12-2016

Carbon and nitrogen dynamics of anthropogenically disturbed seagrass ecosystems

Alison Shepherd
The University of Texas Rio Grande Valley

CARBON AND NITROGEN DYNAMICS OF ANTROPOGENICALLY DISTURBED SEAGRASS ECOSYSTEMS

A Thesis

by

ALISON SHEPHERD

Submitted to the Graduate College of
The University of Texas Rio Grande Valley
In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

December 2016

Major Subject: Biology

CARBON AND NITROGEN DYNAMICS OF ANTHROPOGENICALLY DISTURBED SEAGRASS ECOSYSTEMS

A Thesis
by
ALISON SHEPHERD

COMMITTEE MEMBERS

Dr. Abdullah Rahman
Chair of Committee

Dr. Heather Alexander
Committee Member

Dr. Carlos E. Cintra Buenrostro
Committee Member

December 2016

ABSTRACT

Shepherd, Alison K., Carbon and Nitrogen Dynamics in Anthropogenically Disturbed Seagrass Ecosystems. Master of Science (MS), December, 2016, 54 pp., 8 figures, 2 tables, references: 40 titles.

Abstract: The effects of anthropogenic disturbance from boat propeller scars were measured by quantifying C and nitrogen (N) stocks and fluxes in turtle grass (*Thalassia testudinum*, Banks and Sol. ex K. D. Koenig, 1805) meadows in the Lower Laguna Madre of South Texas. Soil and vegetation C and N pools within disturbed and nearby undisturbed areas were estimated to determine the rate of post-disturbance changes of the historically sequestered C. The study found that damage, which was generally localized to the top 20cm, potentially redistributed 23.94 Mg/ha of previously sequestered C from within the damaged area, although we found no statistical significance to the difference in our cores. Scarred areas did however show a significant increase in bulk density and a decrease in %C, both of which returned to predisturbance levels near the 10 year mark for both parameters, despite still being recognizable as an area of disturbance.

Keywords: Seagrass, Carbon sink, Carbon storage, boat scarring

DEDICATION

To Jay Tunnicliffe without whom this whole south Texas adventure would not have been possible. Thank you for holding down the fort while I was away.

ACKNOWLEDGMENTS

Graduate school has been an unforgettable adventure and I am forever grateful to several people without whom this research would not have been possible. First and foremost, thank you Dr. Abdullah Rahman for welcoming me into your lab and providing both financial support and mentoring throughout this research. Thank you to my co-advisor Dr. Heather Alexander and my committee member Dr. Carlos Cintra Buenrostro for all of your guidance through both my research and fieldwork, as well as the editing of this manuscript. I owe a huge debt of gratitude to all of the staff at the Coastal Studies Lab for all of your guidance, fieldwork assistance, and friendship along this journey. This includes former director Dr. Thomas Whelan, Dr. Hudson Deyoe, Eberto Presas, Les Sweeten, Brigitte Goza, Lorena Longoria, and Maria Infantate. A special thank you to both Eberto Presas for the countless hours working out on the water and for teaching me to back up a boat trailer and Les Sweeten for all the hours spent in the garage tweaking my equipment and fixing everything that I broke. I also need to acknowledge both Texas Parks and Wildlife as well as the Texas General Land Office for permitting me to conduct my research in the Laguna Madre. Thank you to my friend and colleague Linda Jordan and to my summer lab assistant Christian Galvan for all of your hard work both out on the boat and in the lab. I doubt either one will ever want to see a sediment core again. I need to send a special thank you to my roommate, friend, and colleague Shelby Bessette for all you help and support

and for making sure my dog didn't feel like he had been abandoned during all of those late nights at the lab. A very special thank you to my family for supporting my decision to pack up and start over in Texas and to Kevin Sloan for standing by me while I was away and not giving up hope that I would eventually make it back home. And finally, thank you to all of the graduate students, faculty, and friends that I have met along the way. You have all made the time spent in Texas amazing and a period of my life that I will never forget.

TABLE OF CONTENTS

Page

ABSTRACT……………………………………………………………………………iii

DEDICATION…………………………………………………………………………iv

ACKNOWLEDGMENTS………………………………………………………………v

TABLE OF CONTENTS………………………………………………………………vii

LIST OF FIGURES……………………………………………………………….…ix

LIST OF TABLES……………………………………………………………….…..x

CHAPTER I. INTRODUCTION…………………………………………………..…1

CHAPTER II. MATERIALS AND METHODS…………………………………….7

Study Area………………………………………………………………………7

Experimental Design…………………………………………………………9

Statistical Analysis……………………………………………………………..12

CHAPTER III. RESULTS………………………………………………………..14

Organic C percentage…………………………………………………….…14

Organic N percentage…..…………………………………………..……..16

Bulk density…………………..……………………………………………………...…16

Organic C stocks…………….…………………………………………………….…18

Organic N stocks…………..……………………………...……………………….…19

CHAPTER IV. DISCUSSION…………………………..……………………..…………21

CHAPTER V. FUTURE WORK…………………………………...…………………..25

REFERENCES……………………………………………………..………………..28

APPENDIX……………………………………………………………...…………...32

BIOGRAPHICAL SKETCH…………………………………………………..……..…54

LIST OF FIGURES

Page

Figure 1: Study Area: Lower Laguna Madre, Cameron County TX…………………………..…33

Figure 2: Sampling Collection Sites in the Lower Laguna Madre…..…………………..……....…34

