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IMPACT OF OIL AND A TROPICAL CYCLONE ON AN OMNIVORE AND HERBIVORE POPULATION IN SALT MARSHES OF LOUISIANA

A Thesis

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ABSTRACT

Terrestrial arthropods are the ideal ecological indicators for the health of a salt marsh. Salt marshes are under extreme continuous stressors including climate change, land loss, oil spills, and tropical cyclones. Such stressors impact trophic and species level interactions, food resources, dispersal and population size of insects. In the present study, we collected terrestrial arthropods from eleven sites around Barataria Bay, five sites were oiled and five sites were unoiled, to determine the impact of the redistribution of oil from the Deepwater Horizon oil spill. Site C6 was excluded from the oiled and unoiled data because it was in close proximity to site C5 and we wanted equal replicates for comparison. Samples were collected from January 2012 to December 2013 to determine how the population size of an omnivore and a herbivore were impacted by Hurricane Isaac. The results show that the herbivore, *Ischnodemus,* was directly and indirectly affected by Hurricane Isaac. While the omnivore, *Crematogaster,* was not affected by the hurricane but instead impacted by the seasons. In both the herbivore and omnivore weight, length, and head width was affected by the DWH oil. Although the differences were small and it is assumed insect species do recover, long-term monitoring of terrestrial arthropod communities is needed to better understand the recovery and natural succession of marsh ecosystems.

INTRODUCTION

Background

Salt marshes, which are coastal wetlands, are particularly important ecosystems. Most coastal ecosystems are composed of salt marshes with brackish water in the upper coastal intertidal zone. Compared to other wetlands, globally, salt marshes occupy a limited area; though they provide many ecosystem services that have a worldwide economic and cultural impact (Spencer and Harvey 2012). About half of the United States' salt marshes lie along the Gulf Coast. These marshes provide protection from hurricanes, filtration of toxicants and nutrients, and providing habitat for many of the seafood Americans eat.

Between sprawling human settlements and the coast, lie salt marshes that comprise hundreds of miles of coastline in southern Louisiana. Tides and wind-driven water flood and drain salt marshes (Shepard et al 2011). Salt marshes are characterized by wetland plants that are adapted to thrive in marshy soils with a lot of muck and peat with a specific salinity (Shepard et al 2011). Peat is made up of decomposing layers of plant material, some of which are several meters thick.

Salt marshes provide numerous ecosystem services. They protect inland communities and ecosystems from many coastal hazards such as tropical storms, hurricanes, floods, and tsunamis (Shepard et al 2011). Salt marshes also improve water quality by filtering excess nutrients and pollution, providing nurseries for many fish species, storing floodwaters, and decomposition of dead plants, animals, and zoo- and phytoplankton (Shepard et al 2011). The fishing industry relies on salt marshes as well; recreational

fishers stalk fishes hiding in marsh grass while shrimpers drop their nets in the deeper channels adjacent to the marsh. Salt marshes are threatened every day by sea-level rise and ocean warming, which threatens coastal communities (Boesch and Turner 1984).

Although salt marshes have significant economic benefits, they are also extremely prone to damage due to a variety of stresses (Greenberg 2006). Threats to the insect communities in salt marshes include human factors like sea level rise, habitat loss, external inputs like nutrients, and weather occurrences like hurricanes. (Chen et al 2020). Insects are essential in the salt marsh communities for they serve as food source for many species including frogs, fish, and birds. The salt marsh community is negatively impacted by human activities like dredging canals, growing coastal populations, building gas pipelines, drilling for oil, and oil spills (Mitsch and Gosselink 2000). According to Couvillion et al (2011), in the past 50 years, the Louisiana coast has lost more than 4920 square kilometers of coastline land. The fishing, tourism, and recreation sectors together bring in billions of dollars annually from Louisiana's salt marshes (Engle 2011).

Hurricanes also can disrupt the food web and vegetation that the insects feed on (Chen 2020). Though hurricanes are not the greatest cause of salt marsh erosion, they still impact the marshes positively and negatively (Mo et al 2020). Hurricanes are becoming a greater hazard to coastal habitats, as storm intensity and severity are expected to grow as the climate changes (Mo et al 2020). Hurricanes have immediate impacts on salt marshes but according to Mo et al (2020), most marsh recovery occurs a year or two after the hurricane (also see Chen et al 2020). Hurricanes damage marsh plants, reduce biomass production, and can lower marsh elevation by removing marsh substrate through scouring and erosion (Mo et al 2020). But storm surges can also raise marsh elevation by dumping substantial amounts of sediment onto the flats. Other

positive impacts include a possible increase in below-ground biomass production and stimulation of marsh root growth in the years to follow (Mo et al 2020).

Oil spills are also one of the major threats to coastal wetlands (McCall et al 2012). Due to their low energy and anoxic conditions, coastal marshes are particularly slow to decompose oil. If oil sinks into the sediment within these marshes it can last for many years (McCall et al 2012). This oil can impact both the flora and fauna of an ecosystem. Oil contamination can change the characteristics of soil, which may have detrimental effects on fish populations, plant populations, and arthropod groups (McCall et al 2012). According to a study done by McCall et al (2012), the terrestrial arthropod community in salt marshes is vulnerable to oil exposure, but can also recover within a year if host plants continue in good health. However, Bam et al (2018) shows slower recovery and a more complicated picture.

Insects are a key component of the salt marsh ecosystem. By grazing or sucking on vascular plants, phytophagous insects play a vital role in the salt marsh ecology (Costa et al 2001). The insect community is influenced by wind, rain, temperature, sea-level rise, salinity, competition, predation, and vegetation (Rippel et al 2021). These impacts can have a direct or indirect effect on the arthropod community such as tropical cyclones killing host plants or the insects themselves (Harrison and Rasplus 2006). Insects' growth, abundance, and distribution can also be affected by these factors (Speight et al 2008). Insects in salt marshes are also used in ecological research, as well as monitoring and assessment of the environment (Costa et al 2001). Adams et al (2017) found that *Chironomini* and *Crematogaster* are good indicator species for marsh health. *Crematogaster* is an easily recognizable ant species characterized by the heart-shaped gaster (abdomen) (Blaimer et al 2012). These insects play a significant role in energy and nutrient processing, including nutrient capture and return to terrestrial ecosystems and water

purification. Insects are also considered bioindicators that are used to detect changes in the environment; these changes are often caused by anthropogenic or natural factors (Rochlin et al 2011). The idea behind utilizing bioindicators is that the insect community represents the health of a salt marsh and responds to disruptions through measurable changes such as diversity and abundance.

Problem Statement

Tropical cyclone Isaac formed on 21 August 2012 and dissipated on 1 September 2012 (Berg 2013). It was a tropical cyclone that became a category 1 hurricane on 28 August 2012. Isaac made two landfalls in Louisiana; the first landfall occurred at Southwest Pass in the Mississippi River at about 0000 UTC on 29 August 2012 with maximum sustained winds of 70 kt and then wobbled westward back over water in the Gulf of Mexico. Hurricane Isaac then made a second landfall west of Port Fourchon, Louisiana, around 0800 UTC (Berg 2013). The marsh on the west side of the Mississippi River in Louisiana – Barataria Bay – received the heaviest impact from the hurricane. Sajo (1987) observed that during barometric depressions insects may become unusually active. Hurricane Isaac's barometric pressure measured 965 mbar (hPa) or 28.5 Hg. Hurricane Isaac was also concomitant with a high tide event and was slow moving. These combined factors caused the marsh to be covered with water for more than 72 hours (Chen et al 2020).

Hurricane Isaac impacted a marsh that was already stressed from the 2010 Deepwater Horizon drilling disaster. In April 2010, about 4.9 million barrels of oil from the Macondo well were released into the Gulf of Mexico (Burns et al 2014). This event is one of the largest oil spills in history, known as the Deepwater Horizon (DWH) drilling disaster (Crone et al 2010).

On May 5, 2010, the oil was detected in the water near the coast of Louisiana which is approximately 70 kilometers from the incident. The oil impacted the coastal ecosystem both directly and indirectly, covering about 45% of coastal marshes (Turner et al 2014). The crude oil from the DWH oil spill immediately threatened the marine ecosystem and directly impacted the coastal habitats. Bam et al (2018) and Chen et al (2020) both document the impacts of hurricanes on insects and Bam et al (2018) and Pennings et al (2014) and others show impacts of oil on insect populations. Hurricane Isaac redistributed the oil from the Deepwater Horizon Oil Spill, contaminating Louisiana salt marshes (Chen et al 2020). An open question remains about the impact of hurricanes and oil stressors on body size and weight of insects in the marsh.

Objectives

1. To study impact of oil and a cyclone on the weight and length of the herbivore *Ischnodemus* individuals;
2. To determine the impact of oil and a cyclone on the weight, length, and head width of the omnivore *Crematogaster* individuals.

I hypothesized that there would be differences in the weight, length, and head width of the individuals of smooth cordgrass bugs and acrobat ants among the oiled and unoiled sites in Louisiana marshes. I hypothesized that there would be a difference in individuals of smooth cordgrass bugs and acrobat ants before and after Hurricane Isaac in the saltmarshes.

METHODS AND MATERIALS

Study Area

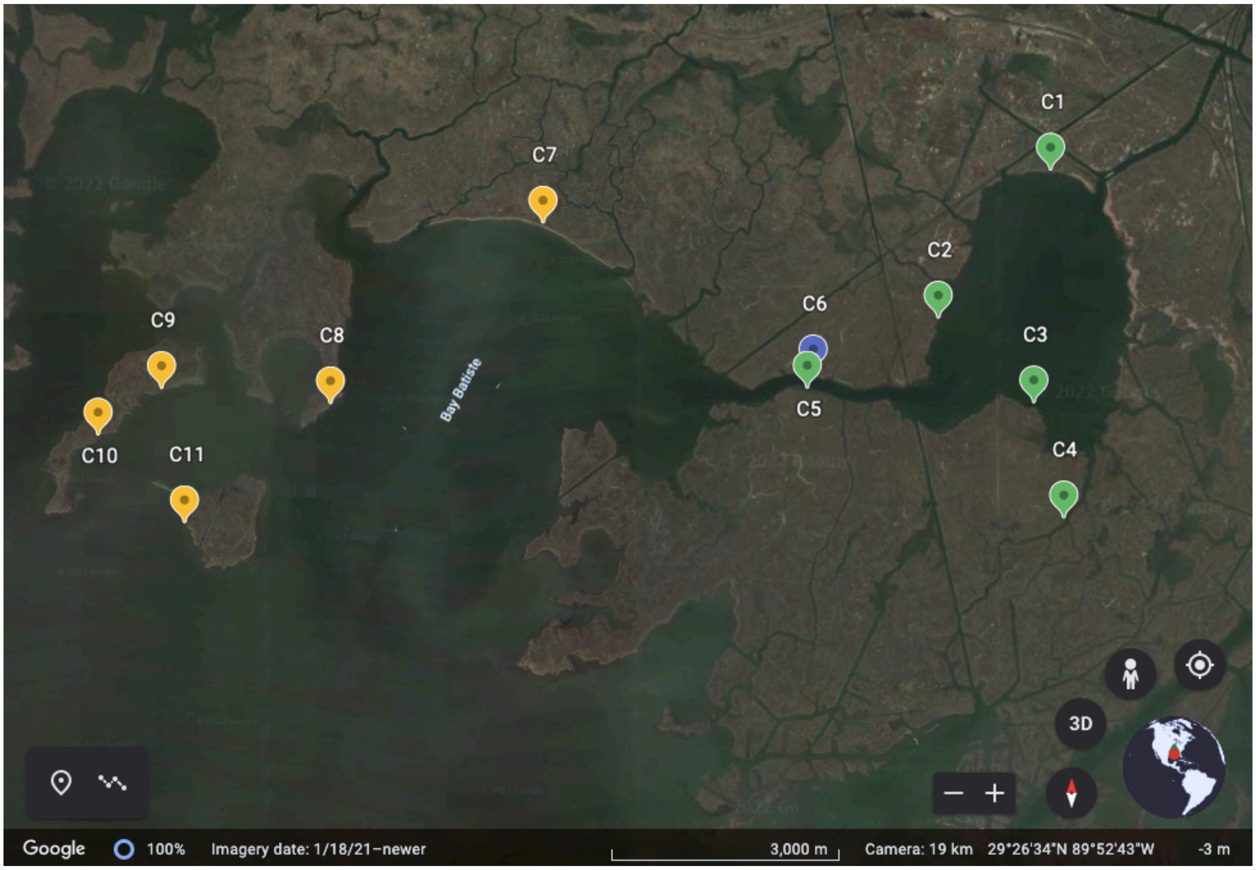


Figure 1. The site locations in the salt marshes of Louisiana. Oiled sites are shown with a yellow marker. Unoiled sites are shown with a light green marker. Site C6 is not used in the oiled and unoiled data so it is shown with a light purple marker.

Study sites were located in Barataria Bay, (Bay Batiste, and Bay Sansbois) in Plaquemines Parish Louisiana, USA, as seen in Figure 1. According to Bam et al (2018), the study area has low tidal ranges and has typical salt marsh vegetation dominated by *Spartina alterniflora*, *Juncus roemearianus*, *Distichlis spicata*, and *Avicennia germinans*. All the sites were impacted by Hurricane Isaac so I examined insect data from the sites before the hurricane hit and after. Study sites (named C1-C11) were selected for the analysis of samples collected from January 2012 to December 2013 to investigate hurricane impacts in insect size and weight.

Additionally, ten study sites were selected of which five sites were oiled and five sites were unoiled. Louisiana sweet crude oil from Macondo Canyon 252 impacted the oiled sites in 2010 in the aftermath of the Deepwater Horizon drilling disaster (Hooper-Bui, Turner).

Bay Batiste, Bay Sansbois, and Barataria Bay all are brackish marsh with low-level tides, and wind-driven water. These sites are characterized as Bam et al (2018) described them and are dominated by *Spartina alterniflora* and *Juncus roemearianus* except for C1 which appears to be higher in elevation and is dominated by *Distichlis spicata*. C2, C5, C6, were the most degraded with many small ponds. Care was taken to avoid the ponds when possible. Sites may vary in salinity from 3.7 to 12.1 ppt throughout the study. From flora to insects to birds, the dominant organisms are comparable between each site.

Sample Collection

Terrestrial arthropods were collected in the salt marsh vegetation by use of sweep nets along linear transects, measured from the marsh's edge to 20 meters inland (40m x 2m plots) as described in Bam et al (2018). The insects were collected during the summer, spring, fall, and winter. The sweep net method is one of the most popular methods of sampling terrestrial arthropods. We sampled a few days in the months before and after the hurricane, between 6 am and 10:30 am. Rainy days weren't included to prevent bias in the sampling. To transport the arthropods to the lab located at Louisiana State University, we transferred them from the nets into Ziploc bags containing 95% ethanol. The insects were then sorted by species into separate vials with site number, date, number of individuals, and species name. Using appropriate taxonomic keys, we then sorted the samples into orders and families and then recorded numbers for each of the taxa, using the Insect Index created by myself and Dr. Linda Hooper-Bui.

An herbivore and an omnivore were chosen to examine because, in particular, there are a lot of insects. We chose the herbivore, *Ischnodemus,* because it was the most common collected herbivore across all the sites. We split the *Ischnodemus* into two groups, adults and juveniles, because the sizes between these two stages of life are so different it would give unclear results. We chose the omnivore, *Crematogaster,* because it is this insect, we have the most knowledge on. We sorted specimens by the years 2012 and 2013 and then sorted by insect species, *Ischnodemus* and *Crematogaster,* and then "before" and "after" Hurricane Isaac, 29 August 2012. We measured the length in millimeters with Mitutoyo calipers (Mitutoyo Corp. Kawasaki, Japan) and weight in ug using the Sartorius microbalance (Sartorius, Gottingen, Germany) of the two species of insects. For the *Crematogaster* ants, the head widths were measured as well. We measured the head widths of ants because the amount of nutrients ants received as juveniles influence their adult head widths. I excluded sites EWB, WWB, and LGE because they were not consistent enough to measure the data. Also excluded was ES1-ES6 because these sites were on the east side of the Mississippi River, which had minor impact from the hurricane. C1-C5 were "oiled" after the hurricane while C7-C11 were "historically non-oiled."

Statistical Analysis

Analysis of variance (ANOVA) was used to analyze the data, in which independent variables included sites, oiled and unoiled, and seasons, before and after the hurricane. The dependent variables were the weight (mg) and length (mm) of the adult and juvenile *Ischnodemus*, and weight (mg), length (mm), and head width (mm) of *Crematogaster* ants. This analysis was used to calculate any connection between the seasons or sites and the weight, length, and/or head width of the insect populations. If the p-value was less than 0.05 and the f-value greater than 3.95 there was a significance and a Tukey test (HSD) was done. The Tukey

test was used to compare the mean within the multiple groups, sites and seasons. The Tukey test was also used to determine exactly where the significance lay and between what groups. Shapiro-Wilk test was used to test for normality and skewness. Since the Shapiro-Wilks test found the data not to be normally distributed, a nonparametric version of the test was used, which does not assume normality. The test used was the Kruskal- Wallis test which is a nonparametric approach to the one-way ANOVA (Leon 2000).

RESULTS

Ischnodemus

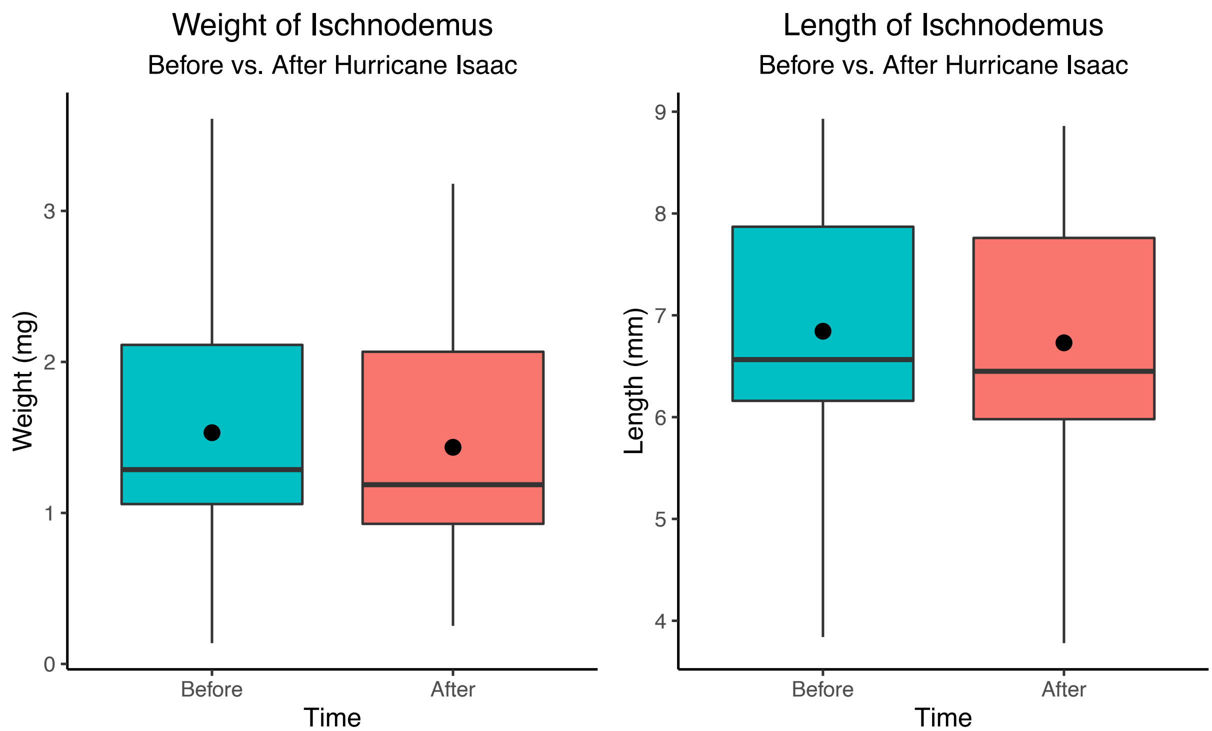


Figure 2.1. Weight and length of Ischnodemus compared before and after Hurricane Isaac.

A total of eleven sites resulted in 1,007 *Ischnodemus* individuals. There were 568 individuals before Hurricane Isaac and 439 individuals after. Figure 2.1. shows the mean weight and length of *Ischnodemus* before and after Hurricane Isaac. The average weight of *Ischnodemus* before the hurricane was significantly higher at 1.53 mg than the average weight after at 1.43 mg (p=0.03, f=4.75, df=1). The average length of *Ischnodemus* before the hurricane was 6.84 mm and the average length after was 6.73 mm, the difference was not statistically significant (p=0.10, f=2.65, df=1).

