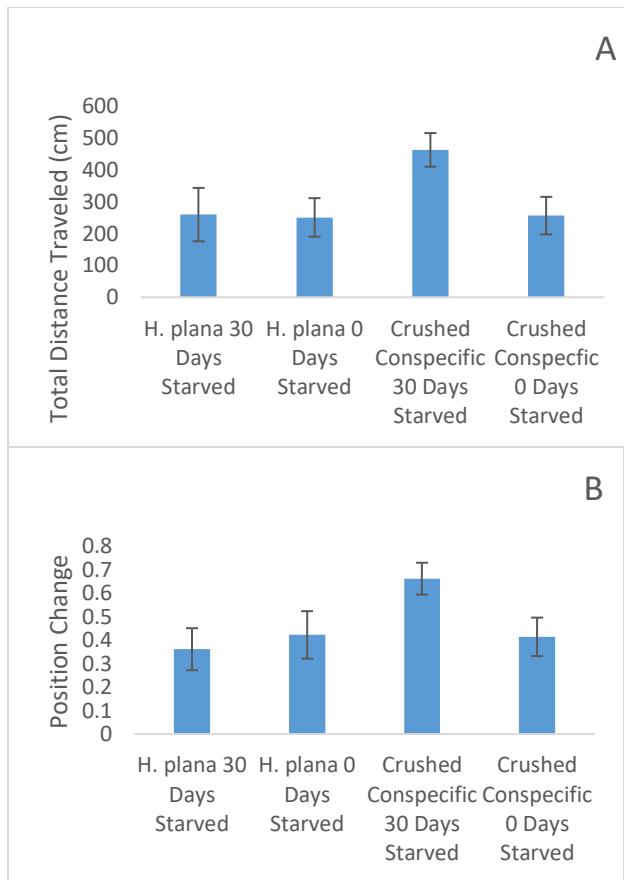
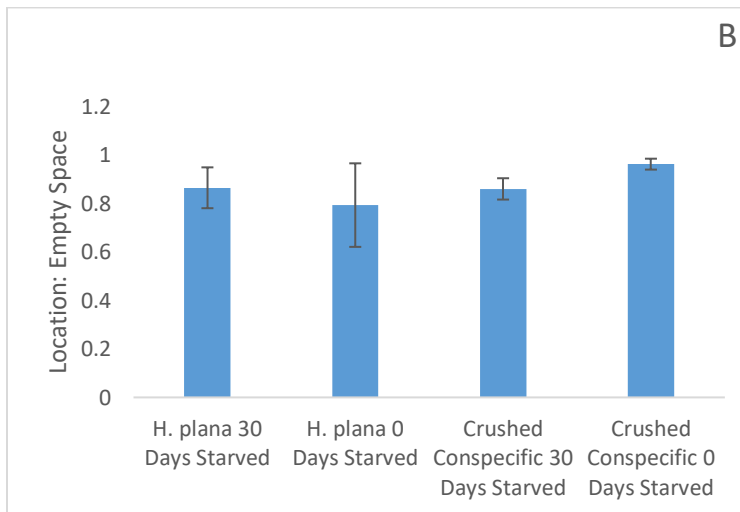
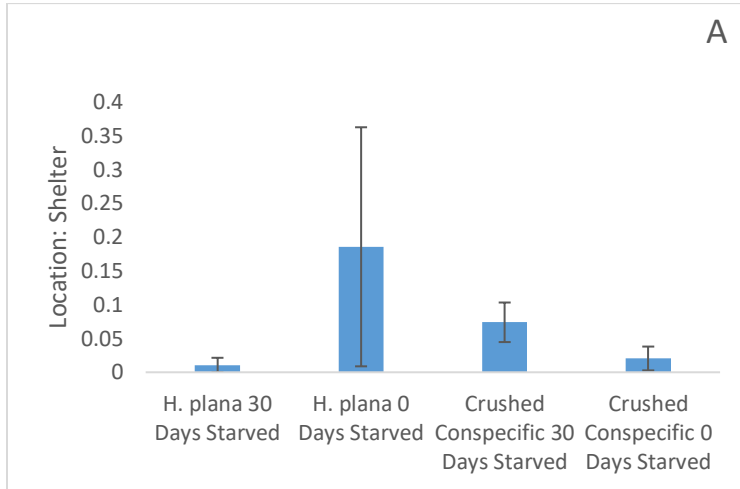


Figure 4.1: Mean distance traveled (A) and mean number of position changes (B) by *T. tridentata* for the three treatments over the 56 observations.

