Evaluating the Interactions Between Intertidal Marine Invertebrates and Plastic Fishing Lures and Their Implications for Human Health

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Abstract

Plastic pollution, especially from fishing gear, poses a considerable threat to marine ecosystems and human health. While the adverse effects of marine plastic pollution on large marine animals are well-documented, its impact on smaller marine invertebrates remains largely unexplored. Additionally, there is a large gap in research regarding the effects of bioplastics on marine environments, despite their promotion as a solution to marine plastic pollution. Our study in the seagrasses of Minjerribah reveal complex relationships in the interactions between intertidal invertebrates and biodegradable, semi-biodegradable, and non-biodegradable soft plastic fishing lures. Our results showed that the biodegradable fishing lure type attracted the most interactions, especially from *Phyllodoce novaehollandiae*, a Green Paddle Worm. Statistical analysis confirmed a significant mass decrease for the biodegradable lure compared to the others. The strong scent emitted by biodegradable lures likely enhances their attractiveness, raising concerns about environment and health impacts associated with their consumption. The ingestion of microplastics by marine invertebrates poses a direct threat to human health through the bioaccumulation and biomagnification of the plastic particles and their accompanying chemicals. Our findings highlight the urgent need for further research to better understand and mitigate the adverse effects of plastic pollution on human health.

Keywords

Plastics, Bioplastics, Invertebrates, Interactions, Human Health

Introduction

Plastics are synthetic materials derived from organic polymers that can be molded or shaped into a wide variety of forms while maintaining their durability and resistance to degradation. They are used in countless applications ranging from packaging and construction to electronics and medical devices (Brydson, 1999). Consequently, there are different types of plastics, each with unique properties and characteristics such as flexibility, transparency, and heat resistance. To improve the performance of plastics, they contain a range of different chemicals, many of which have concerning properties and toxins (DCCEEW, 2022). Most plastic in use today comes from hydrocarbons derived from crude oil, natural gas, and coal (Gironi & Piemonte, 2011). When not properly managed or discarded, plastic can easily find its way into oceans and other marine environments (Peng et al., 2020). Each year, the world produces around 350 million tonnes of plastic waste (Ritchie, 2023). Of that amount, one-quarter, or 19 million tonnes, is leaked into the surrounding environment, with at least 6 million tonnes reaching marine environments. Currently, the amount of plastic flowing into the oceans is on track to double from 2010 to 2025 (Dauverge, 2018).

Abandoned fishing gear presents a significant source of marine plastic pollution worldwide, causing disproportionate harm to wildlife, as well as marine and coastal ecosystems (Richardson et al., 2022). The amount, distribution, and effects of abandoned, lost, and discarded fishing gear plastics have likely increased in recent decades due to the rapid expansion of fishing activities and fishing areas, as well as the shift towards using synthetic materials that are less expensive, more long-lasting, and more buoyant for fishing gear (Gilman et al., 2021). Additionally, marine organisms may be potentially attracted to plastics, as their chemical scent mimics that of their prey. A study proposed that DMS (Dimethyl Sulfide) is able to attach to microplastics, increasing their attractiveness to copepods (Proctor et al., 2019). One way to mitigate the impacts of plastic pollution from fishing gear on marine environments is by switching to alternative materials, such as bioplastics.

A plastic material is classified as a bioplastic if it is biobased, biodegradable, or considered to be both (Venâncio et al., 2022). "Biobased" refers to matter that is either fully or partially derived from renewable or natural resources, while "biodegradable" reflects an object's ability to be broken down by other organisms, generally microorganisms (Goel et al., 2021). Because of these characteristics, bioplastics are argued to have lower environmental impacts compared to common petroleum-based plastics (Goel et al., 2021; Venâncio et al., 2022). However, many bioplastics have been found to degrade in marine environments four times slower than in terrestrial habitats, exacerbating the prevalence of microplastics in the ocean and likely causing psychological and cellular impairments upon digestion (Dilkes-Hoffman et al., 2019). This emphasizes the importance of understanding how marine fauna interacts with bioplastics, as they are among the life forms most likely to come in contact with them.