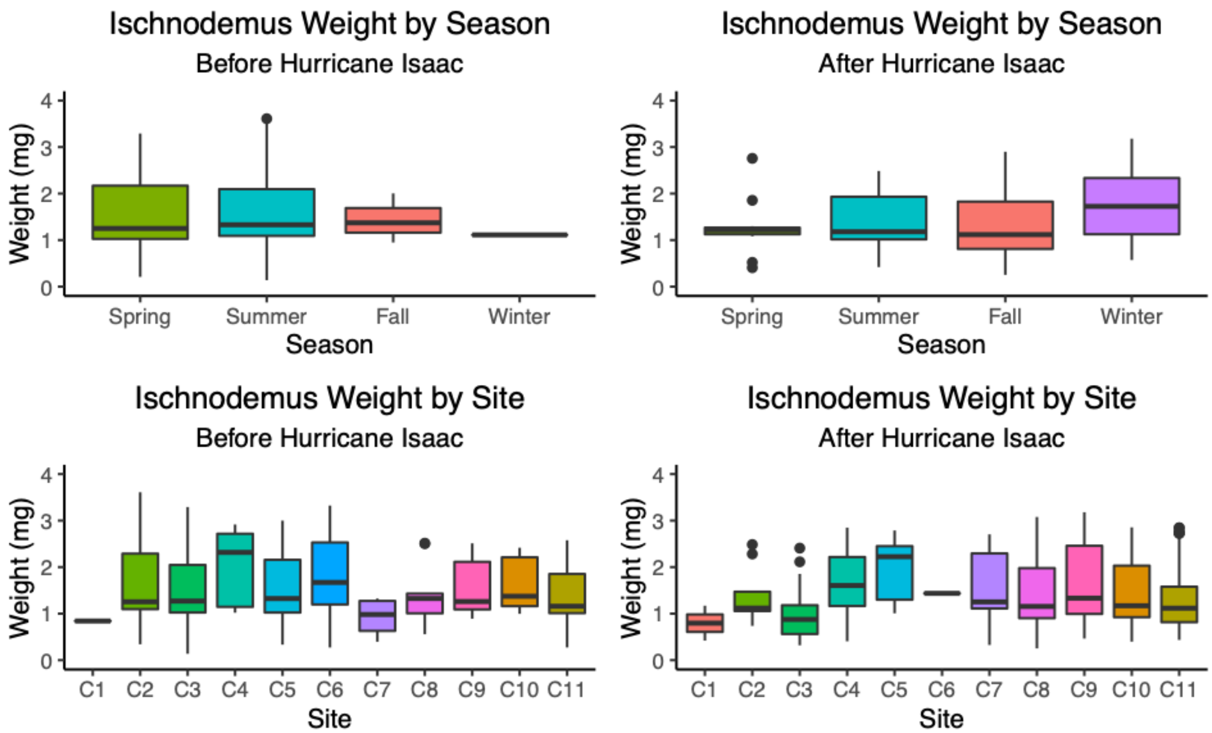


Figure 2.2. Ischnodemus weight compared amongst seasons and sites before and after Hurricane Isaac.

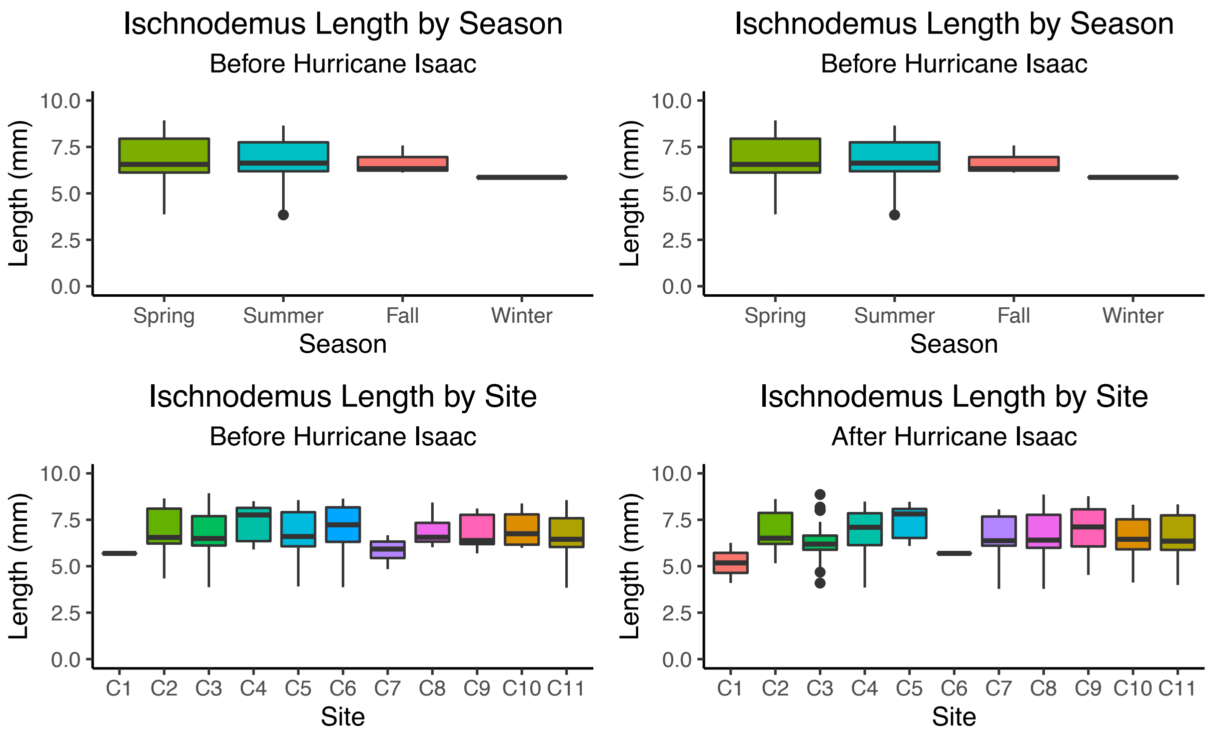


Figure 2.3. Ischnodemus length compared amongst seasons and sites before and after Hurricane Isaac.

Table 1.1. Ischnodemus overall mean table results.

	WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
C1	1.23	6.92	28
C2	1.57	6.96	87
C3	1.42	6.69	193
C4	1.74	7.00	69
C5	1.61	6.89	122
C6	1.80	7.02	54
C7	1.50	6.56	23
C10	1.46	6.68	69
C11	1.31	6.645	191
FALL	1.32	6.59	284
SPRING	1.49	6.81	287
SUMMER	1.55	6.85	328
WINTER	1.75	7.12	108
BEFORE	1.53	6.84	568
AFTER	1.43	6.73	439

Table 1.2. Ischnodemus mean table results before Hurricane Isaac.

	WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
C1	1.26	7.05	26
C2	1.60	6.97	78
C3	1.48	6.74	170
C4	2.00	7.32	17
C5	1.53	6.77	100
C6	1.81	7.05	53
C7	0.92	5.84	4
C10	1.62	6.95	17
C11	1.37	6.73	68
FALL	1.44	6.68	3
SPRING	1.50	6.82	275
SUMMER	1.57	6.87	289
WINTER	1.11	5.86	1

Table 1.3. Ischnodemus mean table results after Hurricane Isaac.

	WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
C1	0.80	5.18	2
C2	1.36	6.88	9
C3	0.97	6.34	23
C4	1.66	6.89	52
C5	1.98	7.46	22
C6	1.44	5.69	1
C7	1.62	6.72	19
C8	1.42	6.73	98
C10	1.41	6.59	52
C11	1.28	6.60	123
FALL	1.32	6.59	281
SPRING	1.26	6.43	2
SUMMER	1.42	6.73	39
WINTER	1.76	7.13	107

Table 1.4. Ischnodemus overall ANOVA test results.

		WEIGHT (MG)	LENGTH (MM)
SEASON	P-Value	1.79e-07	1.48e-04
	F-Value	11.6	6.83
	DF	3	3
BEFORE VS. AFTER	P-Value	0.03	0.10
	F-Value	4.75	2.65
	DF	1	1
SITE	P-Value	1.28e-06	0.02
	F-Value	4.48	2.13
	DF	11	11

Table 1.5. Ischnodemus ANOVA results before and after Hurricane Isaac.

		BEFORE		AFTER	
		Weight	Length	Weight	Length
SEASON	P-Value	0.59	0.77	5.93e-07	0.0002
	F-Value	0.64	0.38	10.96	6.55
	DF	3	3	3	3
SITE	P-Value	0.002	0.17	4.78e-06	0.01
	F-Value	2.76	1.40	4.49	2.34
	DF	11	11	10	10

Figure 2.2 shows the mean weight of *Ischnodemus* collected during all four seasons and eleven sites, before and after Hurricane Isaac. Figure 2.3 shows the mean length of *Ischnodemus* collected before and after the hurricane amongst the seasons and sites. There was no significant difference found between weight among seasons (p=0.59, f=0.64, df=3) or sites (p=0.77, f=0.38, df=3) and length among sites (p=0.17, f=1.40, df=11) before the hurricane. Weight amongst sites did however show a significant difference before Hurricane Isaac (p=0.002, f=2.76, df=11). After the hurricane, the weight (p=5.93e-07, f=10.96, df=3) and length (p=0.0002, f=6.55, df=3) of the *Ischnodemus* were significantly different among the seasons. The weight (p=4.78e-06, f=4.49, df=10) and length (p=0.01, f=2.34, df=10) of *Ischnodemus* were also significantly different among the sites after the hurricane. Overall, there was a significant difference between weight amongst seasons (p =1.79e-07, f=11.59, df=3) and sites (p=1.28e-06, f=4.48, df=11), as well as length amongst seasons (p=1.48e-04, f=6.83, df=3) and sites (p=0.02, f=2.13, df=11).

Table 1.6. Ischnodemus overall Kruskal-Wallis results.

		WEIGHT (MG)	LENGTH (MM)
SEASON	P-Value	5.79e-09	5.20e-05
	Chi-Squared	413.	22.5
	DF	3	3
BEFORE VS. AFTER	P-Value	0.006	0.02
	Chi-Squared	7.53	5.12
	DF	1	1
SITE	P-Value	3.85e-07	0.0008
	Chi-Squared	51.2	31.82
	DF	11	11

Table 1.7. Ischnodemus Kruskal-Wallis results before and after Hurricane Isaac.

		BEFORE		AFTER	
		Weight	Length	Weight	Length
SEASON	P-Value	0.45	0.55	2.50e-07	0.0002
	Chi-Squared	2.69	2.12	33.5	19.80
	DF	3	3	3	3
SITE	P-Value	0.003	0.04	1.48e-06	0.005
	Chi-Squared	28.59	20.56	45.9	25.42
	DF	11	11	10	10

The Kruskal- Wallis test showed that there was a significant difference between length and time (p=0.02, x^2=5.12, df=1), unlike the ANOVA test which showed no difference. Also, the Kruskal- Wallis test showed a significant difference in length and site before Hurricane Isaac (p=0.04, x^2=20.56, df=11).

Juvenile *Ischnodemus*

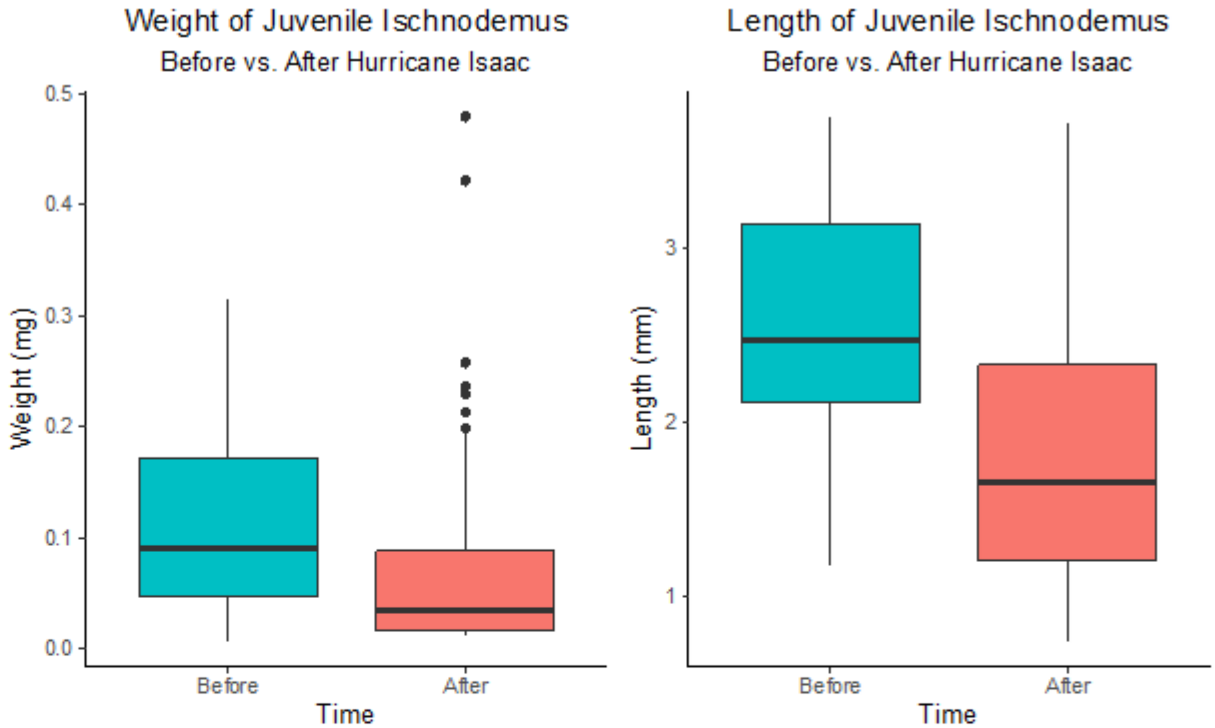


Figure 3.1. Juvenile Ischnodemus weight and length compared to before and after Hurricane Isaac.

A total of one hundred and thirty juvenile *Ischnodemus* were analyzed. Sixty-two juveniles were collected before and sixty-eight were analyzed after the hurricane. Figure 3.1. shows the average weight and length of juvenile *Ischnodemus* before and after Hurricane Isaac. The average weight of the juvenile *Ischnodemus* before the hurricane was 0.12 mg and after it was 0.07 mg, the difference was significant (p =0.005, f=8.23, df=1). The average length before the hurricane was 2.55 mm and the average length after the hurricane was 1.88 mm, which showed a significant difference (p=1.51e-06, f=25.47, df=1).

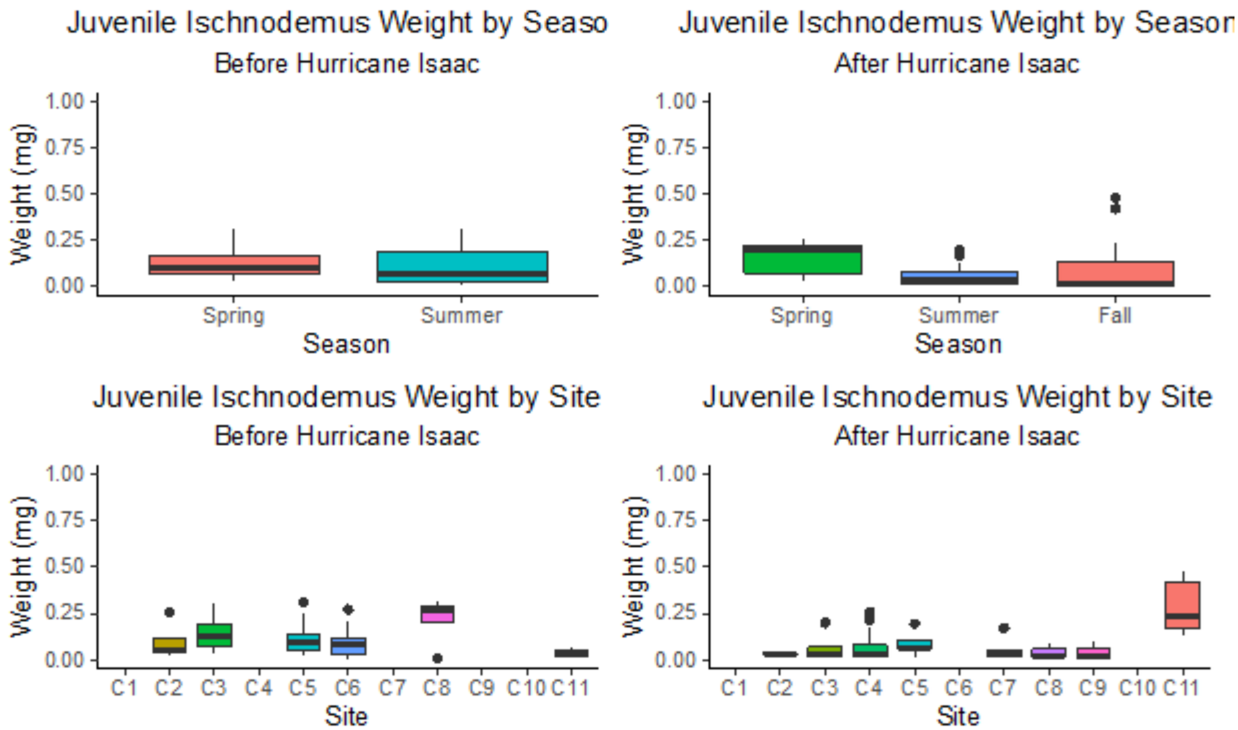


Figure 3.2. Juvenile Ischnodemus weight compared amongst seasons and sites before and after Hurricane Isaac.

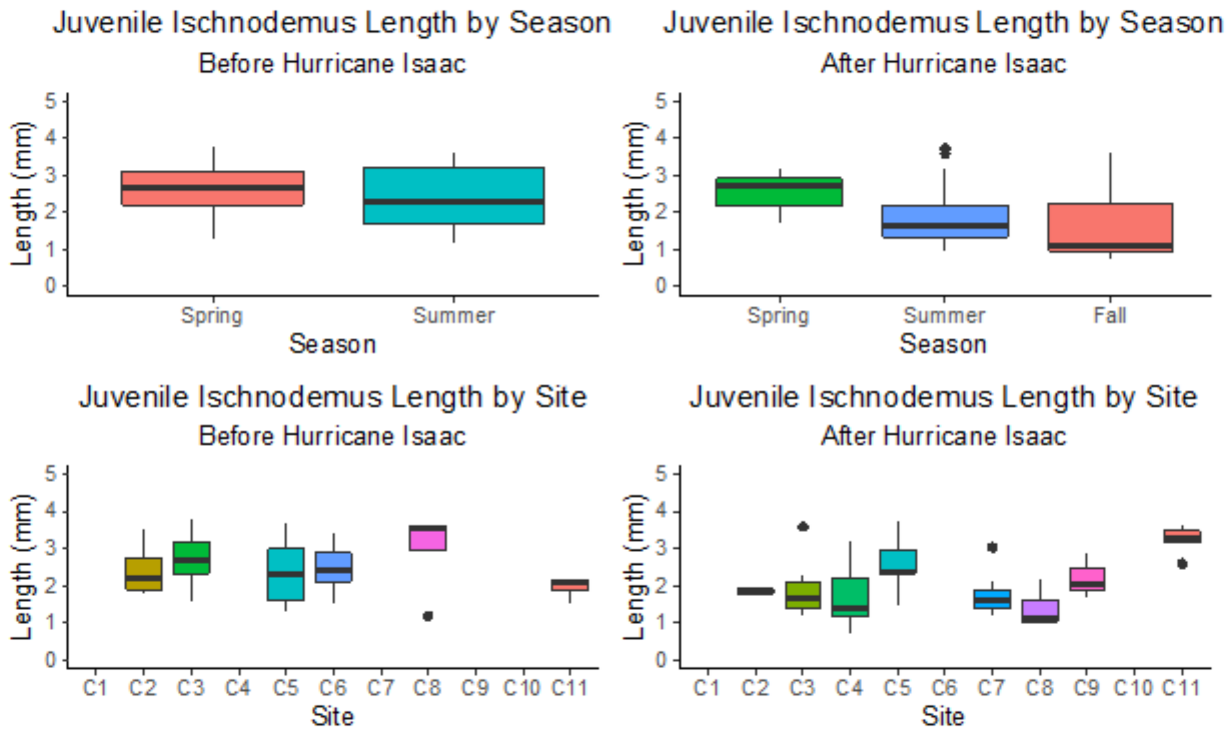


Figure 3.3. Juvenile Ischnodemus length compared amongst seasons and sites before and after Hurricane Isaac.