Chart 3.2: Results of Friedman's Test for location within aquaria and behavior during time of observation during Trial 3. None of the values were significant during this experimental trial.

Analysis	csq_c	P
Location: Shelter	2.22	0.5280
Location: Empty Space	1.68	0.6414
Location: Kelp	0.48	0.9232
Behavior: Hiding	2.22	0.5280
Behavior: Grazing	0.78	0.8542
Behavior: No Movement	2.22	0.5280
Behavior: Turning	2.40	0.4936



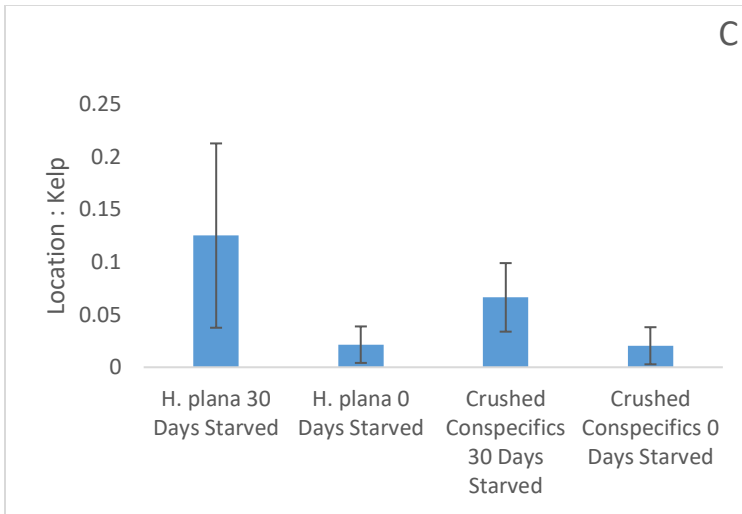
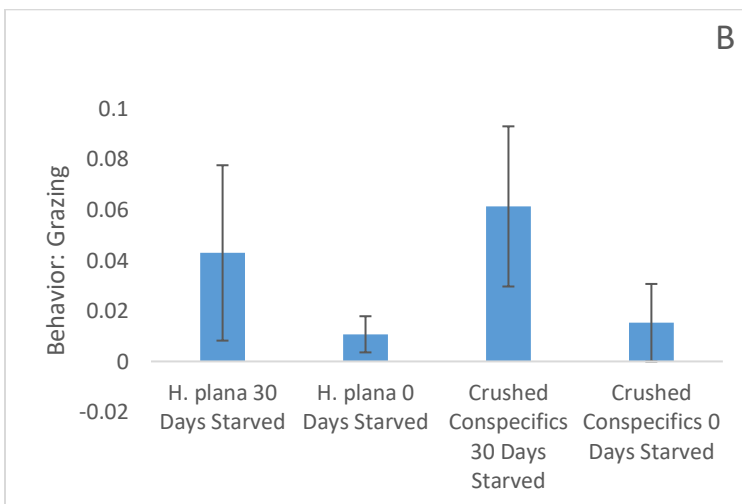
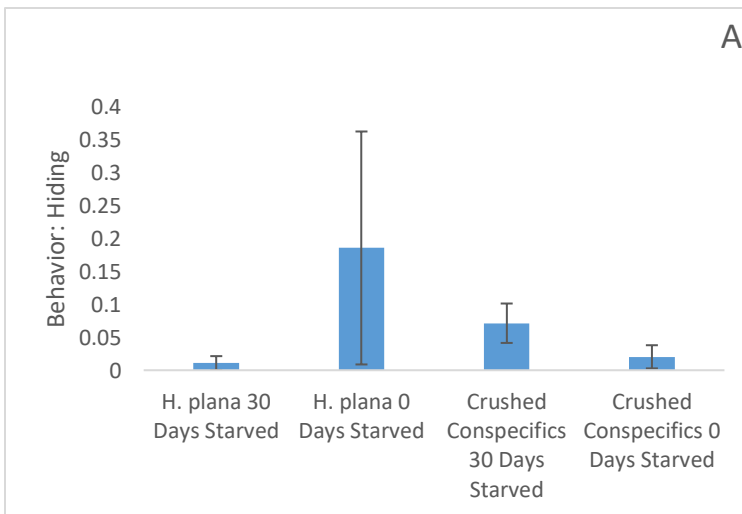


Figure 4.2: Mean values for location within aquaria across all three treatments in Trial 3 over 56 observations.