The impacts of marine plastics on birds, turtles, fish, and large mammals are well-known, with countless documented cases of entanglement and ingestion (Gall & Thompson, 2015). However, the extent to which smaller marine animals, such as invertebrates, interact with discarded fishing plastics is not as well-known or documented (Gall & Thompson, 2015). In contrast, little is known altogether about the rate and extent to which marine life interacts with bioplastics (Venâncio et al., 2022). Due to the important role they play in their ecosystems, this study examines the exchange between marine invertebrates and plastic pollution, including bioplastics.

Comprising more than 92% of marine life, marine invertebrates populate all layers of the water column, contributing significantly to ecosystem functioning and socioeconomic development (Chen, 2021). Species like corals and oysters contribute to marine habitat formation and are essential for the survival of many marine organisms. Other invertebrates such as crabs, clams, octopuses, and marine worms serve as crucial prey for various marine animals, as well as humans (NOAA, 2024). Therefore, it is crucial to understand the ways in which these animals interact with plastics, as processes such as biomagnification and bioaccumulation cause plastics and their accompanying toxins to cascade up food webs (Diepens & Koelmans, 2018), eventually reaching humans and posing a threat to our health (Akhbarizadeh et al., 2019). Additionally, as the fishing industry strives to adopt more regulated and sustainable methods, it's crucial to examine the ecological impacts of using biodegradable fishing lures before scaling up their industrial use.

Within our study, we aim to quantify the amount and extent of interactions that intertidal marine invertebrates have with different types of soft plastic fishing lures (spl): biodegradable, semi-biodegradable, and non-biodegradable, and examine these implications on human health.

Hypotheses

Null hypothesis: There will be no difference in the number of interactions between invertebrates and each type of soft plastic fishing lure.

Alternative hypothesis: There will be more interactions between invertebrates and the Gulp biodegradable soft plastic fishing lure.

Methods and Experimental design

Materials

- BRUV (baited remote underwater camera) (3)
- Baits - 12 of each type (biodegradable, semi-biodegradable, and non-biodegradable)
- Squared grid to place baits (4)
- Mesh covering to put over control group (1)
- Stake to hold camera in place above each trial (4)

Study Site

Our study was conducted in the seagrasses of Minjerribah (North Stradbroke Island), located in Quandamooka (Moreton) Bay. This area holds great cultural value for the First Nations People, who were the island's first inhabitants. Our goal is to produce useful data that can be used by them to assess and monitor human health in relation to the interaction between invertebrates and different kinds of soft plastic fishing lures.

Specifically, we chose to place all three trials and the control group within the seagrass beds of Minjerribah because invertebrates often inhabit these areas, as they provide shelter, food, and suitable grounds for the growth and reproduction for a variety of species. Reference Figure 1 for the map and scale of our trial and control locations.

Time

The tidal cycle over the flats affects the behavior of its inhabitants, creating periodic and brief opportunities for feeding. As the tide ascends and covers the flats, numerous invertebrates retreat into the sediment to evade predators such as fish and stingrays. Alternatively, during low tide, invertebrates often expose themselves to feed on matter such as algae, plankton, and detritus that become increasingly uncovered as the tide retreats. This made low tide the ideal time to set up our experiment. As such, we placed our materials out during the afternoon low tide on April 12th, 2024, at 4:45 in the evening, and left them in place for an hour.

Set Up

All three trials and the control group contained nine baits in total: three of each type of bait. The bait types were as follows: Gulp baits marketed as biodegradable, Bio Tough baits marketed as semi-biodegradable, and Zman baits marketed as non-biodegradable. Gulp and Bio Tough baits are bioplastics.

Each bait was randomly assigned a spot on the wire grid that would be placed in the seagrass. This random assortment ensured that any interactions that occurred were intentional and not just a result of the placement of the baits on the grids. Figure 2 depicts the system that was followed when marking the assignment of each bait on the grid.

When the grids were placed in the seagrass beds, they were pressed into the ground to ensure they were level with the sediment and fully submerged in the water. The accompanying BRUV for each trial was attached to a metal stake via zip ties and placed in the sediment next to the grids. The cameras were then adjusted to capture the entirety of the baits on the grids.

The control contained the same set-up as the trials, with nine randomly assigned baits (three of each type of bait). However, the control was covered by a sealed mesh bag and secured shut with staples and duct tape to ensure no organisms could reach the lures. The control group did not contain a BRUV.