Table 2.1. Juvenile Ischnodemus overall mean results.

	WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
C2	0.08	2.24	6
C3	0.12	2.50	33
C4	0.06	1.66	31
C5	0.10	2.43	19
C6	0.10	2.44	12
C7	0.05	1.77	7
C8	0.11	2.01	10
C9	0.04	2.20	3
C11	0.18	2.65	9
FALL	0.11	1.66	3
SPRING	0.13	2.65	9
SUMMER	0.07	2.02	73
BEFORE	0.12	2.55	62
AFTER	0.07	1.88	68

Table 2.2. Juvenile Ischnodemus before Hurricane Isaac.

	WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
C2	0.10	2.43	4
C3	0.14	2.75	24
C5	0.11	2.38	14
C6	0.10	2.44	12
C8	0.22	2.98	4
C11	0.04	1.95	4
SPRING	0.13	2.63	40
SUMMER	0.11	2.41	22

Table 2.3. Juvenile Ischnodemus after Hurricane Isaac.

	WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
C2	0.03	1.85	2
C3	0.05	1.85	9
C4	0.06	1.66	31
C5	0.08	2.57	5
C7	0.05	1.77	7
C8	0.04	1.36	6
C9	0.04	2.20	3
C11	0.29	3.22	5
FALL	0.11	1.66	11
SPRING	0.16	2.55	6
SUMMER	0.06	1.85	51

Table 2.4. Juvenile Ischnodemus ANOVA overall results.

		WEIGHT (MG)	LENGTH (MM)
SEASON	P-Value	2.43e-03	2.38e-05
	F-Value	6.31	11.6
	DF	2	2
BEFORE VS. AFTER	P-Value	0.005	1.51e-06
	F-Value	8.23	25.5
	DF	1	1
SITE	P-Value	4.93e-02	6.00e-04
	F-Value	2.02	3.74
	DF	8	8

Table 2.5. Juvenile Ischnodemus ANOVA results before and after Hurricane Isaac.

		BEFORE		AFTER	
		Weight	Length	Weight	Length
SEASON	P-Value	0.45	0.26	9.08e-03	0.07
	F-Value	0.58	1.27	5.06	2.74
	DF	1	1	2	2 (table cont'd.)

		BEFORE		AFTER	
		Weight	Length	Weight	Length
SITE	P-Value	0.07	0.20	4.30e-06	0.0003
	F-Value	2.20	1.52	6.93	4.75
	DF	5	5	7	7

Figure 3.2. shows the average weight of juvenile *Ischnodemus* before and after Hurricane Isaac amongst seasons and sites. Figure 3.3. shows the average length of juvenile *Ischnodemus* before and after Hurricane Isaac amongst seasons and sites. There was no significant difference found between weight among seasons (p=0.45, f=0.58, df=1) or sites (p=0.07, f=2.20, df=5) and length among seasons (p=0.26, f=1.27, df=1) or sites (p=0.198, f=1.52, df=5) before the hurricane. However, after the hurricane, the weight was significantly different among the seasons (p=9.08e-03, f=5.06, df=2) and the sites (p=4.80e-06, f=6.93, df=7). The length among the sites after the hurricane also was significantly different (p=0.0003, f=4.75, df=7) but not among the seasons (p=0.0717, f=2.744, df=2). Overall, the weight (p=2.43e-03, f=6.31, df=2) and length (p=2.38e-05, f=11.59, df=2) among the seasons, as well as, weight (p=4.93e-02, f=2.02, df=8) and length (p=6.00e-04, f=3.744, df=8) among sites showed significant differences.

Table 2.6. Juvenile Ischnodemus Kruskal-Wallis results.

		WEIGHT (MG)	LENGTH (MM)
SEASON	P-Value	1.59e-05	1.34e-05
	Chi-Squared	22.1	22.4
	DF	2	2
BEFORE VS. AFTER	P-Value	6.23e-05	1.61e-06
	Chi-Squared	16.03	23.01
	DF	1	1
SITE	P-Value	4.17e-02	5.53e-04
	Chi-Squared	16.1	27.6
	DF	8	8

Table 2.7. Juvenile Ischnodemus before and after Hurricane Isaac Kruskal-Wallis results.

		BEFORE		AFTER	
		Weight	Length	Weight	Length
SEASON	P-Value	1.26e-01	2.54e-01	2.70e-02	1.40e-02
	Chi-Squared	2.34	1.30	7.23	8.54
	DF	1	1	1	1
SITE	P-Value	7.82e-02	1.41e-01	7.58e-02	0.004
	Chi-Squared	9.90	8.30	12.9	20.99
	DF	5	5	7	7

Just as the results for all the juvenile *Ischnodemus* from the ANOVA test, the Kruskal-Wallis test shows similar significance. As well as, the before and after seen in Table 2.7. shows very similar results to the ANOVA tests seen in Table 2.5.

Crematogaster

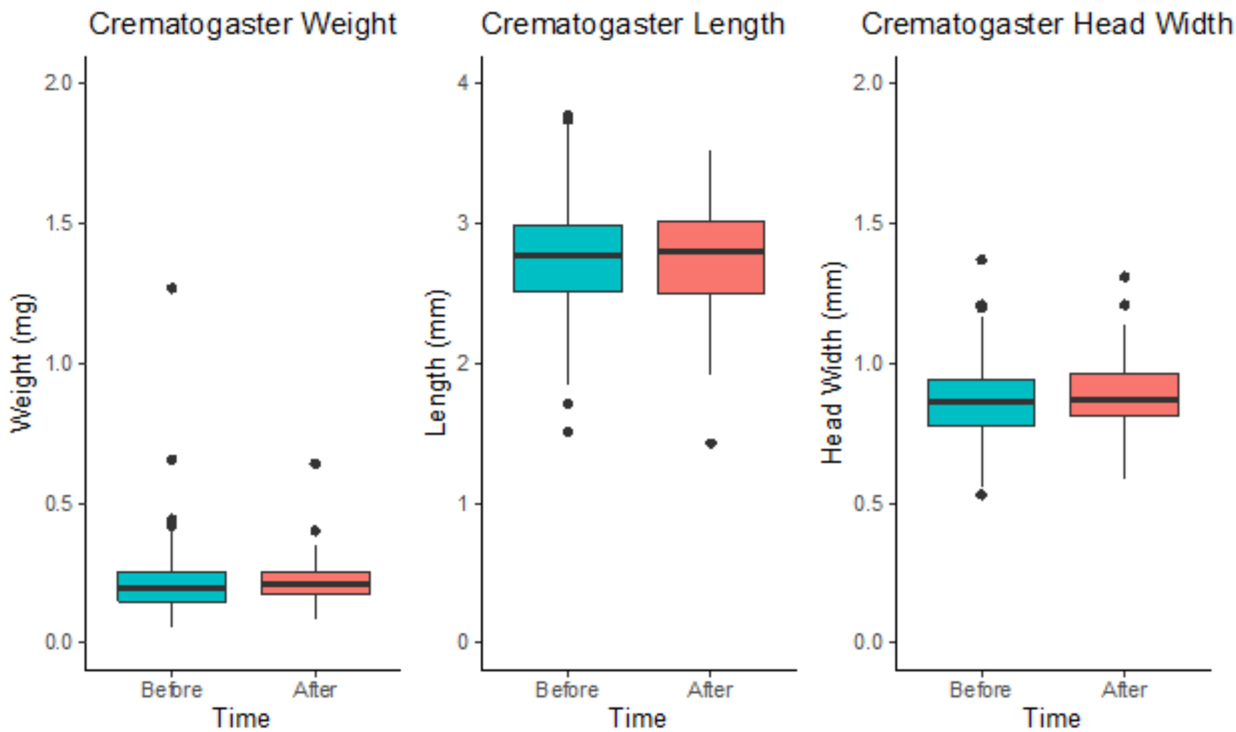


Figure 4.1. Crematogaster weight, length, and head width compared before and after Hurricane Isaac.

A total of four hundred and fifty-six individuals of *Crematogaster* were analyzed. There were 326 individuals before the hurricane and only 130 individuals after the hurricane. This shows that their numbers had decreased by a large amount after the hurricane. The average weight of *Crematogaster* before the hurricane was 0.22 mg and after was 0.21 mg, there was no significant difference (p=0.56, f=0.34, df=1). The average length before the hurricane was 2.76 mm and after was 2.77 mm, which also showed no significance (p=0.83, f=0.05, df=1). The average head width before the hurricane was 0.88 mm and after was 0.86 mm, again no significance (p=0.09, f=2.81, df=1).

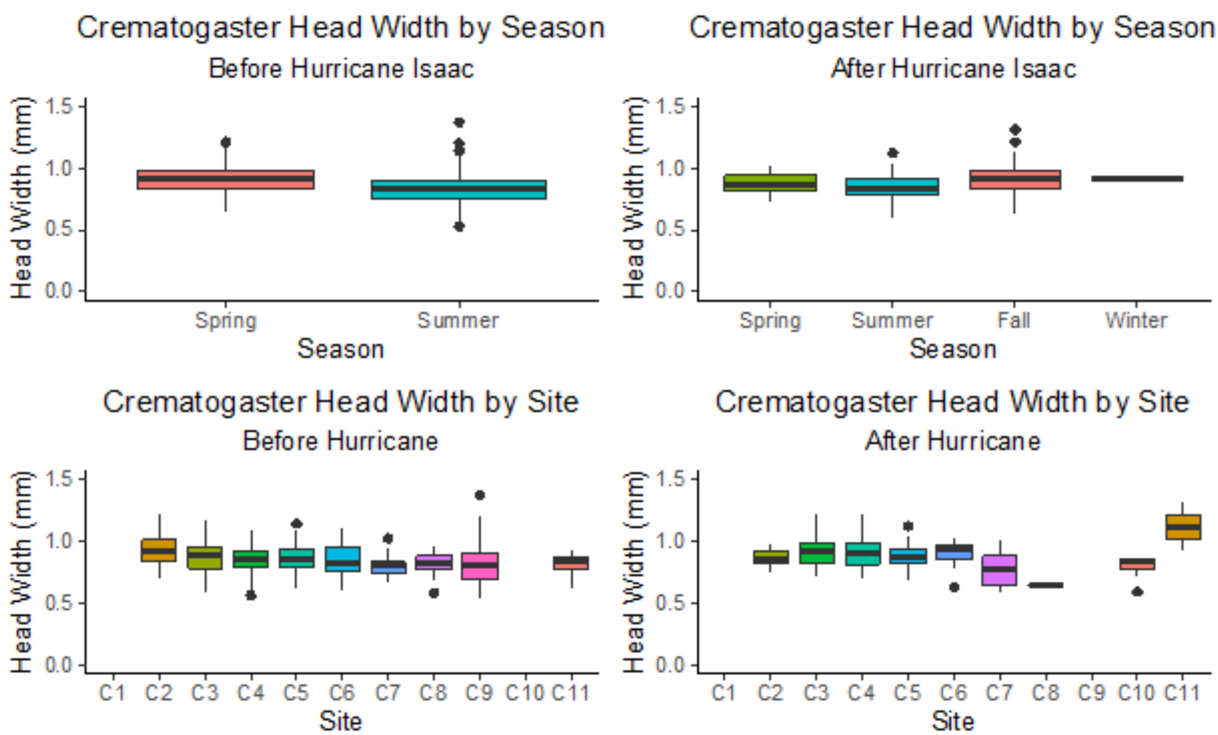


Figure 4.2. Crematogaster head width compared amongst seasons and sites before and after Hurricane Isaac.

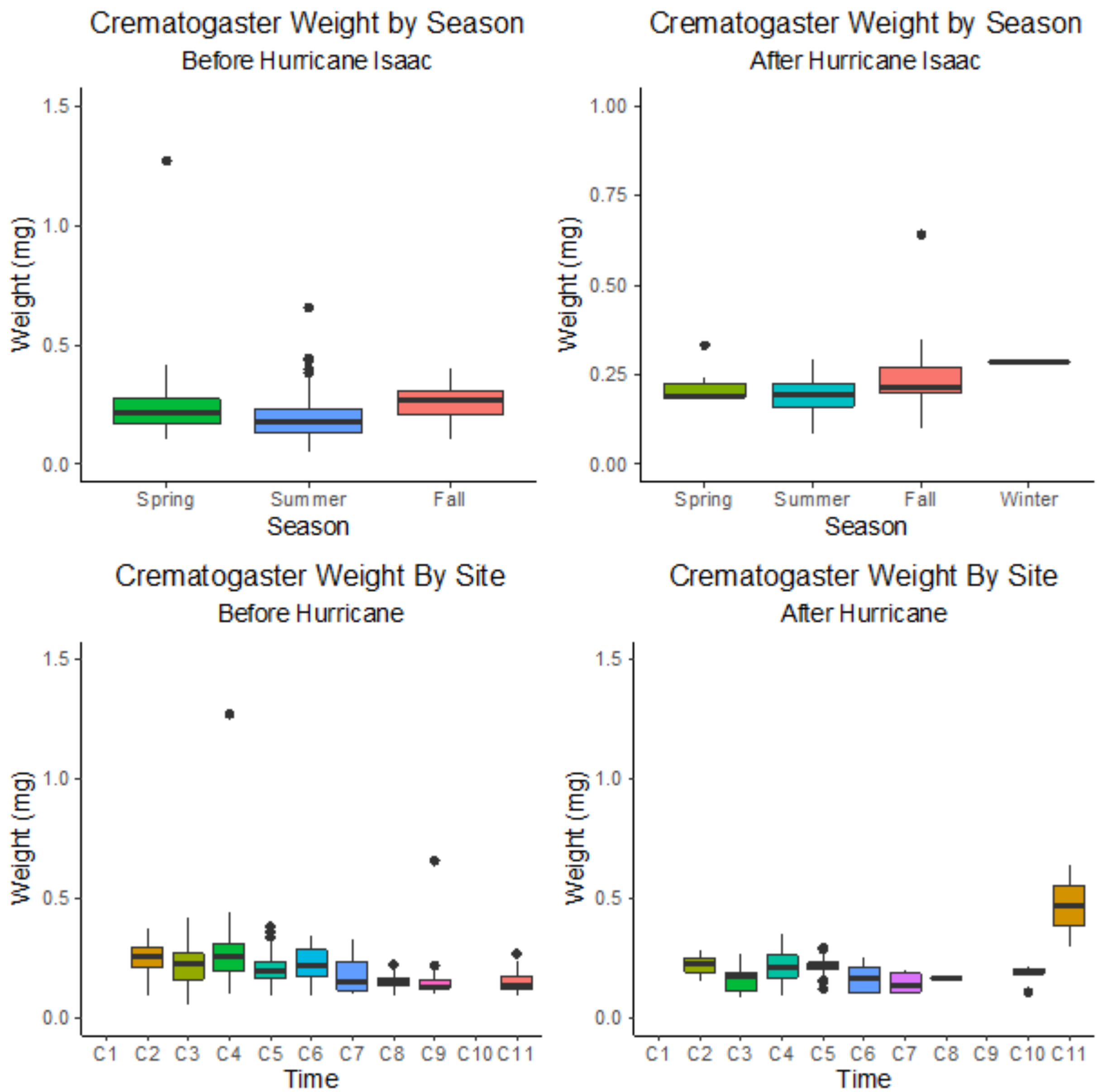


Figure 4.3. Crematogaster weight compared amongst seasons and sites before and after Hurricane Isaac.

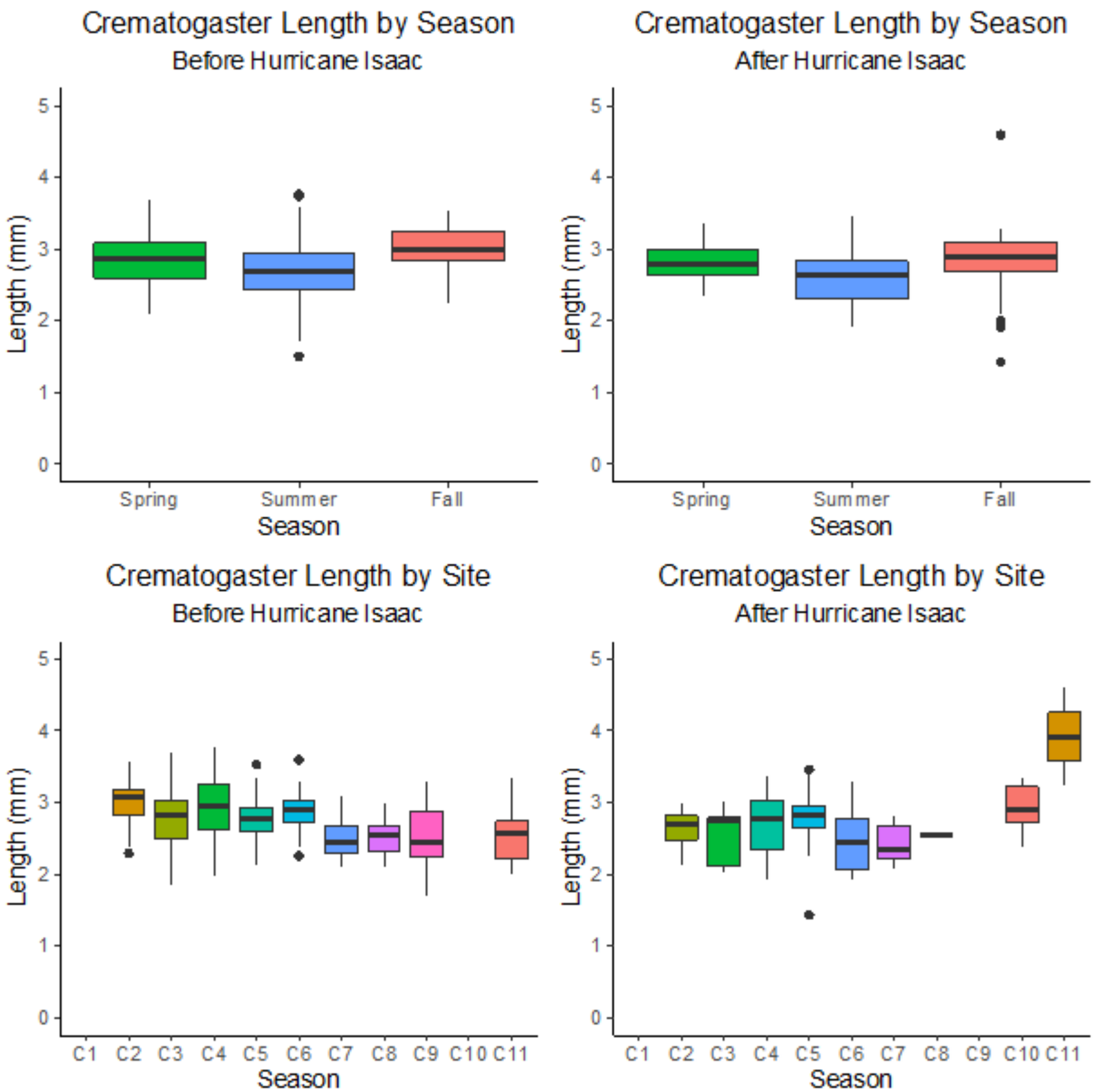


Figure 4.4. Crematogaster length compared amongst seasons and sites before and after Hurricane Isaac.

Table 3.1. Crematogaster overall mean table results.

	WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)	ABUNDANCE
C1	0.16	2.46	0.85	4
C2	0.24	2.87	0.90	39
C3	0.22	2.78	0.88	89
C4	0.25	2.83	0.88	84
C5	0.20	2.78	0.87	131 (table cont'd.)

	WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)	ABUNDANCE
C6	0.21	2.78	0.86	32
C7	0.17	2.49	0.79	24
C8	0.15	2.52	0.80	19
C9	0.17	2.50	0.84	16
C10	0.19	2.92	0.79	8
C11	0.22	2.83	0.87	10
FALL	0.24	2.89	0.92	62
SPRING	0.23	2.85	0.90	160
SUMMER	0.19	2.67	0.83	233
WINTER	0.29	3.03	0.92	1
BEFORE	0.22	2.76	0.88	326
AFTER	0.21	2.77	0.86	130

Figure 3.2. Crematogaster mean table results before Hurricane Isaac.

	WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)	ABUNDANCE
C1	0.13	2.28	0.83	3
C2	0.25	3.01	0.93	25
C3	0.22	2.79	0.88	83
C4	0.28	2.92	0.85	34
C5	0.20	2.78	0.87	99
C6	0.21	2.87	0.85	23
C7	0.17	2.48	0.80	17
C8	0.15	2.52	0.81	18
C9	0.17	2.50	0.84	16
C11	0.15	2.56	0.81	8
SPRING	0.23	2.85	0.90	153
SUMMER	0.19	2.69	0.83	173

Table 3.3. Crematogaster mean table results after Hurricane Isaac.

	WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)	ABUNDANCE
C1	0.27	3.02	0.92	1
C2	0.22	2.64	0.86	14
C3	0.17	2.63	0.93	6
C4	0.23	2.78	0.91	50
C5	0.21	2.81	0.88	32
C6	1.88	2.56	0.89	9
C7	0.16	2.51	0.77	7
C8	0.16	2.54	0.64	1
C10	0.19	2.92	0.79	8
C11	0.47	3.92	1.12	2
FALL	0.24	2.89	0.92	62 (table cont'd.)

	WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)	ABUNDANCE
SPRING	0.22	2.83	0.87	7
SUMMER	0.19	2.61	0.84	60
WINTER	0.29	3.03	0.92	1

Table 3.4. Crematogaster overall ANOVA results.

		WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)
SEASON	P-Value	5.67e-06	1.79e-06	1.19e-09
	F-Value	9.29	10.1	15.6
	Df	3	3	3
BEFORE VS AFTER	P-Value	0.56	0.83	0.09
	F-Value	0.34	0.046	2.81
	DF	1	1	1
SITE	P-Value	1.75e-05	3.19e-05	0.008
	F-Value	4.14	3.98	2.41
	DF	10	10	10

Table 3.5. Crematogaster ANOVA results before and after Hurricane Isaac.

		BEFORE			AFTER		
		Weight	Length	Head Width	Weight	Length	Head Width
SEASON	P-Value	2.82e-04	1.20e-04	4.33e-08	3.22e-04	1.58e-03	0.006
	F-Value	13.5	15.2	31.5	6.68	5.40	4.40
	DF	1	1	1	3	3	3
SITE	P-Value	5.40e-06	1.21e-08	0.04	5.91e-06	0.003	0.003
	F-Value	4.79	6.60	1.99	5.20	3.02	2.99
	DF	9	9	9	9	9	9

Before the hurricane weight (p=2.82e-04, f=13.48, df=1), length (p=1.20e-04, f=15.16, df=1), and head width (p=4.33e-08, f=31.48, df=1) all presented a significant difference amongst the seasons, seen in Table 3.5. Weight (p=5.40e-06, f=4.79, df=9), length (p=1.21e-08, f=6.99, df=9) and head width (p=0.04, f=1.99, df=9) all showed significance amongst the sites as well from before Hurricane Isaac. Weight (p=3.22e-04, f=6.68, df=3), length (p=1.58e-03, f=5.40, df=3), and head width (p=0.006, f=4.40, df=3) amongst seasons after the hurricane all showed significance, as well as weight (p=5.91e-06, f=5.20, df=9), length (p=0.003, f=3.00, df=9), and head width (p=0.003, f=3.02, df=9) amongst sites. Overall weight (p=5.67e-06, f=9.29, df=3),

head width (p=1.19e-09, f=15.56, df=3), and length (p=1.79e-06, f=10.13, df=3) showed a significant difference amongst seasons. As well as amongst sites all three measurements showed a significant difference; weight (p=1.75e-05, f=4.14, df=10), length (p=3.19e-05, f=3.98, df=10), and head width (p=0.008, f=2.41, df=10).

Figure 3.6. Crematogaster Kruskal-Wallis overall results.

		WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)
SEASON	P-Value	9.38e-09	4.33e-07	4.28e-10
	Chi-Squared	40.3	32.4	46.6
	DF	3	3	3
BEFORE VS AFTER	P-Value	0.13	1.00	0.13
	Chi-Squared	2.28	2.48e-06	2.30
	DF	1	1	1
SITE	P-Value	4.45e-09	2.26e-05	0.005
	Chi-Squared	59.5	39.3	25.20
	DF	10	10	10

Figure 3.7. Crematogaster Kruskal-Wallis before and after Hurricane Isaac results.

		BEFORE			AFTER		
		Weight	Length	Head Width	Weight	Length	Head Width
SEASON	P-Value	2.16e-06	1.33e-04	6.26e-09	3.44e-04	2.81e-04	0.007
	Chi-Squared	22.4	14.6	33.8	18.5	18.9	11.98
	DF	1	1	1	3	3	3
SITE	P-Value	4.82e-09	1.36e-07	0.02	2.36e-02	0.09	0.09
	Chi-Squared	57.1	49.5	20.17	19.2	15.17	15.21
	DF	9	9	9	9	9	9

The Kruskal- Wallis test showed that overall *Crematogaster* ants there was no real significance between before and after the hurricane for weight, length, or head width. The difference seen between the Kruskal- Wallis test and ANOVA are between length and site after the hurricane (p=0.09, x^2=15.17, df=9), as well as, head width and site after the hurricane (p=0.09, x^2=15.21, df=9). Overall, it can be seen that the seasons impacted the weight, length,

and head width of the ants rather the sites. Before the hurricane there are only two seasons compared so the difference lies between summer and spring for all three measurements.

Oiled vs. Unoiled

Ischnodemus

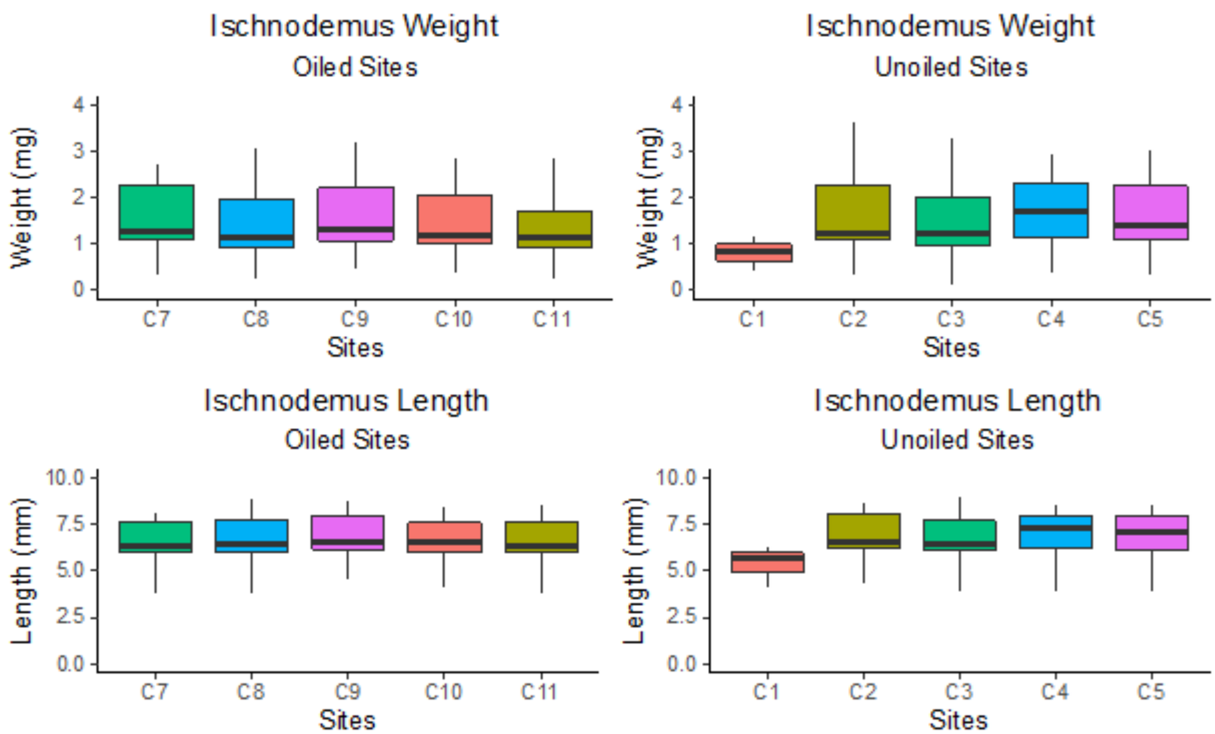


Figure 5.1. Ischnodemus weight and length amongst oiled and unoiled sites.

Table 4.1. Ischnodemus mean table results of oiled sites and unoiled sites.

		WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
OILED SITES	C7	1.50	6.56	23
	C8	1.41	6.75	109
	C9	1.62	6.96	62
	C10	1.46	6.68	69
	C11	1.31	6.64	191
UNOILED SITES	C1	1.23	6.92	28
	C2	1.57	6.96	87
	C3	1.42	6.69	193
	C4	1.74	7.00	69
	C5	1.61	6.89	122

Table 4.2. Ischnodemus ANOVA results for overall, oiled sites, and unoiled sites measuring weight and length.

		WEIGHT (MG)	LENGTH (MM)
OVERALL SITES	P-Value	0.01	0.07
	F-Value	6.99	3.25
	DF	1	1
OILED SITES	P-Value	2.58e-02	3.13e-01
	F-Value	2.80	1.19
	DF	4	4
UNOILED SITES	P-Value	2.17e-03	0.03
	F-Value	3.81	2.59
	DF	5	5

Table 4.3. Ischnodemus Kruskal-Wallis results for overall, oiled sites, and unoiled sites measuring weight and length.

		WEIGHT (MG)	LENGTH (MM)
OVERALL SITES	P-Value	0.003	0.005
	Chi-Squared	8.65	7.77
	DF	1	1
OILED SITES	P-Value	2.90e-02	2.48e-01
	Chi-Squared	10.8	5.41
	DF	4	4
UNOILED SITES	P-Value	1.99e-03	0.01922
	Chi-Squared	18.9	13.49
	DF	5	5

The oiled sites consist of C7, C8, C9, C10, and C11. The unoiled sites consist of C1, C2, C3, C4, and C5. Site C6 was excluded because it located directly across Bayou Dulac from C5 and we wanted to have equal replicates for the comparison of oiled vs unoiled. There was a total of 454 *Ischnodemus* insects collected in the oiled sites and 499 insects collected in the unoiled sites. The mean weight of the cordgrass bugs in oiled sites was 1.41 mg and in unoiled sites 1.52 mg, which showed a significant difference (p=0.01, f=6.99, df=1). The mean length in oiled sites was 6.71 mm and in unoiled sites 6.84 mm, resulting in a significant difference (p=0.07, f=3.25, df=1). There was no significant difference between length amongst oiled sites (p=0.31, f=1.19, df=4). However, there was a significant difference in weight amongst oiled sites for *Ischnodemus* (p=2.58e-02, f=2.80, df=4). Both length (p=0.03, f=2.59, df=5) and weight (p=2.17e-03, f=3.81,

df=5) amongst unoiled sites showed significance. Though there was a significant difference between the mean of lengths amongst unoiled sites, there are no significant p values from the Bonferroni test. The significant difference lies between C9-C11 for the weight of oiled sites and C4-C3 for the weight of unoiled sites. C11 is further out in the Gulf of Mexico compared to the other four oiled sites, so the weight of the *Ischnodemus* was significantly smaller.

Juvenile *Ischnodemus*

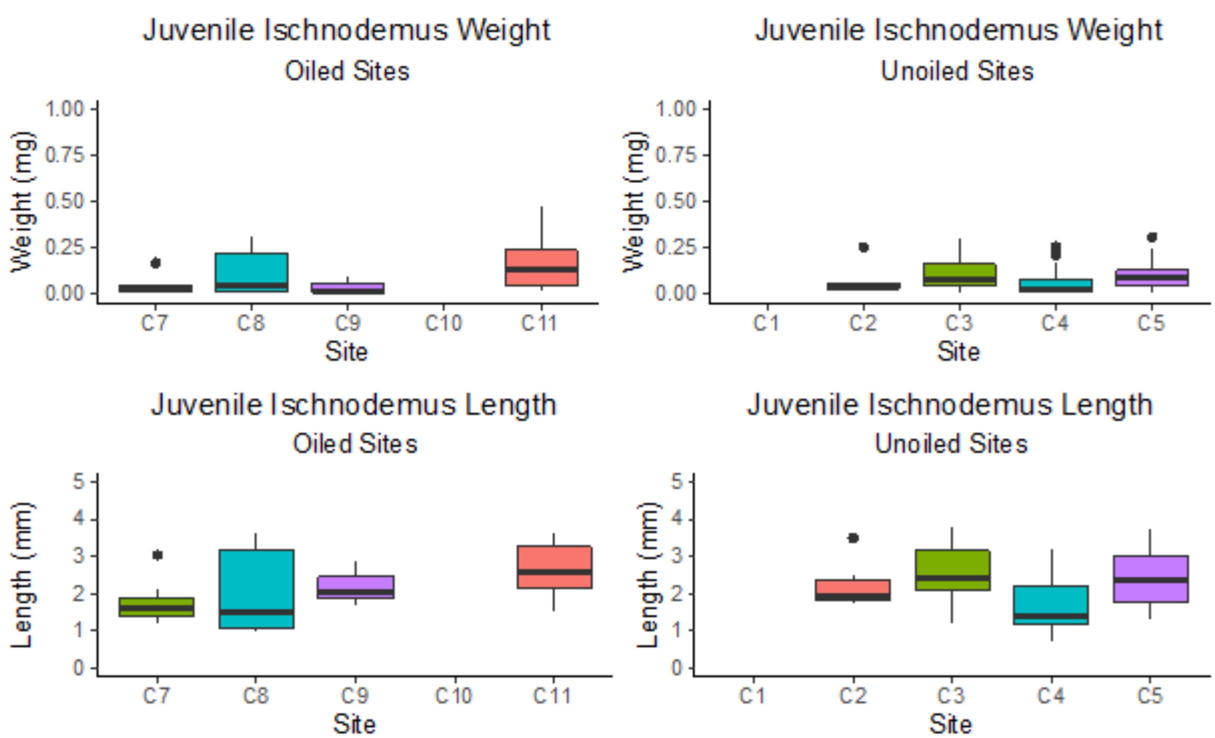


Figure 5.2. Juvenile Ischnodemus weight and length amongst oiled and unoiled sites.

Table 4.4. Juvenile Ischnodemus mean table results of overall sites, oiled sites, and unoiled sites.

		WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
OILED SITES	C7	0.05	1.77	7
	C8	0.11	2.01	10
	C9	0.04	2.20	3
	C11	0.18	2.65	9
	C2	0.08	2.24	6 (table cont'd.)

UNOILED SITES		WEIGHT (MG)	LENGTH (MM)	ABUNDANCE
	C3	0.12	2.50	33
	C4	0.06	1.66	31
	C5	0.10	2.43	19

Table 4.5. Juvenile Ischnodemus ANOVA results for overall, oiled sites, and unoiled sites measuring weight and length.

		WEIGHT (MG)	LENGTH (MM)
OVERALL SITES	P-Value	0.39	0.98
	F-Value	0.75	0.001
	DF	1	1
OILED SITES	P-Value	0.21	0.24
	F-Value	1.61	1.5
	DF	3	3
UNOILED SITES	P-Value	5.23e-02	9.17e-05
	F-Value	2.68	8.01
	DF	3	3

Figure 4.6. Juvenile Ischnodemus Kruskal-Wallis results for overall, oiled sites, and unoiled sites measuring weight and length.

		WEIGHT (MG)	LENGTH (MM)
OVERALL SITES	P-Value	0.60	0.81
	Chi-Squared	0.28	0.06
	DF	1	1
OILED SITES	P-Value	0.49	0.18
	Chi-Squared	3.29	4.85
	DF	3	3
UNOILED SITES	P-Value	6.24e-03	1.41e-04
	Chi-Squared	12.36	20.39
	DF	3	3

There was a total of 29 juvenile *Ischnodemus* insects collected in the oiled sites and 89 juveniles collected in the unoiled sites. The mean weight of the juvenile cordgrass bugs in oiled sites was 0.11 mg and in unoiled sites 0.09 mg, which showed a significant difference (p=0.39, f=0.75, df=1). The mean length in oiled sites was 2.17 mm and in unoiled sites 2.17 mm, resulting in a significant difference (p=0.98, f=0.001, df=1). There was no significant difference found between weight or length of the juveniles and the oiled sites. The ANOVA test did however show a significance for both weight (p=5.23e-02, f=2.68, df=3) and length (p=9.17e-05,

f=8.01, df=3) in unoiled sites. The Kruskal-Wallis test had very similar results to the ANOVA test. The difference seemed to lie between C4-C3 for the weight in unoiled sites and C4-C3, C4-C2, C4-C5 for the length.

Crematogaster

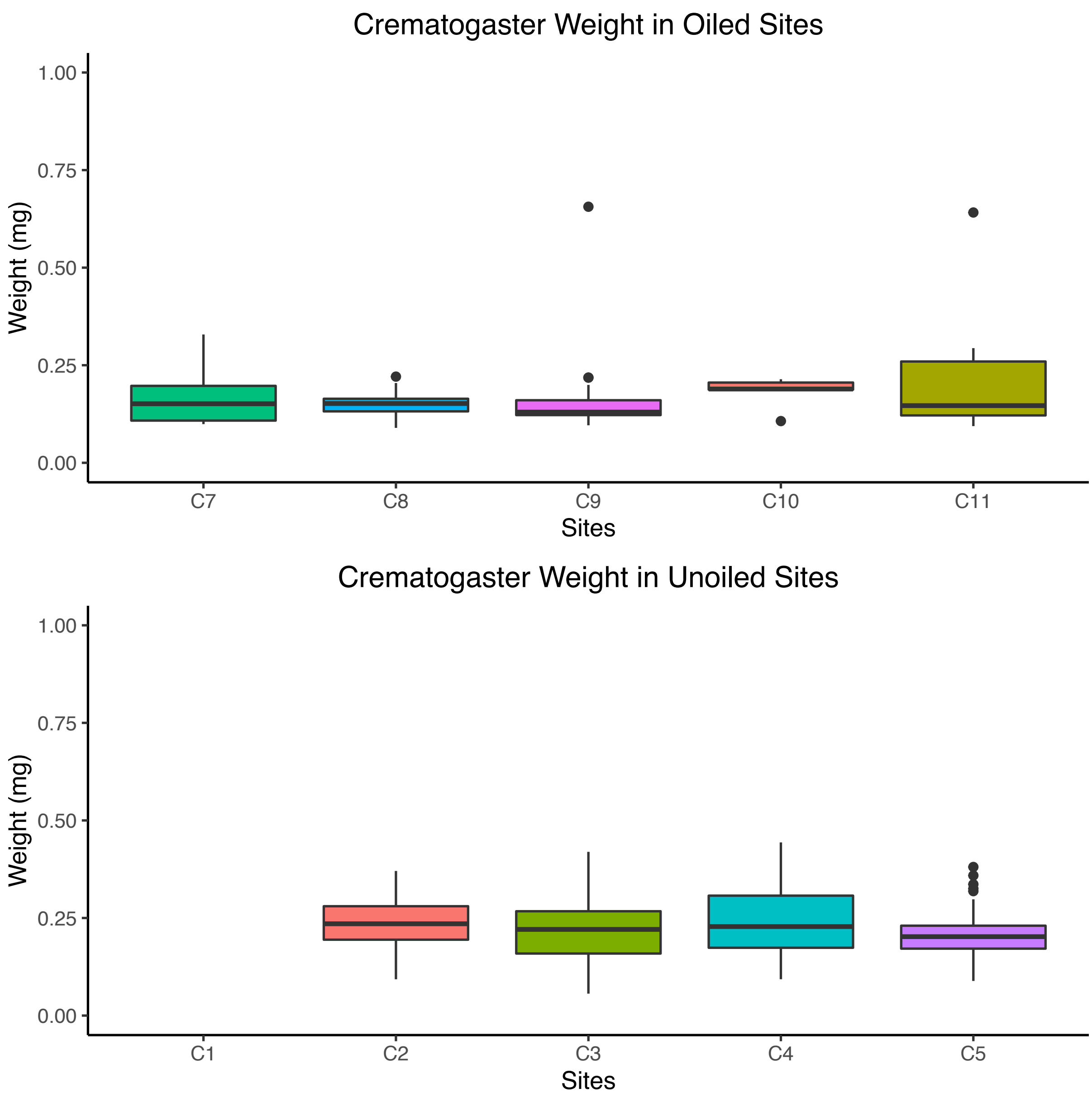


Figure 5.3. Crematogaster weights amongst oiled and unoiled sites.