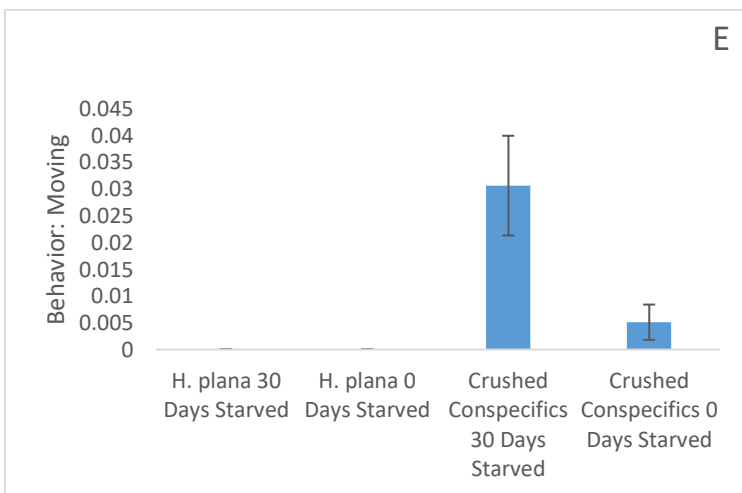
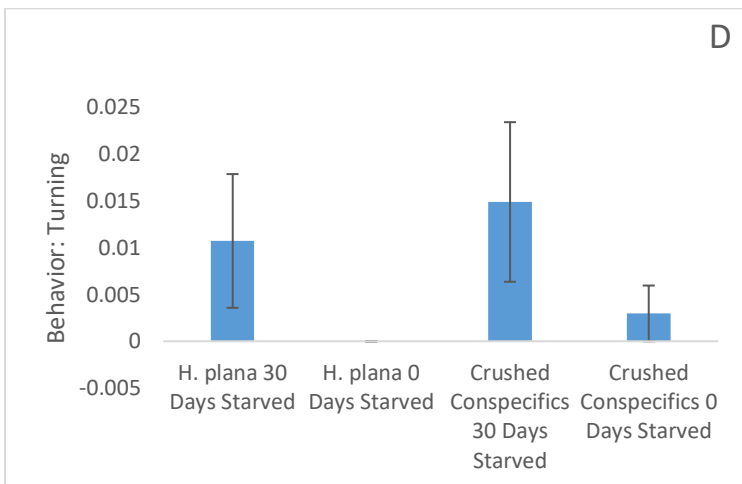
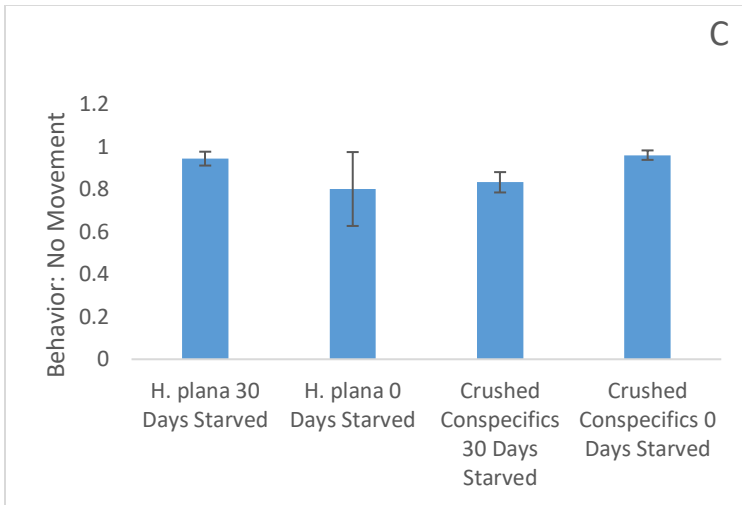


Figure 4.3: Mean values for behavior at time of observation across all three treatments in Trial 3 over 56 observations.