Process

The lures were left in the water for one hour. Each bait on each trial and control grid was weighed before and after the experiment to determine if there was a change in mass. Each trial was accompanied by a BRUV so that we could later quantify the amount and type of interaction occurring between invertebrates and each lure type. The control did not contain a BRUV, as we were only interested in finding the increase in mass of each lure due to water weight. We aimed to calculate the weight loss of the baits due to possible different kinds of interactions between invertebrates and the fishing lures. The baits on the control served as a baseline for water absorption that occurred, against which the other baits in the trials were compared.

To quantify the amount of interactions each species had with each lure type, we calculated the maximum end of the videos. We scrubbed through each video, stopping at five-minute intervals and finding the frame when most animals were interacting with the lures. Interactions were described as purposeful touching, enacting feeding behaviors and directed movement towards a lure. We then counted the number of interactions occurring between each species and all three lure types. After reviewing all of the footage, the maximum number of interactions recorded were used as the data point for each lure present in the trial.

Results

Observational

Results from the BRUV footage indicated the presence of three animals: *Phyllodoce novaehollandiae* (Green Paddle Worm), *Gobiidae* (Goby), and *Scopimera globosa* (Sand Bubbler Crab). Reference Figures 3a and 3b which show the abundance of each species interacting with each bait type at sites one and three. These figures depict *Phyllodoce novaehollandiae* as the most abundant species, having the highest proportion of individuals interacting with each bait type at both sites compared to the other species.

Overall, site three contained the highest number of interactions and species richness in comparison to site one, perhaps due to its proximity to the shore. The bait type that was interacted with the most by *Phyllodoce novaehollandiae* was the Gulp bait, shown by the boxplots in Figures 4a and 4b. One Gulp lure at site three had a maximum number of 21 interactions with *Phyllodoce novaehollandiae*, while Bio Tough and Zman had a maximum number of interactions of four. Although all species had the highest number of interactions with the Gulp lure, *Phyllodoce novaehollandiae* were used for this analysis because they were the most abundant species.

Statistical

A statistical analysis was conducted in order to determine the percent mass decrease of each lure type at all three sites. Reference Figures 5a, 5b, and 5c which depict the percent mass decrease of each bait type at each site.

These box plots indicate that the Gulp bait type had the most significant percentage of mass decrease out of all of the lures, with a p-value of 0.001685. The weight data for the Zman and Bio Tough bait types did not show a significant difference from the control. Bio Tough lures had a p-value of 0.464, and the Zman lures had a p-value of 0.4222. Regarding material composition, our tests found that the Gulp lure exhibited the highest water absorbency, with a 12.04% increase in water absorption after being submerged for one hour. Bio Tough followed with a 1.30% increase in wet weight, while Zman absorbed only 0.01% of the available water.

It's crucial to highlight the clear link between the observed interactions with invertebrates, primarily *Phyllodoce novaehollandiae*, and the mass reduction of this biodegradable Gulp lure over a brief period of time. This relationship is shown on the scatterplot in Figure 6. A notable instance was observed with one of the site three Gulp lures, which had 21 interactions with *Phyllodoce novaehollandiae*, resulting in a loss of 7.66% of its initial mass.

When visualized on a scatter plot, this relationship showed a significant negative relationship, suggesting that interactions significantly influenced the mass reduction of each exposed lure.

Discussion

After conducting a thorough analysis, encompassing both observational and statistical methods, of the interactions between invertebrates and the three distinct plastic lure types, our group confidently rejects the null hypothesis. Consequently, we accept the alternative hypothesis: there were indeed more interactions between invertebrates and the Gulp biodegradable fishing lure.

Phyllodoce novaehollandiae emerged as the most interactive species, exhibiting the highest number of interactions with each bait at sites one and three. These creatures are carnivorous predatory scavengers primarily found in the mud and sand flats of eastern Australia.

It remains unclear whether the prevalence of interactions with *Phyllodoce novaehollandiae* and each soft plastic lure is due to their abundance in the area or a specific attraction to the baits. Regardless, the notably higher number of interactions between the worms and the Gulp bait type strongly suggests that these lures possess qualities that are particularly attractive to the worms.