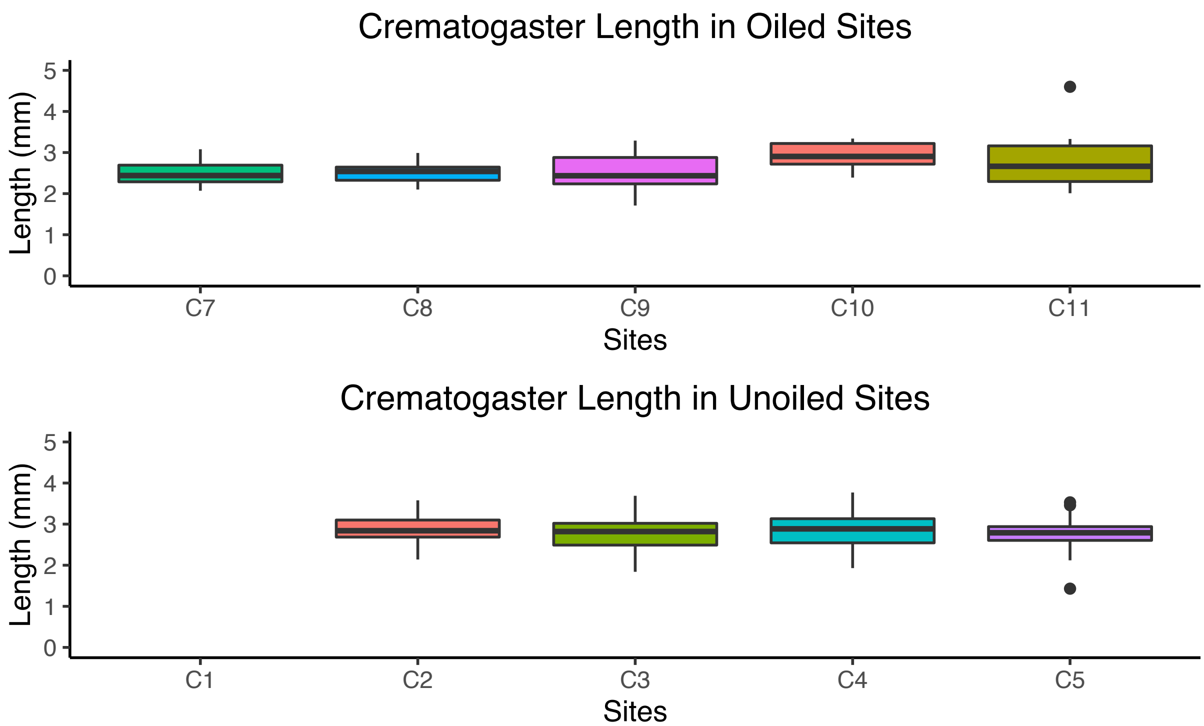


Figure 5.4. Crematogaster lengths amongst oiled and unoiled sites.

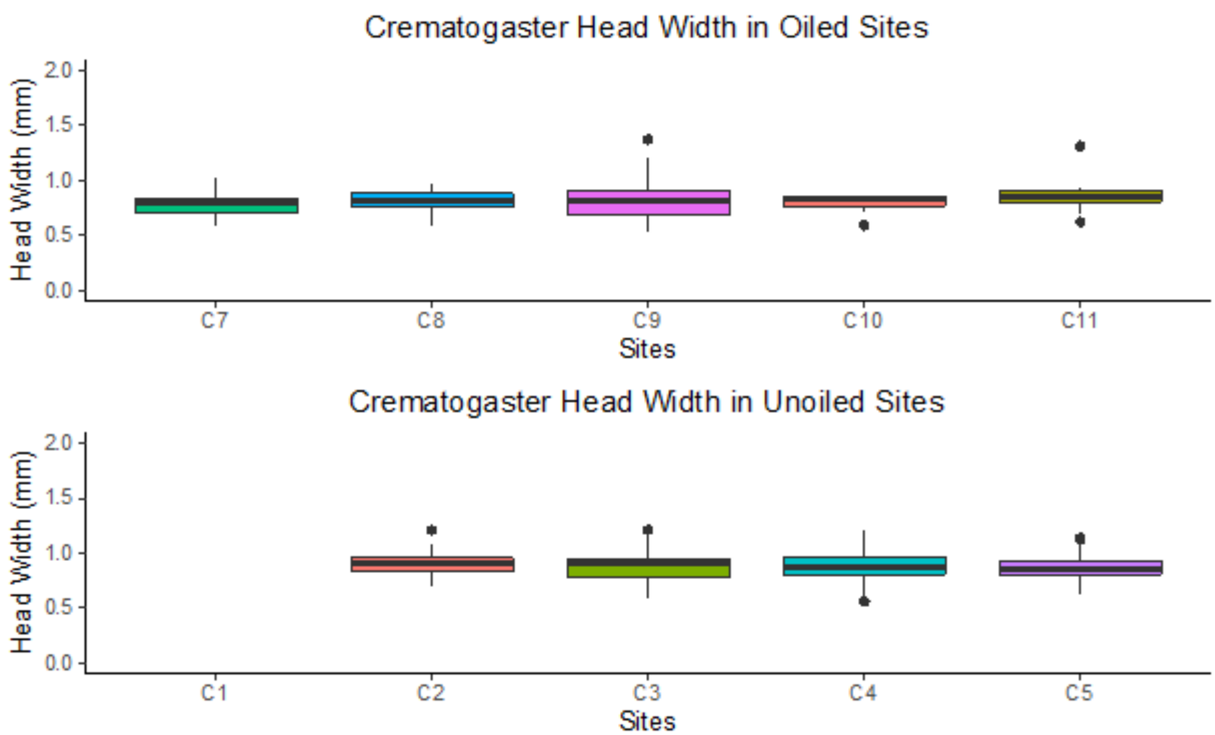


Figure 5.5. Crematogaster head widths amongst oiled and unoiled sites.

Table 4.7. Crematogaster oiled and unoiled mean table results.

		WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)	ABUNDANCE
OILED SITES	C7	0.17	2.49	0.79	24
	C8	0.15	2.52	0.80	19
	C9	0.17	2.50	0.84	16
	C10	0.19	2.92	0.79	8
	C11	0.22	2.83	0.87	10
UNOILED SITES	C1	0.16	2.46	0.85	4
	C2	0.24	2.87	0.90	39
	C3	0.22	2.78	0.88	89
	C4	0.25	2.83	0.88	84
	C5	0.20	2.78	0.87	131

Table 4.8. Crematogaster ANOVA test results for overall sites, oiled sites, and unoiled sites.

		WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)
OVERALL SITES	P-Value	1.79e-05	1.10e-05	2.37e-05
	F-Value	18.83	19.8	18.27
	DF	1	1	1
OILED SITES	P-Value	4.98e-01	2.51e-02	0.643
	F-Value	0.851	2.97	0.629
	DF	4	4	4
UNOILED SITES	P-Value	1.92e-03	0.198	0.594
	F-Value	4.35	1.51	0.697
	DF	4	4	4

Table 4.9. Crematogaster Kruskal-Wallis results for overall sites, oiled sites, and unoiled sites.

		WEIGHT (MG)	LENGTH (MM)	HEAD WIDTH (MM)
OVERALL SITES	P-Value	6.52e-11	8.90e-07	5.07e-06
	Chi-Squared	42.66	24.15	20.182
	DF	1	1	1
OILED SITES	P-Value	4.23e-01	6.60e-02	0.79
	Chi-Squared	3.88	8.81	1.69
	DF	4	4	4
UNOILED SITES	P-Value	3.44e-03	0.3108	0.59
	Chi-Squared	15.7	4.78	2.81
	DF	4	4	4

There were 109 individuals of *Crematogaster* in oiled sites and 347 in unoiled sites. The mean weight of the ants in oiled sites was 0.17 mg and in unoiled sites 0.22 mg, which showed a significant difference (p=1.79e-05, f=18.83, df=1). The mean length in oiled sites was 2.59 mm and in unoiled sites 2.80 mm, resulting in a significant difference (p=1.10e-05, f=19.3, df=1). The mean head width of the ants in oiled sites was 0.81 mm and in unoiled sites was 0.88 mm, also resulting in a significant difference (p=2.37e-05, f=18.27, df=1). In the oiled sites the ants head width and weight showed no significant difference. There was however significance in the length of ants at oiled sites (p=2.51e-02, f=2.97, df=4). There was a significant difference in weight between the unoiled sites (p=1.92e-03, f=4.35, df=4). The difference between weight and

unoiled sites lies between C5-C4 as C5 is far more degraded than C4, a nearly pristine saltmarsh. The Kruskal-Wallis test showed remarkably similar significance to the ANOVA tests.

DISCUSSION

The *Ischnodemus* insects were slenderer after the hurricane which could be because they were stressed. There were no differences in length but they are less robust (skinnier). There is evidence that the hurricane stressed the system, because seasonally there is no difference among the *Ischnodemus*. The changes in food quality amongst the seasons is not what is stressing the *Ischnodemus* insects, the hurricane is their biggest stressor. Further, apart from the adults, the juveniles are both shorter and lighter after the hurricane. Indicating either delayed development and/ or lower acceptable food resources. Juveniles were differentially impacted by the hurricane compared with the adults. Juveniles cannot fly and adults can, so at these sites *Ischnodemus* adult insects could be emigrating in whereas the juveniles can only crawl to new plants or move unintentionally on the wind. The adults have the advantage they can move around to get proper nutrition while juveniles cannot. *Ischnodemus* have a much higher turnover rate. *Crematogaster* likely have longer lifespans compared to *Ischnodemus.* These ants are sensitive to shifts in resources, they can change what they eat which is why they were not impacted by the hurricane. The ants were impacted by the seasons not the hurricanes. Both insects in this study showed a significant difference between the unoiled sites and oiled sites. Both species weight, length, and head width for ants were larger in the unoiled sites compared to the oiled sites. Insect populations that were affected by oil spills and tropical cyclones are better indicators of marsh stress and should be studied continuously.

For most plant species, high salinity conditions, such as that which can occur during and immediately after a hurricane, can result in decreased growth and increased mortality (Touchette et al 2009). Pivovaroff and colleagues' study (2015) suggests plant species respond to environmental stressors by making physiological adjustments. For example, *Spartina*

alterniflora, use salt-tolerance mechanisms such as osmotic adjustment and increased tissue rigidity during high salinity conditions (Touchette et al 2009), whereas *Juncus roemerianus* uses salt-avoidance mechanisms through decreased stomatal conductance during elevated salinity conditions (Touchette et al 2009). If *Spartina alterniflora* tissues stiffen when salinity conditions increase it may minimize juvenile *Ischnodemus* ability to feed on, making them significantly smaller after the hurricane. Hurricanes can also damage mangroves, such as *Avicennia germians,* resulting in loss of foliage, broken trunks, and even uprooting (Wang et al 2016) similar uprooting happens to *Spartina*. Damage from environmental stressors may vary depending on plant species, locations, intensity of stressors, and sediment structure (Wang et al 2016). Wang (2016) also suggests that several of species, not just plants, decrease due to damage and change of habitat following a disturbance. However as seen in these results some species are able to adapt to the disturbance. For example, the ant's weight, length, and head width before and after the hurricane did not show any significant difference suggesting they were able to sustain their population during and after the hurricane and change their food source to what was available.

Oil spills can directly cause PAH (polycyclic aromatic hydrocarbons) pollution (Jajoo et al 2014). Bam and Hooper-Bui (2018) indicated the higher total sediment PAH concentrations were likely due to Hurricane Isaac redistributing DWH (Deepwater Horizon) oil. PAHs are a very toxic and persistent environmental pollutant which can accumulate in soil and affect growth of plants (Jajoo et al 2014). Turner et al (2014) found that PAHs increased over the first 2.5 years after the DWH oil spill. Pennings et al (2014) found that in some oiled zones plants were not affected while arthropod densities were reduced. Our study only looked at two insect species >2 years after oil spill and when there are hundreds more in the terrestrial arthropod community, continuing to study the impacts of oil spills and tropical cyclones on these other species can give

more information on the recovery and succession of the marsh ecosystems. Studying marshes that are dominated by different plant species, for example, *Spartina alterniflora* are resilient against oil exposure while other plant species may not be (Pennings et al 2014). Our study also lacks data on stable isotopes, which limits our results. Studies including stable isotopes analysis can explore food resources across diverse insect species, trophic and species level interactions, movement, and dispersal of insects (Hyodo 2015).

These results suggest that DWH oil and Hurricane Isaac both directly and indirectly impacted an herbivore and an omnivore population in the Louisiana salt marsh. This study only looked at a little over a year after Hurricane Isaac, further studies should look at the long-term impacts of oil and tropical cyclones on terrestrial arthropod communities. This short-term data shows that while numbers decreased weight, length, and head width for the ants were not all affected suggesting that long-term studies are needed to completely understand the recovery capability after such disturbances on the ecosystems.

APPENDIX A. INSECT INDEX

Order: Diptera
Family: *Ulidiidae*
Genus: ***Chaetopsis***

- Markings on wings (three stripes)
- Stem-boring larvae

Order: Diptera
Family: *Ulidiidae*
Genus: ***Chaetopsis apicalis***

- Distinct markings on the tips of wings only

https://gcelter.marsci.uga.edu/public/app/species_details.asp?id=Chaetopsis%20apicalis

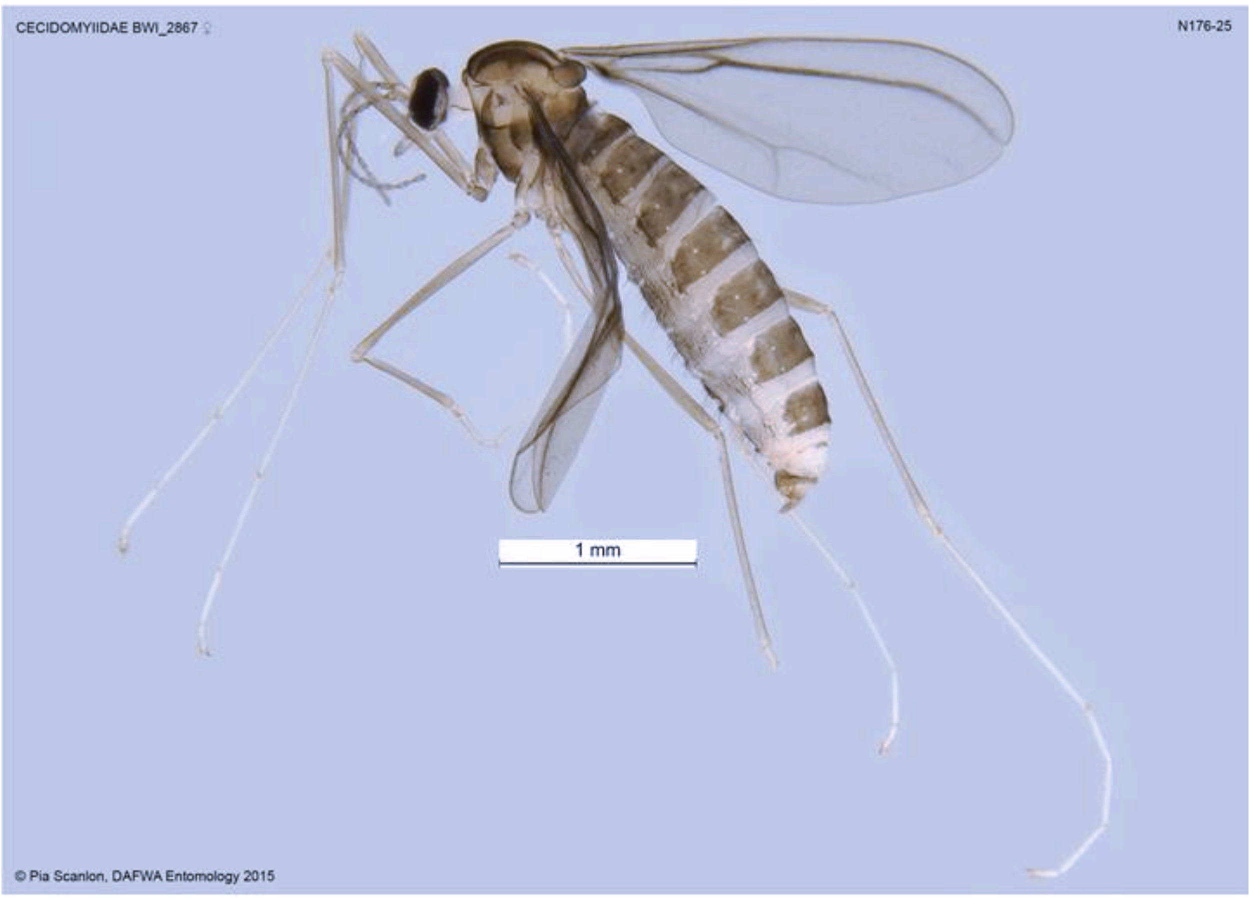
Order: Diptera
Family: *Chloropidae*
Genus: ***Incertella***

- Common name: grass fly
- Yellow and dark brown striped bodies
- Large red eyes

https://bugguide.net/node/view/926499

Order: Diptera
Family: ***Cecidomyiidae***

- Common name: midges
- Highly reduced wing venation (~3 veins), long moniliform antennae
- Stem-boring larvae
- Wings shorter than body
- Different from mosquitos which wings are longer than body
- Midge's also have feathered antennaes
- Mosquitos are larger
- Midges do not have a proboscis long needle-like mouthpart



https://www.padil.gov.au/barrow-island/pest/main/143157/51915

Order: Diptera
Family: *Calliphoridae*
Genus: ***Cochliomyia sp.***

- Hairy fly
- Large
- Metallic/ shiny bodies

https://entnemdept.ufl.edu/creatures/livestock/secondary_screwworm.htm

Order: Diptera
Family: *Tephritidae*
Genus: ***Neotephritis finalis***

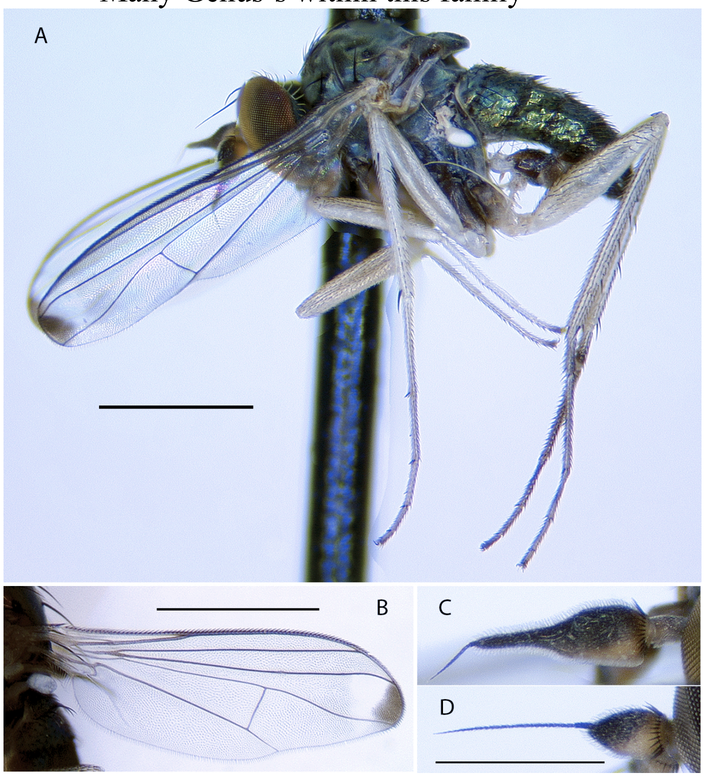
- White spotted wings

https://bugguide.net/node/view/833904/bgima

Order: Diptera

Family: ***Dolichopodidae***

- Common name: long-legged flies
- Long legs; large body, usually metallic
- Stem-boring larvae
- Many Genus's within this family



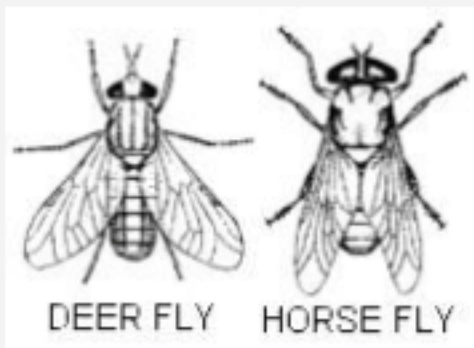
https://zookeys.pensoft.net/article/55192/list/7/

Order: Diptera
Family: *Tabanidae*
Deer Flies aka “true” flies

- smaller with dark bands across the wings and colored eyes

Horse flies

- usually have clear or solidly colored wings and brightly colored eyes
- unless it is the all black horse fly



Deer Fly and Horse Fly


https://nwdistrict.ifas.ufl.edu/nat/2019/06/07/yellow-flies-deer-flies-and-horse-flies-oh-my/

Order: Neuroptera
Family: *Chrysopidae*
Genus: ***Chrysoperla rufilabris***

- Common name: Lacewing
- Net-winged insects
- Long thin cylindrical body
- Large wings
- Large eyes