Discussion

The *T. tridentata* in this study displayed the ability to distinguish between unique predators and responded differently to different predators. Kairomones caused the snails (even when starved) to use predator avoidance behaviors (hiding within shelters). *T. tridentata* in Trial 1 behaved similarly across all three treatments, but when presented with the option of a larger shelter and also starved for 20 days in Trial 2, the snails responded differently based on the treatment, with snails in the *H. plana* treatment utilizing the shelters. In Trial 3, both the presence of *H. plana* and injured (crushed) conspecifics appeared to elicit similar responses, potentially showing that both *H. plana* and injured conspecifics affect *T. tridentata* equally; however, due to the lack of a control in the statistical analysis, more tests would be necessary to confirm if this is the case.

One possible explanation for these results is that *H. plana* are more mobile and morphologically more imposing than *M. gelatinosus* and therefore pose a greater risk to *T. tridentata*. *M. gelatinosus* generally use a “hovering” technique (remaining in the same location) about 50% of the time when foraging (Mahen *et al.* 1977); meanwhile, *H. plana* are more mobile, move at faster rates than *M. gelatinosus*, and are often opportunistic predators that locate and then attack their prey (Morales & Antezana, 1983). Since *H. plana* are more mobile in their environment and are also a faster predator than *M. gelatinosus*, it may be more advantageous for *T. tridentata* to seek shelter more often when they detect *H. plana* since *H. plana* could potentially pose a higher risk of predation or possible injury. Granted, *M. gelatinosus* has been shown to react quickly upon detection of prey within its environment (Mahen *et al.* 1977); specimens used in this study often began to move towards *T. tridentata* within only a few minutes after the

snails were placed in the aquariums with them. However, *H. plana* are still able to approach and launch an attack on prey faster than *M. gelatinosus* and therefore could be considered a higher risk to *T. tridentata*. *H. plana* also have a more formidable morphology, with large armored bodies and powerful claws (Morales & Antezana, 1983) as opposed to the soft-bodied *M. gelatinosus*. The claws found on *H. plana* could potentially inflict serious damage or even result in death for *T. tridentata*; snails fed to *H. plana* during the experimental trials were often shredded (both the shell and the body of *T. tridentata*), leaving them injured or close to death if the crab did not immediately consume them after the encounter. While both predator species examined in this study are voracious predators, the risks associated with *H. plana* could possibly be higher for *T. tridentata*, therefore leading to a stronger behavioral response in *T. tridentata* even when starved.

Complex and intricate relationships between invertebrate organisms abound in coastal subtidal ecosystems, and these interactions can have implications for the algal populations within the ecosystem as well. For example, the presence of *Cancer borealis* (Jonah crab) reduces *Strongylocentrotus droebachiensis* (green sea urchin) kelp grazing by almost 80% (McKay & Heck, 2008). This pressure from predators prevents overgrazing by marine invertebrate herbivores and helps to maintain a balance within the kelp community ecosystem. In Chile, *H. plana* is a culturally popular seafood that is often harvested from the coastal ecosystems (Fernandez & Castilla, 1998). Kelp is also a major commercial resource in Chile that is taken from the coastal ecosystem, with over 320,000 wet tons being taken in a year, and it is exploited for a variety of reasons, such as the alginate present in the kelp and for its use as a food (Buschmann, Hernandez-

Gonzalez & Varela, 2008). *T. tridentata* consume kelp, placing them in direct competition with businesses that harvest the kelp. *H. plana* was shown in this study to have the greatest effect on *T. tridentata*, causing them to reduce foraging activities and remain hidden even when faced with a long starvation period. Therefore, if *H. plana* were removed from the system for commercial purposes via overharvesting, *T. tridentata* would not have the predatory pressure of *H. plana* and may be more willing to graze on kelp and thus could potentially overgraze it. Overgrazing could have a negative impact on the Chilean kelp industry as harvesters may not be able to obtain as many healthy, viable fronds because the fronds are overgrazed and therefore may not be able to obtain as high of a profit as they normally would. With the economic weight of the kelp industry resting on the health and availability of the kelp, it may be advantageous to take a deeper look into the impact of *H. plana* on foraging behaviors of *T. tridentata* in an effort to understand their relationship with the kelp and ultimately with the kelp harvesting industry.