The Gulp bait was the marketed “biodegradable” type of lure. This bait was found to have a significant scent in comparison to the other two lure types, which may explain its popularity to marine organisms. The strong scent of these lures acts as an olfactory stimulus, which is largely effective in murky or low-visibility water when visual cues can be less effective (Mollo et al., 2017). As many aquatic animals have a strong sense of smell, and they use it to locate their food, the scent emitted by the Gulp lure may be the reason this lure was the most appealing to the organisms. Additionally, the biodegradable materials that supposedly make up the Gulp lure may release organic compounds as they degrade in marine environments, further enhancing the lure’s scent over time (Lokkeborg et al., 2014). The strong initial scent, coupled with the potential ongoing release of enticing compounds, enhances the effectiveness of the Gulp biodegradable lure in attracting a diverse array of aquatic species.

This raises questions about the impacts of these bioplastics on overall marine environments. While these lures are designed to degrade more quickly than traditionally plastics, they may potentially have more adverse effects on the environments they end up in. As biodegradable plastics break down, they may release chemicals into the water (Raison et al., 2014). The impacts of these chemicals on marine environments is still not entirely clear and needs to be studied further.

The use of plastic fishing lures carries the risk of habitat destruction, as discarded lures can contribute to ocean litter. An accumulation of plastic lures in our oceans may attract a diverse array of aquatic species. While this is beneficial for fishing purposes, it could also result in heightened interactions between marine wildlife and fishing gear. This could potentially disrupt natural behaviors or inadvertently cause harm to the wildlife.

The quality limitations of our cameras prevented us from observing whether the worms' tentacles were extracted during their interactions with the lures, leaving uncertainty regarding their feeding behavior towards the lures. Nevertheless, the observed loss in mass of the lures indicates that the worms were detaching pieces of the plastic lures, potentially for feeding or to release microplastics into the water.

The repercussions of fragmented microplastics present significant hazards to human health. Microplastics (MPs) are defined as particles ranging in size from 1µm to 5 mm (Bermúdez & Swarzenski, 2021). Due to their small size, MPs are readily and frequently ingested by aquatic invertebrates compared to larger particles. Consequently, the ingestion of microplastics by marine invertebrates introduces these plastic particles into food chains. As humans consume seafood, there is the potential for direct ingestion of microplastics due to biomagnification and bioaccumulation processes which allow microplastics to accumulate and escalate in concentration within organisms and entire food chains, ultimately reaching humans (Sana et al., 2020). Moreover, as previously noted, plastics often contain various toxic chemicals. Therefore, as these plastics magnify and accumulate up the food chain, there is a risk of these chemicals also reaching humans. A study investigating the presence of microplastics in tumoral and non-tumoral colon tissues revealed elevated MP levels in tumoral colon tissue, indicating a potential direct correlation between the two (Cetin et al., 2023). Similar studies have investigated other impacts of MPs on human health, including immune responses and translocation across biological barriers to enter systemic circulation, possibly reaching various organs and tissues in the human body (Smith et al., 2018).

Although there is growing awareness of the potential risks to human health posed by microplastics, further research is needed to fully understand these risks and to develop effective risk assessment and management strategies. For First Nations People who fish as a significant source of food, the evidence gathered from this experiment could serve as a valuable tool for understanding and mitigating human health effects related to the ingestion of plastics.

Sources of Error

Several potential sources of error warrant consideration. Upon reviewing the BRUVs footage, it became evident that site two was not positioned correctly over the lures, resulting in some lures being partially or entirely out of frame. Consequently, we were unable to use the data from these lures for observational analysis, which compromised the overall accuracy of our findings. Furthermore, the constraints of time limited our sample size to three BRUVs and 27 lures, which also contributed to a less precise analysis. Lastly, as is the case with any study, the potential for human error exists during weighing, data input, and material setup. While none of us are professional scientists, I think we did the best we could have, all things considered ☺.