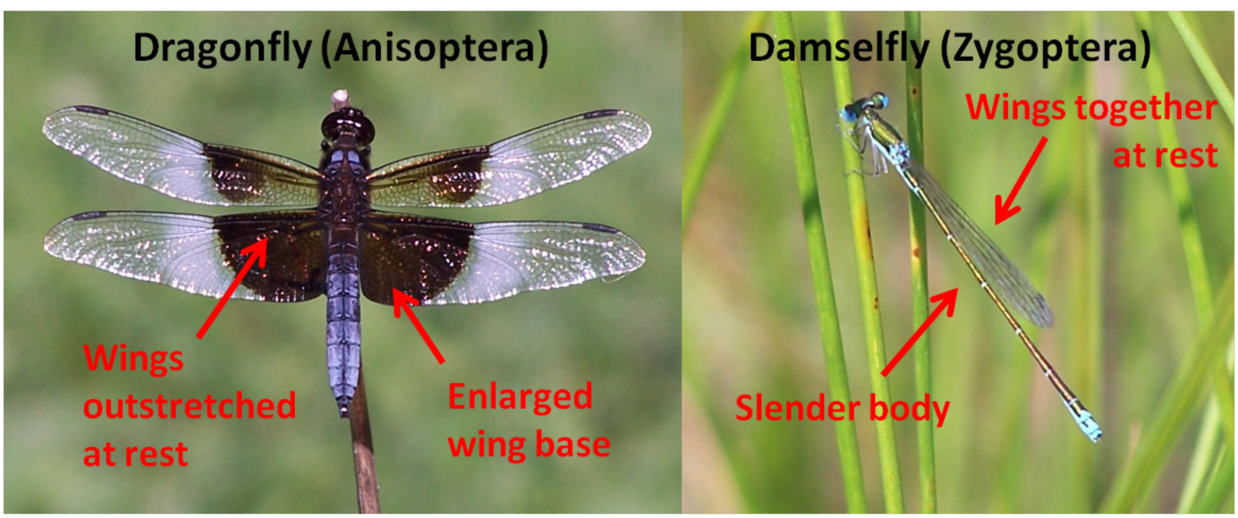
https://bugguide.net/node/view/1183762

Order: Odonata
Damselfly

- Damselfly with the blue tipped tail—Ischura ramburii
- Slender bodies

Dragonfly

- Larger bodies



https://katatrepsis.com/2011/08/14/dragonflies-vs-damselflies/

Order: Coleoptera
Family: *Coccinellidae*
Genus: ***Naemia seriata***

- Predacious
- Color fades in alcohol
- Different from a ladybug
- Ladybug Genus is **Coccinella**

http://nathistoc.bio.uci.edu/coleopt/Naemia.htm

Order: Coleoptera
Family: *Curculioniidae*

- Common name: **Weevil**
- A well-developed downward-curved snout (rostrum)
- Antennae elbowed, clubbed

https://www.quikkill.com/rice-weevils

Order: Coleoptera
Family: *Chrysomelidae*
Pigweed Flea Beetle

- Red and black head
- The red shield-like pronotum has a black dot in the center
- The wing coverings have four yellow vertical lines

https://bugguide.net/node/view/64649

Order: Coleoptera
Family: *Phalacridae*
Genus: ***Stilbus***

- Spherical-oval brownish body, with a yellowish-reddish apex
- Head and pronotum are dark

https://www.kerbtier.de/cgi-bin/enFSearch.cgi?Fam=Phalacridae

Order: Thysanoptera
Family: ***Thripidae***

- Common name: Thrips
- Elongate bodies, wings fringed with tiny hairs
- Small ~1mm

Order: Hemiptera
Family: *Blissidae*
Genus: ***Ischnodemus badius***

- Common name: Cordgrass bugs
- Long brown bodies
- Juveniles are bright orange and brown
- Tips of antennae's and legs are a light brown

Order: Hemiptera
Family: *Miridae*
Genus: ***Tytthus***

- Long, fragile legs and antennae
- Long piercing mouthparts

https://www.inaturalist.org/taxa/330153-Tytthus-parviceps/browse_photos

Order: Hemiptera
Family: ***Cicadellidae***

- Common name: Leaf Hoppers
- Triangulated head and rows of spines on tibias
- Adults have green wing coverings
- The nymphs will have no color and will be smaller

Order: Hemiptera
Family: *Miridae*
Genus: ***Trigonotylus sp.***

- Common name: Seed bugs
- Slender body, elongated abdomen; long fragile legs and antennae; piercing mouthparts; yellow-green coloration
- May lose color in alcohol
- Two dorsal orange stripes

Order: Hemiptera
Family: *Pentatomidae*

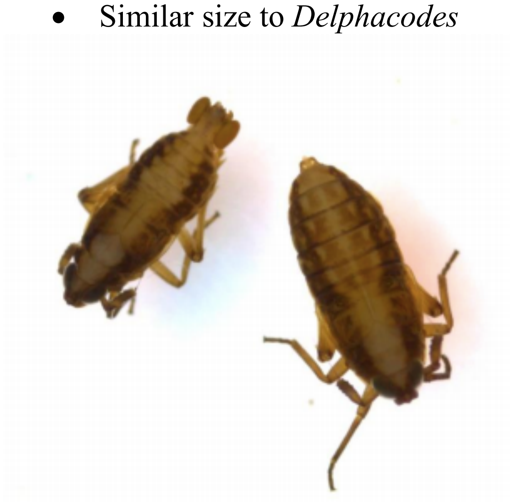
- Common name: Stink bug
- Top- ***Chlorochroa senilis***
- Bottom- ***Oebalus pugnax***

Order: Hemiptera
Family: *Delphacidae*
Genus: ***Delphacodes***

- Common name: Planthoppers
- Often mottled coloration on dorsal abdomen
- Dark genital cap on males

Order: Hemiptera
Family: *Delphacidae*
Genus: ***Megamealus***

- Common name: Planthoppers
- Usually dark brown with lighter stripe down back
- Rust colored genital cap on males
- Similar size to *Delphacodes*



Difference between *Delphacodes* and *Megamealus*

Order: Hemiptera
Family: *Delphacidae*
Genus: ***Prokelisia***

- Most abundant herbivore
- Lightly colored

https://bugguide.net/node/view/1451266

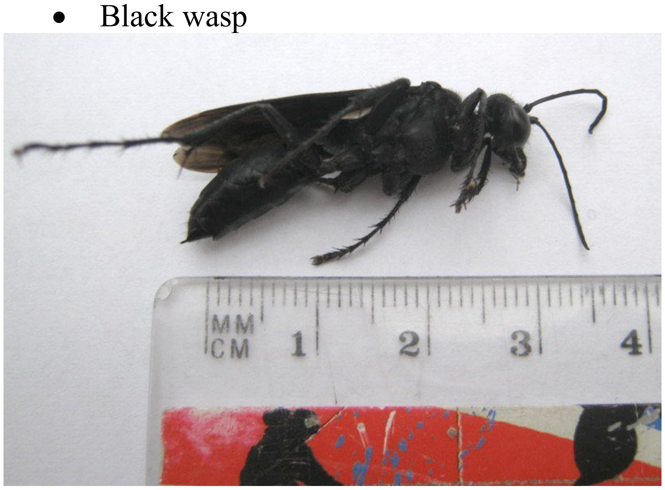
Order: Hymenoptera
Family: ***Braconidae***
Scientific name: *Doryctobracon areolatus*

- Wasp
- Orange coloring
- Long antennae
- Small waist

https://entnemdept.ufl.edu/creatures/beneficial/wasps/doryctobracon_areolatus.htm

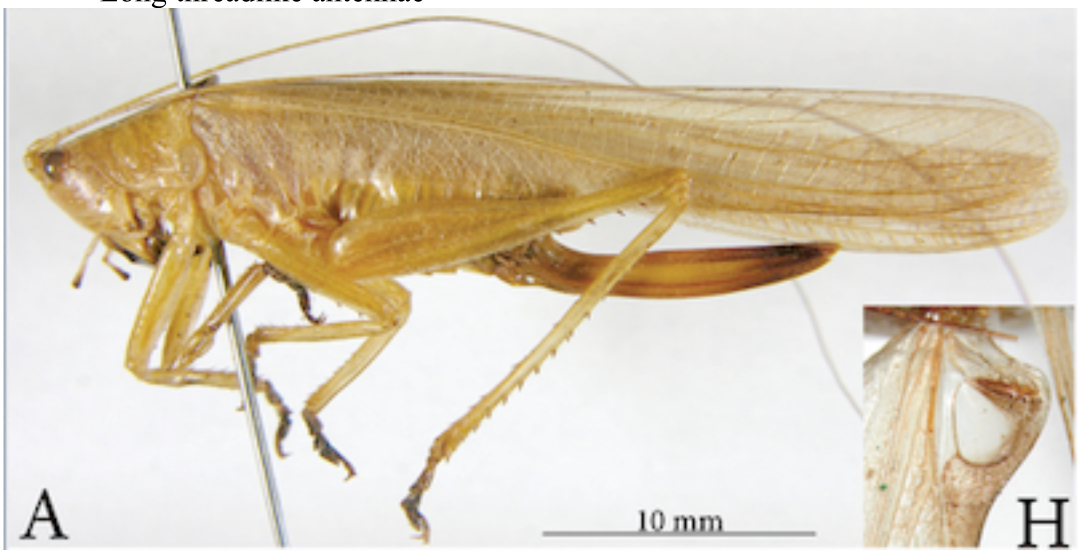
Order: Hymenoptera
Family: *Sphecidae*
Genus: ***Sphex Linnaeus***

- Black wasp



Order: Orthoptera
Family: ***Tettigoniidae***

- Common name: Long Horned Grasshoppers or Katydids
- Long threadlike antennae



https://evolsyst.pensoft.net/article/60525/

Order: Hymenoptera
Family: *Formicidae*
Genus: ***Crematogaster***

- Heart-shaped abdomen
- 11 segmented antennae with 3 segmented antennal clubs

Order: Hymenoptera
Family: *Formicidae*
Genus: ***Pseudomyrmex***

- Large compound eyes
- Bright orange yellow color
- Slender ants

https://en.wikipedia.org/wiki/Pseudomyrmex_apache

Order: Hymenoptera
Family: *Formicidae*
Pavement Ants

- Scientific name: *Tetramorium bicarinatum*
- 2-segmented petiole
- 12-segmented antennae with a 3-segmented club
- Ridge at the posterior border of clypeus
- Body heavily sculptured
- Small
- Light tan to brown

References

Bugfinder. Insect, Bugs and Spider Identification - North America. (n.d.). https://www.insectidentification.org/bugfinder-start.php.

INaturalist. iNaturalist. (n.d.). Retrieved June 13, 2022, from https://www.inaturalist.org/.

Phylum arthropoda - arthropods. BugGuide.Net. (n.d.). https://bugguide.net/node/view/3/bgpage

APPENDIX B. *ISCHNODEMUS* ANALYSIS AND GRAPHS RSTUDIO

```
```{r}

isch <- read.csv("Ischnodemus_seasons.csv", header = TRUE)

library(ggplot2)

summary(isch)

ischbefore <- subset(isch, Time=="Before",

select=Season:Month)

# i took the original dataset and subsetted it to Before and After to compare the two

ischafter <- subset(isch, Time=="After",

                    select=Season:Month)

summary(ischafter)

summary(ischbefore)

data.frame(table(ischbefore$Site))

data.frame(table(ischbefore$Season))

data.frame(table(isch$Time))

data.frame(table(isch$Site))

data.frame(table(isch$Season))

data.frame(table(ischafter$Site))

data.frame(table(ischafter$Season))

aggregate(isch$Weight..mg., list(isch$Site), FUN = mean)

aggregate(isch$Length..mm., list(isch$Site), FUN = mean)

aggregate(isch$Weight..mg., list(isch$Time), FUN = mean)

aggregate(isch$Length..mm., list(isch$Time), FUN = mean)
```
```

````
aggregate(isch$Weight..mg., list(isch$Season), FUN = mean)

aggregate(isch$Length..mm., list(isch$Season), FUN = mean)

aggregate(ischbefore$Weight..mg., list(ischbefore$Site), FUN = mean)

aggregate(ischbefore$Length..mm., list(ischbefore$Site), FUN = mean)

aggregate(ischbefore$Weight..mg., list(ischbefore$Season), FUN = mean)

aggregate(ischbefore$Length..mm., list(ischbefore$Season), FUN = mean)

aggregate(ischafter$Weight..mg., list(ischafter$Site), FUN = mean)

aggregate(ischafter$Length..mm., list(ischafter$Site), FUN = mean)

aggregate(ischafter$Weight..mg., list(ischafter$Season), FUN = mean)

aggregate(ischafter$Length..mm., list(ischafter$Season), FUN = mean)

```

ANOVA and Tukey Test

```{r}

anovtime<- aov(Weight..mg.~ Time, data = isch)

summary(anovtime)

anovtime2<- aov(Length..mm.~ Time, data = isch)

summary(anovtime2)

anova1<- aov(Weight..mg.~ Season, data = ischbefore)

summary(anova1)

anova2<- aov(Weight..mg.~ Season, data = ischafter)

summary(anova2)

TukeyHSD(anova2, conf.level = 0.95)
````

```
tuk.tab <- TukeyHSD(anova2, conf.level = 0.95)
anova3<- aov(Length..mm.~ Season, data = ischbefore)
anova3
summary(anova3)
anova4<- aov(Length..mm.~ Season, data = ischafter)
summary(anova4)
TukeyHSD(anova4, conf.level = 0.95)
tuk.tab4 <- TukeyHSD(anova4, conf.level = 0.95)
anovasite1<- aov(Weight..mg.~ Site, data = ischbefore)
summary(anovasite1)
anovasite2<- aov(Length..mm.~ Site, data = ischbefore)
summary(anovasite2)
anovasite3<- aov(Weight..mg.~ Site, data = ischafter)
summary(anovasite3)
TukeyHSD(anovasite3, conf.level = 0.95)
tuk.tabsite3 <- TukeyHSD(anovasite3, conf.level = 0.95)
anovasite4<- aov(Length..mm.~ Site, data = ischafter)
summary(anovasite4)
ao1 <- aov(Weight..mg.~ Site, data = isch)
summary(ao1)
TukeyHSD(ao1, conf.level = 0.95)
tuk.tabao1 <- TukeyHSD(ao1, conf.level = 0.95)
ao2 <- aov(Length..mm.~ Site, data = isch)
```

```
summary(ao2)

ao3 <- aov(Weight..mg.~ Season, data = isch)

summary(ao3)

TukeyHSD(ao3, conf.level = 0.95)

tuk.tabao3 <- TukeyHSD(ao3, conf.level = 0.95)

ao4 <- aov(Length..mm.~ Season, data = isch)

summary(ao4)

TukeyHSD(ao4, conf.level = 0.95)

tuk.tabao4 <- TukeyHSD(ao4, conf.level = 0.95)
```

Kruskal-Wallis and Bonferroni Test

```{r}
kruskal.test(Weight..mg. ~ Season, data = isch)

kruskal.test(Length..mm. ~ Season, data=isch)

kruskal.test(Weight..mg. ~ Time, data=isch)

kruskal.test(Length..mm. ~ Time, data=isch)

kruskal.test(Weight..mg. ~ Site, data=isch)

kruskal.test(Length..mm. ~ Site, data=isch)

pairwise.t.test(isch$Weight..mg., isch$Season, p.adjust.method="bonferroni")

pairwise.t.test(isch$Length..mm., isch$Season, p.adjust.method="bonferroni")

pairwise.t.test(isch$Weight..mg., isch$Time, p.adjust.method="bonferroni")

pairwise.t.test(isch$Length..mm., isch$Time, p.adjust.method="bonferroni")

pairwise.t.test(isch$Weight..mg., isch$Site, p.adjust.method="bonferroni")
```

```
pairwise.t.test(isch$Length..mm., isch$Site, p.adjust.method="bonferroni")
kruskal.test(Weight..mg. ~ Season, data = ischbefore)
kruskal.test(Length..mm. ~ Season, data=ischbefore)
kruskal.test(Weight..mg. ~ Site, data=ischbefore)
kruskal.test(Length..mm. ~ Site, data=ischbefore)
pairwise.t.test(ischbefore$Weight..mg., ischbefore$Season, p.adjust.method="bonferroni")
pairwise.t.test(ischbefore$Length..mm., ischbefore$Season, p.adjust.method="bonferroni")
pairwise.t.test(ischbefore$Weight..mg., ischbefore$Site, p.adjust.method="bonferroni")
pairwise.t.test(ischbefore$Length..mm., ischbefore$Site, p.adjust.method="bonferroni")
kruskal.test(Weight..mg. ~ Season, data = ischafter)
kruskal.test(Length..mm. ~ Season, data=ischafter)
kruskal.test(Weight..mg. ~ Site, data=ischafter)
kruskal.test(Length..mm. ~ Site, data=ischafter)
pairwise.t.test(ischafter$Weight..mg., ischafter$Season, p.adjust.method="bonferroni")
pairwise.t.test(ischafter$Length..mm., ischafter$Season, p.adjust.method="bonferroni")
pairwise.t.test(ischafter$Weight..mg., ischafter$Site, p.adjust.method="bonferroni")
pairwise.t.test(ischafter$Length..mm., ischafter$Site, p.adjust.method="bonferroni")
```

Ischnodemus Graphs

```{r}
isch <- read.csv("Ischnodemus_seasons.csv", header = TRUE)
isch
library(ggplot2)
```

```
summary(isch)
ischbefore <- subset(isch, Time=="Before",
select=Season:Month)
ischbefore
# i took the original dataset and subsetted it to Before and After to compare the two
ischafter <- subset(isch, Time=="After",
                    select=Season:Month)
ischafter
summary(ischbefore)
bg1 <- ggplot(ischbefore, aes(x = Season, y = Weight..mg., fill=Season)) +
  ylim(0,4.0) +
  scale_x_discrete(limits=c("Spring","Summer","Fall","Winter")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Weight by Season", subtitle ="Before Hurricane Isaac",
x="Season", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bg1
bg2 <- ggplot(ischafter, aes(x = Season, y = Weight..mg., fill=Season)) +
  ylim(0,4.0) +
  scale_x_discrete(limits=c("Spring","Summer","Fall","Winter")) +
```

```
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Weight by Season", subtitle="After Hurricane Isaac", x="Season",
y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bg2
bp1 <- ggplot(ischbefore, aes(x = Season, y = Length..mm., fill=Season)) +
  ylim(0,10) +
  scale_x_discrete(limits=c("Spring","Summer","Fall","Winter")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Length by Season", subtitle ="Before Hurricane Isaac",
x="Season", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp1
bp2 <- ggplot(ischafter, aes(x = Season, y = Length..mm., fill=Season)) +
  ylim(0,10) +
  scale_x_discrete(limits=c("Spring","Summer","Fall","Winter")) +
  geom_boxplot() +
```

```
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Length by Season", subtitle="After Hurricane Isaac", x="Season",
y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp2
weightbva<- (bg1 + bg2)/ (bp5 +bp6)
weightbva
ggsave("Isch-Weight-B-A.pdf", weightbva)
boxplotbeforevsafter <- ggplot(isch, aes(x = Time, y = Weight..mg., fill=Time)) +
  geom_boxplot() +
  stat_summary(fun=mean) +
  labs(title="Weight of Ischnodemus", subtitle= "Before vs. After Hurricane Isaac",
x="Time", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title = element_text(hjust = 0.5),plot.subtitle=element_text(hjust=0.5)) +
  scale_x_discrete(limits=c("Before", "After")) +
  theme(legend.position = "none")
boxplotbeforevsafter
newischbp <- ggplot(isch, aes(x = Time, y = Length..mm., fill=Time)) +
  geom_boxplot() +
  stat_summary(fun=mean) +
```

```
  labs(title="Length of Ischnodemus", subtitle = "Before vs. After Hurricane Isaac",
x="Time", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title = element_text(hjust = 0.5),plot.subtitle=element_text(hjust=0.5)) +
  scale_x_discrete(limits=c("Before", "After")) +
  theme(legend.position = "none")
newischbp
library(patchwork)
overall<- boxplotbeforevsafter + newischbp
bp3 <- ggplot(ischbefore, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,10) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11"))
+
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Length by Site", subtitle="Before Hurricane Isaac", x="Site", y =
"Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp3
bp4 <- ggplot(ischafter, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,10) +
```

```
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11"))
+
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Length by Site", subtitle="After Hurricane Isaac", x="Site", y =
"Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp4
bp5 <- ggplot(ischbefore, aes(x = Site, y = Weight..mg., fill=Site)) +
  ylim(0,4) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11"))
+
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Weight by Site", subtitle="Before Hurricane Isaac", x="Site", y =
"Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp5
bp6 <- ggplot(ischafter, aes(x = Site, y = Weight..mg., fill=Site)) +
```

````
  ylim(0,4) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Weight by Site", subtitle="After Hurricane Isaac", x="Site", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp6
lengthbva<- (bp1 + bp1)/ (bp3 +bp4)
lengthbva
```
````
````