Literature Cited

- Aizaki, K., & Yusa, Y. (2008). Field observations of the alarm response to crushed conspecifics in the freshwater snail *Pomacea canaliculata*: effects of habitat, vegetation, and body size. *Journal Of Ethology*, (1).
- Brown Jr., W. L., Eisner, T., & Whittaker, R. H. (1970). Allomones and Kairomones: Transspecific Chemical Messengers. *Bioscience*, 20(1), 21-22.

- Buschmann, A. H., Hernandez-Gonzalez, M. C., & Varela, D. (2008). Seaweed future cultivation in Chile: perspectives and challenges. *International Journal Of Environment And Pollution*, (4).
- Fernandez, M., & Castilla, J. C. (1998). The Chilean artisanal stone crab (*Homalaspis plana*) fishery: Catch trends in open access zones and the effect of management areas in central Chile. *Journal Of Shellfish Research*, 17(1), 285-292.
- Fortin, D., Beyer, H. L., Boyce, M. S., Smith, D. W., Duchesne, T., & Mao, J. S. (2005). Wolves Influence Elk Movements: Behavior Shapes a Trophic Cascade in Yellowstone National Park. *Ecology*, (5), 1320.
- Gilliam, J., & Fraser, D. (1987). Habitat Selection Under Predation Hazard: Test of a Model with Foraging Minnows. *Ecology*, 68(6), 1856-1862.
- Jacobsen, H. P., & Stabell, O. B. (2004). Antipredator behavior mediated by chemical cues: the role of conspecific alarm signaling and predator labelling in the avoidance response of a marine gastropod. *Oikos*, (1), 43.
- Kopecký, O. (2013). Predation-Induced Injuries in Wild Populations of Alpine Newt. *Pakistan Journal Of Zoology*, 45(2), 417.
- Mahen, L. C., Antezana, T., Dayton, P. K., & Rosenthal, R. J. (1977). Population Structure and Foraging Biology of the Predaceous Chilean Asteroid *Meyenaster gelatinosus* and the Escape Biology of Its Prey. *Marine Biology*, 39(4), 361.
- McKay, K. M., & Heck, K. L. (2008). Presence of the Jonah crab *Cancer borealis* significantly reduces kelp consumption by the green sea urchin

Strongylocentrotus droebachiensis. *Marine Ecology -Progress Series-*, 356295-298.

Morales, C., & Antezana, T. (1983). Diet selection of the Chilean stone crab *Homalaspis plana*. *Marine Biology*, 7779-83.

O'Connor, C., Reddon, A., Odetunde, A., Jindal, S., & Balshine, S. (2015). Social cichlid fish change behaviour in response to a visual predator stimulus, but not the odour of damaged conspecifics. *Behavioural Processes*, 121-129.

Pereira, M., Tala, F., Fernández, M., & Subida, M. D. (2015). Effects of kelp phenolic compounds on the feeding-associated mobility of the herbivore snail *Tegula tridentata*. *Marine Environmental Research*, 112(Pt B), 40-47.

Rochette, R., Maltais, M., Dill, L., & Himmelman, J. (1999). Interpopulation and context-related differences in responses of a marine gastropod to predation risk. *Animal Behaviour*, 57(4), 977-987.

Soto, R., Castilla, J. C., & Bozinovic, F. (2005). The Impact of Physiological Demands on Foraging Decisions under Predation Risk: A Test with the Whelk *Acanthinamonodon*. *Ethology*, 111(11), 1044-1049.

Staudinger, M. D., Buresch, K. C., Mathger, L. M., Fry, C., McAnulty, S., Ulmer, K. M., & Hanlon, R. T. (2013). Defensive Responses of Cuttlefish to Different Teleost Predators. *Biological Bulletin*, (3). 161.

Trussell, G. C., Ewanchuk, P. J., & Bertness, M. D. (2002). Field evidence of trait-mediated indirect interactions in a rocky intertidal food web. *Ecology Letters*, 5(2), 241-245.

Turner, A. M., Shelley A., F., & Bernot, R. J. (1999). Predator Identity and Consumer Behavior: Differential Effects of Fish and Crayfish on the Habitat Use of a Freshwater Snail. *Oecologia*, (2). 242.

Vasquez, J., & Buschmann, A. (1996). Herbivore-kelp interactions in Chilean subtidal communities: A review. *Revista Chilena De Historia Natural*, 70(1), 41-52.