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Figure Legend

Figure 1: Map and scale of trial and control sites off the coast of Minjerribah North

Figure 2: Illustration of the assortment of baits on grid

Figure 3a: Abundance of each species interacting with each bait type at site 1

Figure 3b: Abundance of each species interacting with each bait type at site 3

Figure 4a: Number of Interactions between Phyllodoce novaehollandiae and bait types at site 1

Figure 4b: Number of Interactions between Phyllodoce novaehollandiae and bait types at site 3

Figure 5a: Percent decrease in mass of Gulp baits at all three sites

Figure 5b: Percent decrease in mass of Bio Tough baits at all three sites

Figure 5c: Percent decrease in mass of Zman baits at all three sites

Figure 6: Relationship between percent mass change of lures and amount of interactions between worms and each bait type

Figure 1

Figure 2

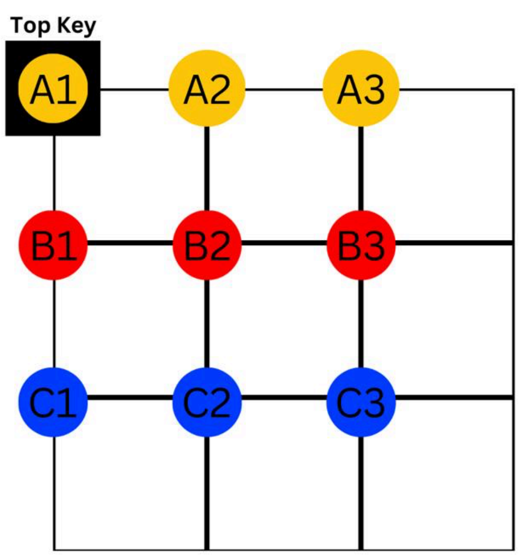
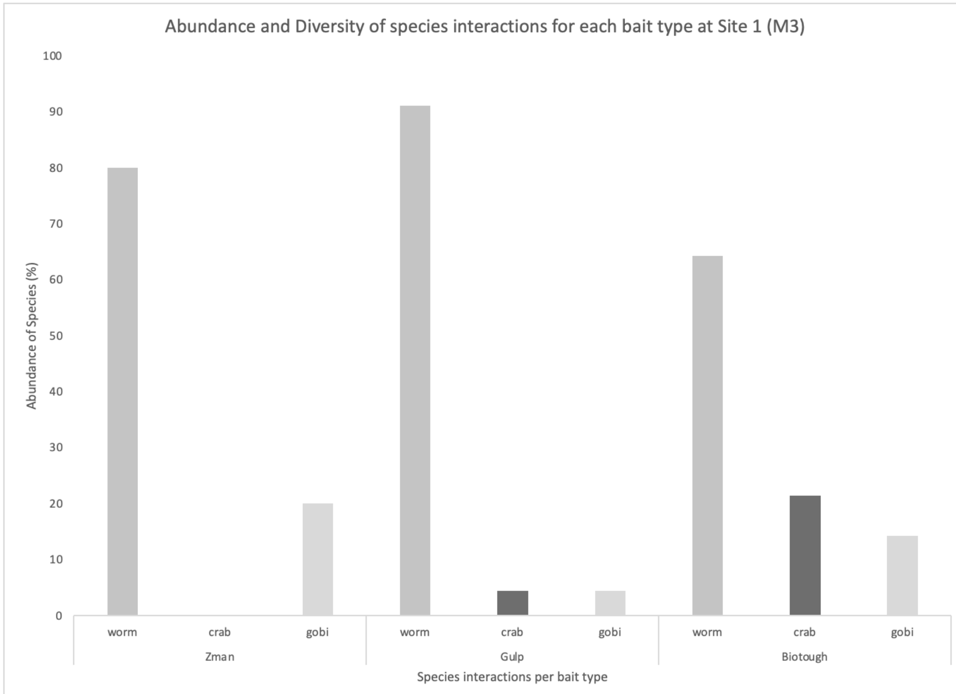