APPENDIX C. JUVENILE *ISCHNODEMUS* ANALYSIS AND GRAPHS RSTUDIO

```
```{r}

juve<- read.csv("Juveniles.csv", header = TRUE)

summary(juve)

juvebefore <- subset(juve, Time=="Before",

                 select=Season:Month)

juveafter <- subset(juve, Time=="After",

                 select=Season:Month)

summary(juvebefore)

summary(juveafter)

data.frame(table(juve$Time))

data.frame(table(juve$Season))

data.frame(table(juvebefore$Site))

data.frame(table(juvebefore$Season))

data.frame(table(juveafter$Site))

data.frame(table(juveafter$Season))

aggregate(juve$Weight, list(juve$Time), FUN = mean)

aggregate(juve$Length, list(juve$Time), FUN = mean)

aggregate(juve$Weight, list(juve$Season), FUN = mean)

aggregate(juve$Length, list(juve$Season), FUN = mean)

aggregate(juvebefore$Weight, list(juvebefore$Site), FUN = mean)

aggregate(juvebefore$Length, list(juvebefore$Site), FUN = mean)

aggregate(juvebefore$Weight, list(juvebefore$Season), FUN = mean)
```
```

```
aggregate(juvebefore$Length, list(juvebefore$Season), FUN = mean)

aggregate(juveafter$Weight, list(juveafter$Site), FUN = mean)

aggregate(juveafter$Length, list(juveafter$Site), FUN = mean)

aggregate(juveafter$Weight, list(juveafter$Season), FUN = mean)

aggregate(juveafter$Length, list(juveafter$Season), FUN = mean)
```

ANOVA Test

```{r}
anovtimej<- aov(Weight~ Time, data = juve)

summary(anovtimej)

anovtimej2<- aov(Length~ Time, data = juve)

summary(anovtimej2)

aovjuv1 <-aov(Weight~ Season, data = juvebefore)

summary(aovjuv1)

aovjuv2 <- aov(Weight ~ Site, data = juvebefore)

summary(aovjuv2)

aovjuv3 <- aov(Length ~ Season, data = juvebefore)

summary(aovjuv3)

aovjuv4 <- aov(Length ~ Site, data = juvebefore)

summary(aovjuv4)

aovjuv5 <-aov(Weight~ Season, data = juveafter)

summary(aovjuv5)

aovjuv6 <-aov(Weight~ Site, data = juveafter)
```

summary(aovjuv6)

aovjuv7 <-aov(Length ~ Season, data = juveafter)

summary(aovjuv7)

aovjuv8 <-aov(Length~ Site, data = juveafter)

summary(aovjuv8)

aovjuvall1<- aov(Weight ~ Season, data = juve)

summary(aovjuvall1)

aovjuvall2<- aov(Weight ~ Site, data = juve)

summary(aovjuvall2)

aovjuvall3<- aov(Length ~ Season, data = juve)

summary(aovjuvall3)

aovjuvall4<- aov(Length ~ Site, data = juve)

summary(aovjuvall4)

aovjuvall5<- aov(Length ~ Time, data = juve)

summary(aovjuvall5)

aovjuvall6<- aov(Weight ~ Time, data = juve)

summary(aovjuvall6)

```

Kruskal-Wallis and Bonferroni Test

```{r}

kruskal.test(Weight ~ Season, data = juve)

kruskal.test(Length~ Season, data=juve)

kruskal.test(Weight ~ Time, data = juve)

```
kruskal.test(Length ~ Time, data=juve)

kruskal.test(Weight ~ Site, data=juve)

kruskal.test(Length ~ Site, data=juve)

pairwise.t.test(juve$Weight, juve$Season, p.adjust.method="bonferroni")

pairwise.t.test(juve$Length, juve$Season, p.adjust.method="bonferroni")

pairwise.t.test(juve$Weight, juve$Time, p.adjust.method="bonferroni")

pairwise.t.test(juve$Length, juve$Time, p.adjust.method="bonferroni")

pairwise.t.test(juve$Weight, juve$Site, p.adjust.method="bonferroni")

pairwise.t.test(juve$Length, juve$Site, p.adjust.method="bonferroni")

kruskal.test(Weight ~ Season, data = juvebefore)

kruskal.test(Length~ Season, data=juvebefore)

kruskal.test(Weight ~ Site, data=juvebefore)

kruskal.test(Length ~ Site, data=juvebefore)

pairwise.t.test(juvebefore$Weight, juvebefore$Season, p.adjust.method="bonferroni")

pairwise.t.test(juvebefore$Length, juvebefore$Season, p.adjust.method="bonferroni")

pairwise.t.test(juvebefore$Weight, juvebefore$Site, p.adjust.method="bonferroni")

pairwise.t.test(juvebefore$Length, juvebefore$Site, p.adjust.method="bonferroni")

kruskal.test(Weight ~ Season, data = juveafter)

kruskal.test(Length~ Season, data=juveafter)

kruskal.test(Weight ~ Site, data=juveafter)

kruskal.test(Length ~ Site, data=juveafter)

pairwise.t.test(juveafter$Weight, juveafter$Season, p.adjust.method="bonferroni")

pairwise.t.test(juveafter$Length, juveafter$Season, p.adjust.method="bonferroni")
```

~~~
pairwise.t.test(juveafter$Weight, juveafter$Site, p.adjust.method="bonferroni")
pairwise.t.test(juveafter$Length, juveafter$Site, p.adjust.method="bonferroni")
```
~~~

Juvenile *Ischnodemus* Graphs

~~~
```{r}
bpjuv1 <- ggplot(juvebefore, aes(x = Site, y = Weight, fill=Site)) +
  ylim(0,0.75) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Weight by Site", subtitle="Before Hurricane Isaac",x="Site",
y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpjuv1
bpjuv2 <- ggplot(juveafter, aes(x = Site, y = Weight, fill=Site)) +
  ylim(0,0.75) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Weight by Site", subtitle="After Hurricane Isaac",x="Site", y
= "Length (mm)") +
~~~

```
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpjuv2
bpjuvbva <- ggplot(juve, aes(x = Time, y = Weight, fill=Time)) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Weight of Juvenile Ischnodemus", subtitle= "Before vs. After Hurricane Isaac",
x="Time", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title = element_text(hjust = 0.5),plot.subtitle=element_text(hjust=0.5)) +
  scale_x_discrete(limits=c("Before", "After")) +
  theme(legend.position = "none")
bpjuvbva
bpjuvbva2 <- ggplot(juve, aes(x = Time, y = Length, fill=Time)) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Length of Juvenile Ischnodemus", subtitle= "Before vs. After Hurricane Isaac",
x="Time", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title = element_text(hjust = 0.5),plot.subtitle=element_text(hjust=0.5)) +
  scale_x_discrete(limits=c("Before", "After")) +
  theme(legend.position = "none")
```

```
bpjuvbva2
overalljuv<- bpjuvbva + bpjuvbva2
overalljuv
ggsave("Weight-Length-Overalljuv.pdf", overalljuv)
bp1 <- ggplot(juvebefore, aes(x = Site, y = Length, fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Length by Site", subtitle="Before Hurricane Isaac", x="Site",
y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp1
bp2 <- ggplot(juvebefore, aes(x = Site, y = Weight, fill=Site)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Weight by Site", subtitle="Before Hurricane Isaac", x="Site",
y = "Weight (mg)") +
  theme_classic() +
```

```
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp2
bp3 <- ggplot(juveafter, aes(x = Site, y = Weight, fill=Site)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Weight by Site", subtitle="After Hurricane Isaac", x="Site", y
= "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp3
bp4 <- ggplot(juveafter, aes(x = Site, y = Length, fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Length by Site", subtitle="After Hurricane Isaac", x="Site", y
= "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
```

```
  theme(legend.position = "none")
bp4
bp5 <- ggplot(juvebefore, aes(x = Season, y = Length, fill=Season)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("Spring","Summer")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Length by Season", subtitle="Before Hurricane Isaac",
x="Season", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp5
bp6 <- ggplot(juvebefore, aes(x = Season, y = Weight, fill=Season)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("Spring","Summer")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Weight by Season", subtitle="Before Hurricane Isaac",
x="Season", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
```

```
bp6
bp7 <- ggplot(juveafter, aes(x = Season, y = Weight, fill=Season)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("Spring","Summer", "Fall")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Weight by Season", subtitle="After Hurricane Isaac",
x="Season", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp7
bp8 <- ggplot(juveafter, aes(x = Season, y = Length, fill=Season)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("Spring","Summer", "Fall")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Length by Season", subtitle="After Hurricane Isaac",
x="Season", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bp8
```

```
weightjbva<- (bp6 + bp7)/ (bp2 +bp3)

weightjbva

ggsave("Juve-Weight-B-A.pdf", weightjbva)

lengthjbva<- (bp5 + bp8)/ (bp1 +bp4)

lengthjbva

ggsave("Juve-Length-B-A.pdf", lengthjbva)
```

APPENDIX D. *CREMATOGASTER* ANALYSIS AND GRAPHS RSTUDIO

```{r}

crem <- read.csv("Final_Crem.csv", header = TRUE)

summary(crem)

crembefore <- subset(crem, Time=="Before",

select=Season:Month)

cremafter <- subset(crem, Time=="After",

select=Season:Month)

summary(crembefore)

summary(cremafter)

data.frame(table(crem$Site))

data.frame(table(crem$Season))

data.frame(table(crembefore$Site))

data.frame(table(crembefore$Season))

data.frame(table(cremafter$Site))

data.frame(table(cremafter$Season))

data.frame(table(crem$Time))

aggregate(crem$Weight..mg., list(crem$Site), FUN = mean)

aggregate(crem$Length..mm., list(crem$Site), FUN = mean)

aggregate(crem$Head.Width..mm., list(crem$Site), FUN = mean)

aggregate(crem$Weight..mg., list(crem$Season), FUN = mean)

aggregate(crem$Length..mm., list(crem$Season), FUN = mean)

aggregate(crem$Head.Width..mm., list(crem$Season), FUN = mean)

aggregate(crembefore$Weight..mg., list(crembefore$Site), FUN = mean)
```

aggregate(crembefore$Length..mm., list(crembefore$Site), FUN = mean)

aggregate(crembefore$Head.Width..mm., list(crembefore$Site), FUN = mean)

aggregate(crembefore$Weight..mg., list(crembefore$Season), FUN = mean)

aggregate(crembefore$Length..mm., list(crembefore$Season), FUN = mean)

aggregate(crembefore$Head.Width..mm., list(crembefore$Season), FUN = mean)

aggregate(cremafter$Weight..mg., list(cremafter$Site), FUN = mean)

aggregate(cremafter$Length..mm., list(cremafter$Site), FUN = mean)

aggregate(cremafter$Head.Width..mm., list(cremafter$Site), FUN = mean)

aggregate(cremafter$Weight..mg., list(cremafter$Season), FUN = mean)

aggregate(cremafter$Length..mm., list(cremafter$Season), FUN = mean)

aggregate(cremafter$Head.Width..mm., list(cremafter$Season), FUN = mean)

aggregate(crem$Weight..mg., list(crem$Time), FUN = mean)

aggregate(crem$Length..mm., list(crem$Time), FUN = mean)

aggregate(crem$Head.Width..mm., list(crem$Time), FUN = mean)

```

ANOVA and Tukey Test

```{r}

anovtimec<- aov(Weight..mg.~ Time, data = crem)

summary(anovtimec)

anovtimec2<- aov(Length..mm.~ Time, data = crem)

summary(anovtimec2)

anovtimec3<- aov(Head.Width..mm.~ Time, data = crem)

summary(anovtimec3)

```
aovants1<- aov(Weight..mg.~ Season, data = crembefore)

summary(aovants1)

TukeyHSD(aovants1, conf.level = 0.95)

tuk.ants1 <- TukeyHSD(aovants1, conf.level = 0.95)

aovants2<- aov(Weight..mg.~ Season, data = cremafter)

summary(aovants2)

TukeyHSD(aovants2, conf.level = 0.95)

tuk.ants2 <- TukeyHSD(aovants2, conf.level = 0.95)

aovantshead<- aov(Head.Width..mm.~ Season, data = crembefore)

summary(aovantshead)

TukeyHSD(aovantshead, conf.level = 0.95)

tuk.antshead1 <- TukeyHSD(aovantshead, conf.level = 0.95)

ead2<- aov(Head.Width..mm.~ Season, data = cremafter)

summary(aovantshead2)

TukeyHSD(aovantshead2, conf.level = 0.95)

tuk.antshead2 <- TukeyHSD(aovantshead2, conf.level = 0.95)

aovantsheadsite<- aov(Head.Width..mm.~ Site, data = crembefore)

summary(aovantsheadsite)

TukeyHSD(aovantsheadsite, conf.level = 0.95)

tuk.antheadsite <- TukeyHSD(aovantsheadsite, conf.level = 0.95)

aovantsheadsite2<- aov(Head.Width..mm.~ Site, data = cremafter)

summary(aovantsheadsite2)

TukeyHSD(aovantsheadsite2, conf.level = 0.95)
```

```
tuk.antheadsite2 <- TukeyHSD(aovantsheadsite2, conf.level = 0.95)
aovweightsite<- aov(Weight..mg.~ Site, data = crembefore)
summary(aovweightsite)
TukeyHSD(aovweightsite, conf.level = 0.95)
tuk.antsws <- TukeyHSD(aovweightsite, conf.level = 0.95)
aovweightsite2<- aov(Weight..mg.~ Site, data = cremafter)
summary(aovweightsite2)
TukeyHSD(aovweightsite2, conf.level = 0.95)
tuk.antsws2 <- TukeyHSD(aovweightsite2, conf.level = 0.95)
aovantsall<- aov(Weight..mg.~ Site, data = crem)
summary(aovantsall)
TukeyHSD(aovantsall, conf.level = 0.95)
tuk.antsall <- TukeyHSD(aovantsall, conf.level = 0.95)
aovantsall2<- aov(Weight..mg.~ Season, data = crem)
summary(aovantsall2)
TukeyHSD(aovantsall2, conf.level = 0.95)
tuk.antsall2 <- TukeyHSD(aovantsall2, conf.level = 0.95)
aovantsall3<- aov(Head.Width..mm.~ Season, data = crem)
summary(aovantsall3)
TukeyHSD(aovantsall3, conf.level = 0.95)
tuk.antsall3 <- TukeyHSD(aovantsall3, conf.level = 0.95)
aovantsall4<- aov(Head.Width..mm.~ Site, data = crem)
summary(aovantsall4)
```

```
aovantsall5<- aov(Length..mm.~ Season, data = crem)

summary(aovantsall5)

TukeyHSD(aovantsall5, conf.level = 0.95)

tuk.antsall5 <- TukeyHSD(aovantsall5, conf.level = 0.95)

aovantsall6<- aov(Length..mm.~ Site, data = crem)

summary(aovantsall6)

aovantsl1<- aov(Length..mm.~ Site, data = crembefore)

summary(aovantsl1)

TukeyHSD(aovantsl1, conf.level = 0.95)

tuk.antsl1 <- TukeyHSD(aovantsl1, conf.level = 0.95)

aovantsl2<- aov(Length..mm.~ Season, data = crembefore)

summary(aovantsl2)

TukeyHSD(aovantsl2, conf.level = 0.95)

tuk.antsl2 <- TukeyHSD(aovantsl2, conf.level = 0.95)

aovantsl3<- aov(Length..mm.~ Site, data = cremafter)

summary(aovantsl3)

TukeyHSD(aovantsl3, conf.level = 0.95)

tuk.antsl3 <- TukeyHSD(aovantsl3, conf.level = 0.95)

aovantsl4<- aov(Length..mm.~ Season, data = cremafter)

summary(aovantsl4)
```

Kruskal-Wallis and Bonferroni Test

````
```{r}
kruskal.test(Weight..mg. ~ Season, data = crembefore)
kruskal.test(Length..mm. ~ Season, data=crembefore)
kruskal.test(Head.Width..mm. ~ Season, data=crembefore)
kruskal.test(Weight..mg. ~ Site, data=crembefore)
kruskal.test(Length..mm. ~ Site, data=crembefore)
kruskal.test(Head.Width..mm. ~ Site, data=crembefore)
kruskal.test(Weight..mg. ~ Season, data=cremafter)
kruskal.test(Length..mm. ~ Season, data=cremafter)
kruskal.test(Head.Width..mm. ~ Season, data=cremafter)
kruskal.test(Weight..mg. ~ Site, data=cremafter)
kruskal.test(Length..mm. ~ Site, data=cremafter)
kruskal.test(Head.Width..mm. ~ Site, data=cremafter)
pairwise.t.test(crembefore$Weight..mg., crembefore$Season, p.adjust.method="bonferroni")
pairwise.t.test(crembefore$Length..mm., crembefore$Season, p.adjust.method="bonferroni")
pairwise.t.test(crembefore$Head.Width..mm., crembefore$Season,
p.adjust.method="bonferroni")
pairwise.t.test(crembefore$Weight..mg., crembefore$Site, p.adjust.method="bonferroni")
pairwise.t.test(crembefore$Length..mm., crembefore$Site, p.adjust.method="bonferroni")
pairwise.t.test(crembefore$Head.Width..mm., crembefore$Site, p.adjust.method="bonferroni")
pairwise.t.test(cremafter$Weight..mg., cremafter$Season, p.adjust.method="bonferroni")
pairwise.t.test(cremafter$Length..mm., cremafter$Season, p.adjust.method="bonferroni")
pairwise.t.test(cremafter$Head.Width..mm., cremafter$Season, p.adjust.method="bonferroni")
````
````

```
pairwise.t.test(cremafter$Weight..mg., cremafter$Site, p.adjust.method="bonferroni")

pairwise.t.test(cremafter$Length..mm., cremafter$Site, p.adjust.method="bonferroni")

pairwise.t.test(cremafter$Head.Width..mm., cremafter$Site, p.adjust.method="bonferroni")

kruskal.test(Weight..mg. ~ Season, data = crem)

kruskal.test(Length..mm. ~ Season, data=crem)

kruskal.test(Head.Width..mm. ~ Season, data=crem)

kruskal.test(Weight..mg. ~ Time, data = crem)

kruskal.test(Length..mm. ~ Time, data=crem)

kruskal.test(Head.Width..mm. ~ Time, data=crem)

kruskal.test(Weight..mg. ~ Site, data=crem)

kruskal.test(Length..mm. ~ Site, data=crem)

kruskal.test(Head.Width..mm. ~ Site, data=crem)

pairwise.t.test(crem$Weight..mg., crem$Season, p.adjust.method="bonferroni")

pairwise.t.test(crem$Length..mm., crem$Season, p.adjust.method="bonferroni")

pairwise.t.test(crem$Head.Width..mm., crem$Season, p.adjust.method="bonferroni")

pairwise.t.test(crem$Weight..mg., crem$Time, p.adjust.method="bonferroni")

pairwise.t.test(crem$Length..mm., crem$Time, p.adjust.method="bonferroni")

pairwise.t.test(crem$Head.Width..mm., crem$Time, p.adjust.method="bonferroni")

pairwise.t.test(crem$Weight..mg., crem$Site, p.adjust.method="bonferroni")

pairwise.t.test(crem$Length..mm., crem$Site, p.adjust.method="bonferroni")

pairwise.t.test(crem$Head.Width..mm., crem$Site, p.adjust.method="bonferroni")
```