Figure 3a



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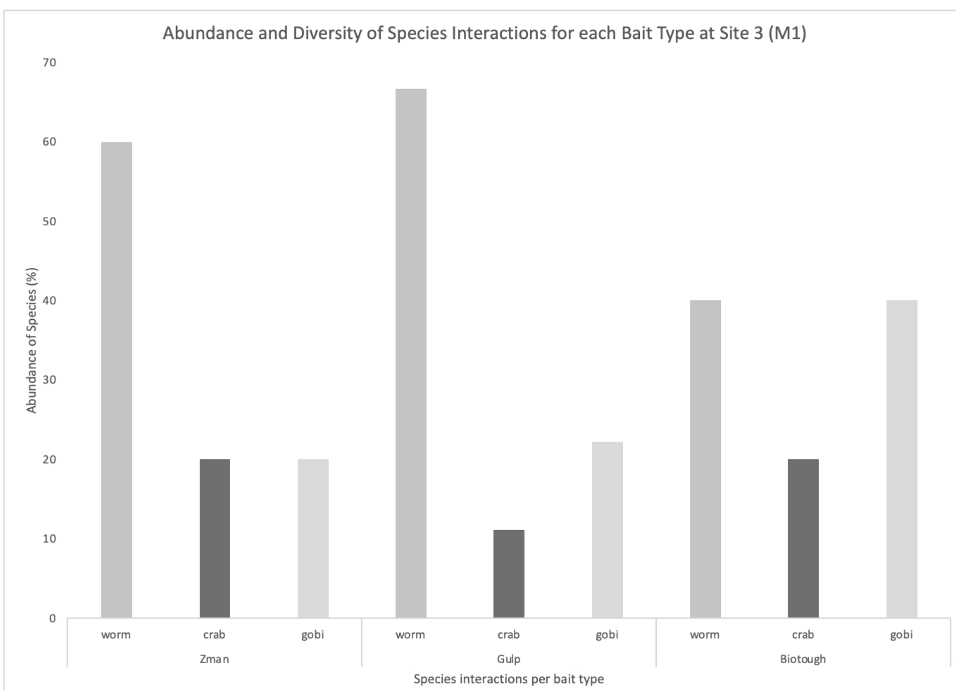

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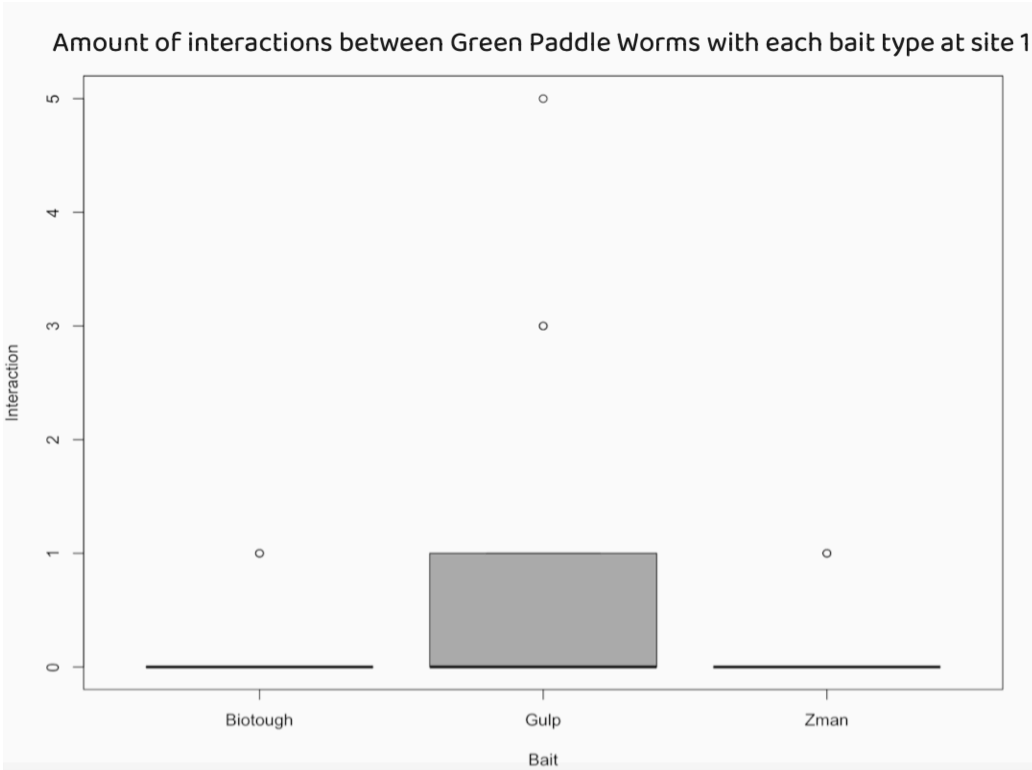

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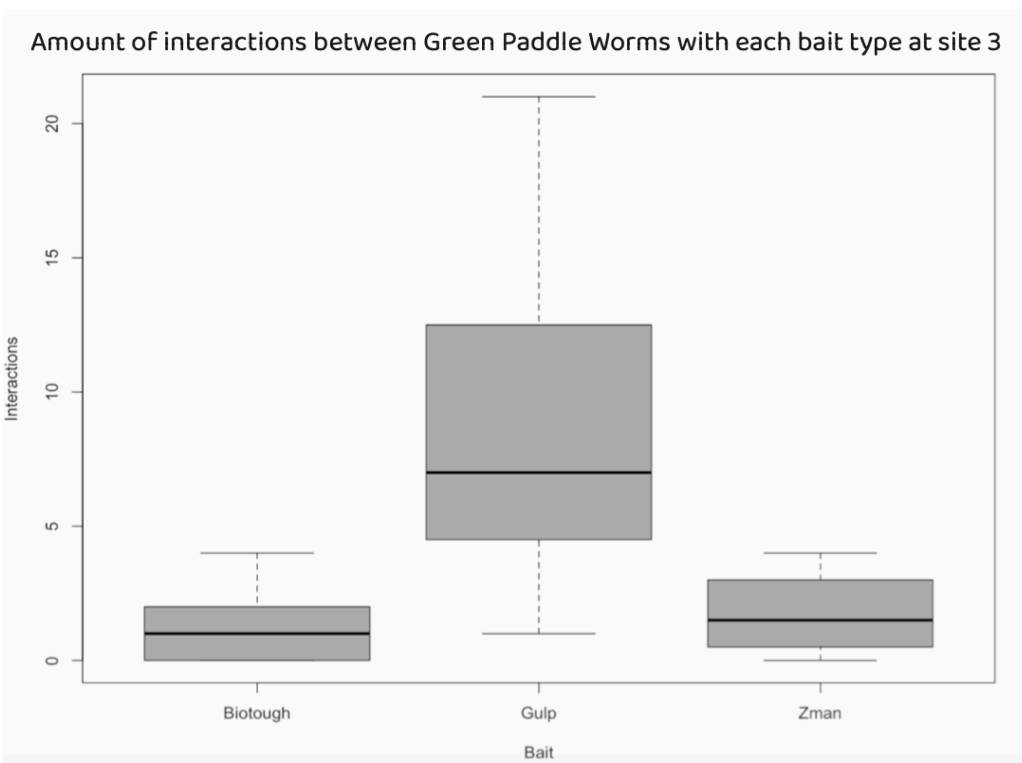

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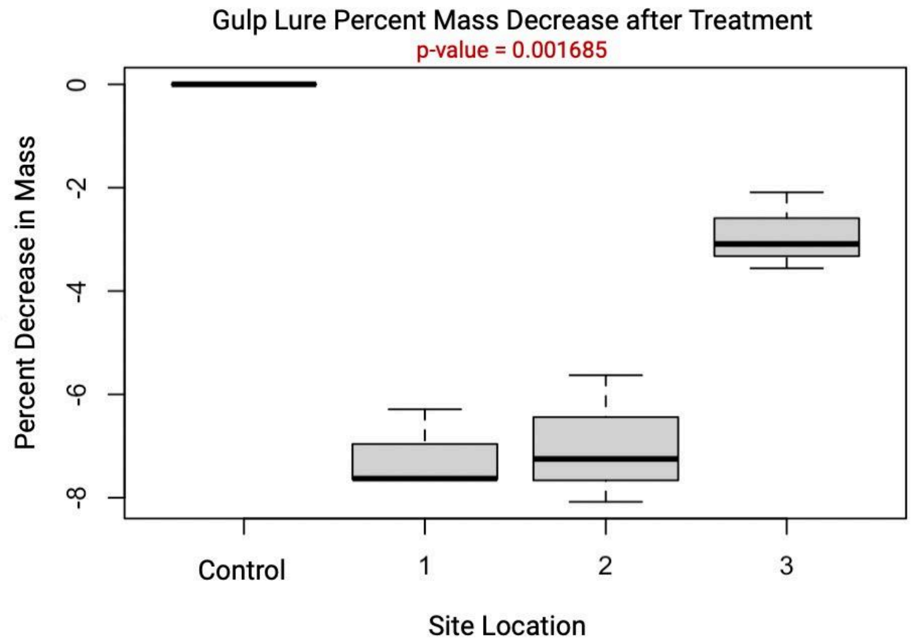