Crematogaster Graphs

````
```{r}

crem <- read.csv("Final_Crem.csv", header = TRUE)

summary(crem)

crembefore <- subset(crem, Time=="Before",

  select=Season:Month)

summary(crembefore)

cremafter <- subset(crem, Time=="After",

select=Season:Month)

library(ggplot2)

summary(crembefore)

summary(cremafter)

bpants1 <- ggplot(crembefore, aes(x = Season, y = Weight..mg., fill=Season)) +

  ylim(0,1.5) +

  scale_x_discrete(limits=c("Spring","Summer")) +

  geom_boxplot() +

  #stat_summary(fun=mean) +

  labs(title="Crematogaster Weight by Season", subtitle="Before Hurricane Isaac",x="Season", y
= "Weight (mg)") +

  theme_classic() +

  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +

  theme(legend.position = "none")

bpants1

bpants2 <- ggplot(cremafter, aes(x = Season, y = Weight..mg., fill=Season)) +
````
````

```
  ylim(0,1) +
  scale_x_discrete(limits=c("Spring","Summer","Fall", "Winter")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Weight by Season", subtitle="After Hurricane Isaac",x="Season", y =
"Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpants2
bpants3 <- ggplot(crembefore, aes(x = Site, y = Weight..mg., fill=Site)) +
  ylim(0,1.5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Weight By Site", subtitle="Before Hurricane",x="Time", y =
"Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpants3
bpants4 <- ggplot(cremafter, aes(x = Site, y = Weight..mg., fill=Site)) +
  ylim(0,1.5) +
```

```
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Weight By Site", subtitle="After Hurricane", x="Time", y = "Weight
(mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpants4
antsseasonbva<- (bpants1 + bpants2)/ (bplength1 +bplength2)
antsseasonbva
ggsave("Ants-Season-B-A.pdf", antsseasonbva)
bphead1 <- ggplot(crembefore, aes(x = Season, y = Head.Width..mm., fill=Season)) +
  ylim(0,1.5) +
  scale_x_discrete(limits=c("Spring","Summer")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Head Width by Season", subtitle="Before Hurricane
Isaac",x="Season", y = "Head Width (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bphead1
```

```
bphead2 <- ggplot(cremafter, aes(x = Season, y = Head.Width..mm., fill=Season)) +
  ylim(0,1.5) +
  scale_x_discrete(limits=c("Spring","Summer","Fall", "Winter")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Head Width by Season", subtitle="After Hurricane
Isaac",x="Season", y = "Head Width (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bphead2
bphead3<- ggplot(crembefore, aes(x = Site, y = Head.Width..mm., fill=Site)) +
  ylim(0,1.5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Head Width by Site", subtitle="Before Hurricane",x="Site", y =
"Head Width (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bphead3
bphead4 <- ggplot(cremafter, aes(x = Site, y = Head.Width..mm., fill=Site)) +
```

```
  ylim(0,1.5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Head Width by Site", subtitle="After Hurricane",x="Site", y = "Head
Width (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bphead4
antsheadbva<- (bphead1 + bphead2)/ (bphead3 +bphead4)
antsheadbva
ggsave("Ants-Head-B-A.pdf", antsheadbva)
bplength1 <- ggplot(crembefore, aes(x = Season, y = Length..mm., fill=Season)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("Spring","Summer")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Length by Season", subtitle="Before Hurricane Isaac",x="Season", y
= "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
```

```
bplength1
bplength2 <- ggplot(cremafter, aes(x = Season, y = Length..mm., fill=Season)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("Spring","Summer","Fall", "Winter")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Length by Season", subtitle="After Hurricane Isaac",x="Season", y =
"Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bplength2
bplength3 <- ggplot(crembefore, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Length by Site", subtitle="Before Hurricane Isaac",x="Season", y =
"Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bplength3
```

```
bplength4 <- ggplot(cremafter, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Length by Site", subtitle="After Hurricane Isaac",x="Season", y =
"Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bplength4
antssitebva<- (bpants3 + bpants4)/ (bplength3 +bplength4)
antssitebva
ggsave("Ants-Site-B-A.pdf", antssitebva)
bpants5 <- ggplot(crem, aes(x = Time, y = Weight..mg., fill=Time)) +
  ylim(0,2) +
  scale_x_discrete(limits=c("Before","After")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Weight",x="Time", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
```

```
bpants5
bpants6 <- ggplot(crem, aes(x = Time, y = Length..mm., fill=Time)) +
  ylim(0,4) +
  scale_x_discrete(limits=c("Before","After")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Length ",x="Time", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpants6
bpants7 <- ggplot(crem, aes(x = Time, y = Head.Width..mm., fill=Time)) +
  ylim(0,2) +
  scale_x_discrete(limits=c("Before","After")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Head Width ",x="Time", y = "Head Width (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpants7
overallant<- bpants5 +bpants6+ bpants7
overallant
```

```
ggsave("Weight-Length-HW-Overall.pdf", overallant)
bpheadseason <- ggplot(crem, aes(x = Season, y = Head.Width..mm., fill=Season)) +
  ylim(0,1.5) +
  scale_x_discrete(limits=c("Spring","Summer","Fall")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Head Width to Season",x="Season", y = "Head Width (mm)") +
  theme_classic() +
  theme(legend.position = "none")
bpheadseason
bpweightseason <- ggplot(crem, aes(x = Season, y = Weight..mg., fill=Season)) +
  ylim(0,1.5) +
  scale_x_discrete(limits=c("Spring","Summer","Fall")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Weight to Season",x="Season", y = "Weight (mg)") +
  theme_classic() +
  theme(legend.position = "none")
bpweightseason
bplengthsite <- ggplot(crem, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5","C6","C7","C8","C9","C10","C11")) +
  geom_boxplot() +
```

```
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Length to Site",x="Site", y = "Length (mm)") +
  theme_classic() +
  theme(legend.position = "none")
bplengthsite
```

APPENDIX E. OILED AND UNOILED ANAYLSIS AND GRAPHS RSTUDIO

Ischnodemus

```
```{r setup, include=FALSE}

combisch<- read.csv("Isch_oil_unoil.csv", header=TRUE)

combisch

library(ggplot2)

ischoil <- subset(combisch, DWH=="oiled",

                  select=Season:Month)

ischunoil <- subset(combisch, DWH=="unoiled",

                 select=Season:Month)

summary(ischoil)

summary(ischunoil)

data.frame(table(ischoil$Season))

data.frame(table(ischunoil$Season))

data.frame(table(ischoil$Site))

data.frame(table(ischunoil$Site))

data.frame(table(ischafter$Site))

aggregate(ischoil$Weight..mg., list(ischoil$Site), FUN = mean)

aggregate(ischoil$Length..mm., list(ischoil$Site), FUN = mean)

aggregate(ischunoil$Weight..mg., list(ischunoil$Site), FUN = mean)

aggregate(ischunoil$Length..mm., list(ischunoil$Site), FUN = mean)

aggregate(combisch$Weight..mg., list(combisch$Site), FUN = mean)

aggregate(combisch$Length..mm., list(combisch$Site), FUN = mean)
```
```

aggregate(ischunoil$Weight..mg., list(ischunoil$Season), FUN = mean)

aggregate(ischunoil$Length..mm., list(ischunoil$Season), FUN = mean)

```

Kruskal-Wallis Test

```{r}
107onferr.test(Weight..mg. ~ DWH, data=combisch)

107onferr.test(Length..mm. ~ DWH, data=combisch)

107onferr.test(Weight..mg. ~ Site, data=ischoil)

107onferr.test(Length..mm. ~ Site, data=ischoil)

107onferr.test(Weight..mg. ~ Site, data=ischunoil)

107onferr.test(Length..mm. ~ Site, data=ischunoil)

pairwise.t.test(combisch$Weight..mg., combisch$DWH, p.adjust.method=”107onferroni”)

pairwise.t.test(combisch$Length..mm., combisch$DWH, p.adjust.method=”107onferroni”)

pairwise.t.test(ischoil$Weight..mg., ischoil$Site, p.adjust.method=”107onferroni”)

pairwise.t.test(ischoil$Length..mm., ischoil$Site, p.adjust.method=”107onferroni”)

pairwise.t.test(ischunoil$Weight..mg., ischunoil$Site, p.adjust.method=”107onferroni”)

pairwise.t.test(ischunoil$Length..mm., ischunoil$Site, p.adjust.method=”107onferroni”)
```

ANOVA and Tukey Test

```{r}
aovoil1 <- aov(Weight..mg. ~ Site, data = ischoil)

summary(aovoil1)

aovoil2 <- aov(Length..mm. ~ Site, data = ischoil)

~~~
summary(aovoil2)

aovunoil1 <- aov(Weight..mg. ~ Site, data = ischunoil)

summary(aovunoil1)

aovunoil2 <- aov(Length..mm. ~ Site, data = ischunoil)

summary(aovunoil2)

aisch1 <- aov(Weight..mg. ~ DWH, data=combisch)

summary(aisch1)

aisch2 <- aov(Length..mm. ~ DWH, data= combisch)

summary (aisch2)

TukeyHSD(aovoil1, conf.level = 0.95)

TukeyHSD(aovoil2, conf.level = 0.95)

TukeyHSD(aovunoil1, conf.level = 0.95)

TukeyHSD(aovunoil2, conf.level = 0.95)

```
~~~

Graphs

~~~
```{r}

bpischunoil <- ggplot(ischunoil, aes(x = Site, y = Weight..mg., fill=Site)) +

  ylim(0,4.0) +

  scale_x_discrete(limits=c(“C1”,”C2”,”C3”,”C4”,”C5”)) +

  geom_boxplot() +

  #stat_summary(fun=mean) +

  labs(title=”Ischnodemus Weight”, subtitle= “Unoiled Sites”,x=”Sites”, y = “Weight (mg)”) +

  theme_classic() +
~~~

```
    theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
 theme(legend.position = “none”)
bpischunoil
bpischoil <- ggplot(ischoil, aes(x = Site, y = Weight..mg., fill=Site)) +
 ylim(0,4.0) +
 scale_x_discrete(limits=c(“C7”,”C8”,”C9”,”C10”,”C11”)) +
 geom_boxplot() +
 #stat_summary(fun=mean) +
 labs(title=”Ischnodemus Weight”, subtitle= “Oiled Sites”,x=”Sites”, y = “Weight (mg)”) +
 theme_classic() +
    theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
 theme(legend.position = “none”)
bpischoil
bpischunoiled2 <- ggplot(ischunoil, aes(x = Site, y = Length..mm., fill=Site)) +
 ylim(0,10) +
 scale_x_discrete(limits=c(“C1”,”C2”,”C3”,”C4”,”C5”)) +
 geom_boxplot() +
 #stat_summary(fun=mean) +
 labs(title=”Ischnodemus Length”, subtitle=”Unoiled Sites”,x=”Sites”, y = “Length (mm)”) +
 theme_classic() +
    theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
 theme(legend.position = “none”)
bpischunoiled2
```

```
bpischoil2 <- ggplot(ischoil, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,10.0) +
  scale_x_discrete(limits=c("C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Ischnodemus Length", subtitle="Oiled Sites",x="Sites", y = "Length (mm)") +
  theme_classic() +
    theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
bpischoil2
oiledvunoiledisch<- (bpischoil + bpischunoil) /(bpischoil2 + bpischunoiled2)
oiledvunoiledisch
ggsave("Isch-Oiled-Unoiled.pdf", oiledvunoiledisch)
```

Juvenile *Ischnodemus*

```{r}
juvdwh <- read.csv("Juveniles_oil_unoil.csv", header = TRUE)
summary(juvdwh)
juvoil <- subset(juvdwh, DWH=="oiled",
                    select=Season:Month)
juvunoil <- subset(juvdwh, DWH=="unoiled",
                   select=Season:Month)
summary(juvoil)
```

summary(juvunoil)

aggregate(juvunoil$Weight, list(juvunoil$Site), FUN = mean)

aggregate(juvunoil$Length, list(juvunoil$Site), FUN = mean)

data.frame(table(juvoil$Site))

data.frame(table(juvoil$Time))

data.frame(table(juvoil$Season))

data.frame(table(juvunoil$Site))

data.frame(table(juvunoil$Season))

data.frame(table(juvunoil$Time))

data.frame(table(cremafter$Season))

```

Kruskal-Wallis anf Bonferroni Test

```{r}

kruskal.test(Weight ~ Site, data = juvunoil)

kruskal.test(Length ~ Site, data=juvunoil)

kruskal.test(Weight ~ Site, data=juvoil)

kruskal.test(Length ~ Site, data=juvoil)

kruskal.test(Weight ~ DWH, data=juvdwh)

kruskal.test(Length ~ DWH, data=juvdwh)

pairwise.t.test(juvoil$Weight, juvoil$Site, p.adjust.method="bonferroni")

pairwise.t.test(juvoil$Length, juvoil$Site, p.adjust.method="bonferroni")

pairwise.t.test(juvunoil$Weight, juvunoil$Site, p.adjust.method="bonferroni")

pairwise.t.test(juvunoil$Length, juvunoil$Site, p.adjust.method="bonferroni")

```

ANOVA

```{r}
ajunoil1 <- aov(Weight ~ Site, data = juvunoil)
summary(ajunoil1)
ajunoil2 <- aov(Length ~ Site, data=juvunoil)
summary(ajunoil2)
ajoil1<- aov(Weight ~ Site, data=juvoil)
summary(ajoil1)
ajoil2 <- aov(Length ~ Site, data=juvoil)
summary(ajoil2)
ajdwh1 <- aov(Weight ~ DWH, data=juvdwh)
summary(ajdwh1)
ajdwh2 <- aov(Length ~ DWH, data=juvdwh)
summary(ajdwh2)
```

Graphs

```{r}
oilbp1 <- ggplot(juvoil, aes(x = Site, y = Length, fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +

```
  labs(title="Juvenile Ischnodemus Length", subtitle="Oiled Sites", x="Site", y = "Length (mm)")
+
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
oilbp1
oilbp2 <- ggplot(juvoil, aes(x = Site, y = Weight, fill=Site)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Weight", subtitle="Oiled Sites", x="Site", y = "Weight (mg)")
+
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
oilbp2
unoilbp2 <- ggplot(juvunoil, aes(x = Site, y = Weight, fill=Site)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
```

~~~
  labs(title="Juvenile Ischnodemus Weight", subtitle="Unoiled Sites", x="Site", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
unoilbp2
unoilbp1 <- ggplot(juvunoil, aes(x = Site, y = Length, fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Juvenile Ischnodemus Length", subtitle="Unoiled Sites", x="Site", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5),plot.subtitle=element_text(hjust=0.5)) +
  theme(legend.position = "none")
unoilbp1
joilvunoil<- (oilbp2 + unoilbp2)/ (oilbp1 +unoilbp1)
joilvunoil
ggsave("Juve-oil-unoil.pdf", joilvunoil)
```
~~~

Crematogaster

~~~
```{r setup, include=FALSE}
~~~

```
combants<- read.csv("Crem_oiled_vs_unoiled.csv", header=TRUE)
combants
antoil <- subset(combants, DWH=="oiled",
                 select=Season:Month)
antunoil <- subset(combants, DWH=="unoiled",
                select=Season:Month)
summary(antoil)
summary(antunoil)
data.frame(table(antoil$Season))
data.frame(table(antunoil$Season))
data.frame(table(antoil$Site))
data.frame(table(antunoil$Site))
aggregate(antoil$Weight..mg., list(antoil$Season), FUN = mean)
aggregate(antoil$Length..mm., list(antoil$Season), FUN = mean)
aggregate(antoil$Head.Width..mm., list(antoil$Season), FUN = mean)
aggregate(antunoil$Weight..mg., list(antunoil$Season), FUN = mean)
aggregate(antunoil$Length..mm., list(antunoil$Season), FUN = mean)
aggregate(antunoil$Head.Width..mm., list(antunoil$Season), FUN = mean)
aggregate(antoil$Weight..mg., list(antoil$Site), FUN = mean)
aggregate(antoil$Length..mm., list(antoil$Site), FUN = mean)
aggregate(antoil$Head.Width..mm., list(antoil$Site), FUN = mean)
aggregate(antunoil$Weight..mg., list(antunoil$Site), FUN = mean)
aggregate(antunoil$Length..mm., list(antunoil$Site), FUN = mean)
```

````
aggregate(antunoil$Head.Width..mm., list(antunoil$Site), FUN = mean)
```
````

ANOVA and Tukey Test

````
```{r}
aovcom1<- aov(Weight..mg. ~ DWH, data = combants)
summary(aovcom1)
aovcom2<- aov(Head.Width..mm. ~ DWH, data = combants)
summary(aovcom2)
aovcom3<- aov(Length..mm. ~ DWH, data = combants)
summary(aovcom3)
combantstuk <- TukeyHSD(aovcom1, conf.level = 0.95)
combantstuk2 <- TukeyHSD(aovcom2, conf.level = 0.95)
combantstuk3 <- TukeyHSD(aovcom2, conf.level = 0.95)
antoil1<- aov(Weight..mg. ~ Site, data = antoil)
summary(antoil1)
antoil2<- aov(Head.Width..mm. ~ Site, data = antoil)
summary(antoil2)
antoil3<- aov(Length..mm. ~ Site, data = antoil)
summary(antoil3)
antsoiltuk3 <- TukeyHSD(antoil3, conf.level = 0.95)
antsoiltuk3
antunoil1<- aov(Weight..mg. ~ Site, data = antunoil)
````

```
summary(antunoil1)

antunoil2<- aov(Head.Width..mm. ~ Site, data = antunoil)

summary(antunoil2)

antunoil3<- aov(Length..mm. ~ Site, data = antunoil)

summary(antunoil3)

antsunoiltuk1 <- TukeyHSD(antunoil1, conf.level = 0.95)

antsunoiltuk1
```

Kruskal-Wallis and Bonferroni Test

```{r}
kruskal.test(Weight..mg. ~ DWH, data=combants)

kruskal.test(Length..mm. ~ DWH, data=combants)

kruskal.test(Head.Width..mm. ~ DWH, data=combants)

pairwise.t.test(combants$Weight..mg., combants$DWH, p.adjust.method="bonferroni")

pairwise.t.test(combants$Length..mm., combants$DWH, p.adjust.method="bonferroni")

pairwise.t.test(combants$Head.Width..mm., combants$DWH, p.adjust.method="bonferroni")

kruskal.test(Weight..mg. ~ Site, data=antoil)

kruskal.test(Length..mm. ~ Site, data=antoil)

kruskal.test(Head.Width..mm. ~ Site, data=antoil)

pairwise.t.test(antoil$Weight..mg., antoil$Site, p.adjust.method="bonferroni")

pairwise.t.test(antoil$Length..mm., antoil$Site, p.adjust.method="bonferroni")

pairwise.t.test(antoil$Head.Width..mm., antoil$Site, p.adjust.method="bonferroni")

kruskal.test(Weight..mg. ~ Site, data=antunoil)
```

````
kruskal.test(Length..mm. ~ Site, data=antunoil)
kruskal.test(Head.Width..mm. ~ Site, data=antunoil)
pairwise.t.test(antunoil$Weight..mg., antunoil$Site, p.adjust.method="bonferroni")
pairwise.t.test(antunoil$Length..mm., antunoil$Site, p.adjust.method="bonferroni")
pairwise.t.test(antunoil$Head.Width..mm., antunoil$Site, p.adjust.method="bonferroni")
```
Graphs
```{r}
bpantoiled <- ggplot(antoil, aes(x = Site, y = Weight..mg., fill=Site)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Weight in Oiled Sites",x="Sites", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
 bpantoiled
bpantunoiled <- ggplot(antunoil, aes(x = Site, y = Weight..mg., fill=Site)) +
  ylim(0,1) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
````

```
  labs(title="Crematogaster Weight in Unoiled Sites",x="Sites", y = "Weight (mg)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
 bpantunoiled
oilvunoilants<- bpantoiled / bpantunoiled
oilvunoilants
ggsave("Crem-Oiled-Unoiled.pdf", oilvunoilants)
bpantoiled2 <- ggplot(antoil, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Length in Oiled Sites",x="Sites", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
 bpantoiled2
bpantunoiled2 <- ggplot(antunoil, aes(x = Site, y = Length..mm., fill=Site)) +
  ylim(0,5) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
```

```
  labs(title="Crematogaster Length in Unoiled Sites",x="Sites", y = "Length (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
 bpantunoiled2
oilvunoilants2<- bpantoiled2 / bpantunoiled2
oilvunoilants2
ggsave("Crem-Oiled-Unoiled-Length.pdf", oilvunoilants2)
bpantunoiled3 <- ggplot(antunoil, aes(x = Site, y = Head.Width..mm., fill=Site)) +
  ylim(0,2) +
  scale_x_discrete(limits=c("C1","C2","C3","C4","C5")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
  labs(title="Crematogaster Head Width in Unoiled Sites",x="Sites", y = "Head Width (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
 bpantunoiled3
bpantoiled3 <- ggplot(antoil, aes(x = Site, y = Head.Width..mm., fill=Site)) +
  ylim(0,2) +
  scale_x_discrete(limits=c("C7","C8","C9","C10","C11")) +
  geom_boxplot() +
  #stat_summary(fun=mean) +
```

```
  labs(title="Crematogaster Head Width in Oiled Sites",x="Sites", y = "Head Width (mm)") +
  theme_classic() +
  theme(plot.title=element_text(hjust=0.5)) +
  theme(legend.position = "none")
 bpantoiled3
oilvunoilants3<- bpantoiled3 / bpantunoiled3
oilvunoilants3
ggsave("Crem-Oiled-Unoiled-HW.pdf", oilvunoilants3)
```

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VITA

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