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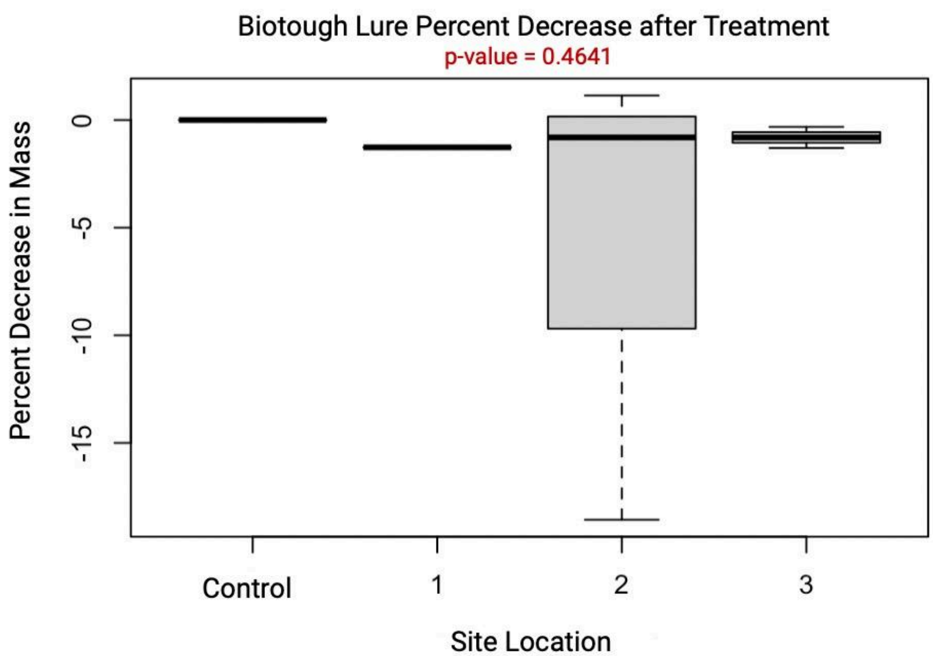

Figure 5c

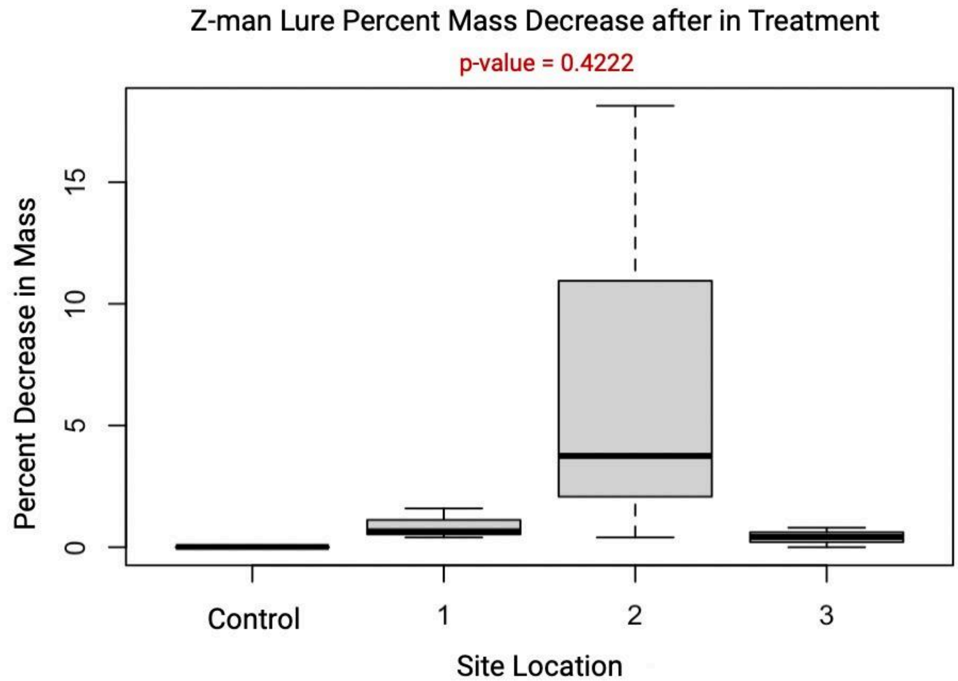

Figure 6