Figure 3: Parts of the Sediment Corer…………………………………………………………35

Figure 4: %C Graphs by Treatment, Depth Group, and Relative Difference…….…………..…36

Figure 5: %N Graphs by Treatment and Relative Difference…..………………...…………..…37

Figure 6: Bulk Density Graphs by Treatment, Age Group, and Relative Difference…...………38

Figure 7: C Pools Graphed by Treatment, Age Group, and Relative Difference…...………..…39

Figure 8: N Pool by Treatment and Relative Difference..………………………………………40

LIST OF TABLES

Page

Table 1: C Pool Totals By Age Group, Treatment, and Depth……….............……………………..…41

Table 2: N Pool Totals by Age Group, Treatment and Depth………………………..…………..42

CHAPTER I

INTRODUCTION

Seagrass ecosystems are essential to several coastal processes. They support high biodiversity, providing food, shelter, and nursery habitat to several commercially and recreationally important species of vertebrates and invertebrates (Waycott *et al.* 2009). Further, seagrass meadows improve water quality and clarity and reduce light attenuation through the water column by collecting suspended particles and reducing resuspension (Greiner *et al*. 2013). They also protect the shoreline by decreasing wave momentum as well as lessening erosion (Duarte *et al*. 2013).

Seagrasses are one of the most productive ecosystems on the planet, with an average net primary production of 404 g C $m^{-2}yr^{-1}$ when considering combined production of leaves, rhizomes, and roots (Duarte and Chiscano 1999, Duarte *et al.* 2013). Direct photosynthetic C fixation inputs C into the soils as production of roots and rhizomes, thus safely burying C in the sediments (Kennedy *et al.* 2010). However, seagrasses also provide a natural C sink through their ability to collect sediments and associated C from outside riverine and oceanic sources (McLeod *et al.* 2011). This ecosystem maintains slow decomposition rates, as is common in wet environments, given the low N and P concentrations (Duarte *et al. op. cit*.). These C deposits from both the seagrass itself, as well as the surrounding inputs accumulate in the sediment layers and build over time, raising the seafloor within the seagrass meadows at a rate ranging between 0.5 and 1.5 mm yr^{-1} (Kennedy *et al.* 2010).

Despite understanding this process of accumulation, little is known regarding how much C is stored and for how long. Previous work has shown that worldwide, seagrass meadows account for less than 0.2% of the area of the world's oceans even though estimates show that 10% of the yearly global C sequestration in marine environments is due to seagrass ecosystems (Fourqurean *et al.* 2012). Seagrass, mangrove and saltmarsh ecosystems are responsible for handling up to 70% of the marine organic C capture, rendering them one of the most efficient and influential C sinks worldwide (Macreadie *et al.* 2014). Collectively called "blue carbon" ecosystems, these "blue" C sinks have a much higher rate of C sequestration compared to many terrestrial forests (Howard *et al.* 2014) Currently, global C burial rates within seagrass ecosystems are estimated to be between 27-44 Tg C yr^{-1} (Kennedy *et al.* 2010). Seagrass ecosystems bury C roughly 35 times faster than tropical rainforests (McLeod *et al.* 2011, Macreadie *et al.* 2014), and their sediments will never become saturated with C due to their vertical accretion in response to sea level rise (McLeod *et al. op. cit.*).

A study published in 2012 conservatively estimates that coastal seagrass ecosystems currently store as much as 8.4 Pg of C (Fourqurean *et al*. 2012). In addition, the length of time that these "blue" C sinks hold their C is much longer than that of many terrestrial ecosystems. For example, seagrass ecosystems have been found to isolate C for thousands of years (Lo Iacono *et al.* 2008), compared to only centuries for rainforest environments (Chambers *et al.* 2001). The longevity of sequestration can be attributed to the dissipation of wave energy which reduces resuspension, as well as the obvious lack of fire that, in many terrestrial ecosystems, would affect the above ground and surface soil C pools, releasing them back into the atmosphere

(Duarte *et al.* 2013). Conversely, the destruction of these areas can turn them into a C source rather than a sink, allowing all of the previously isolated C to potentially be released back into the water column and diffused into the atmosphere through the disturbed area's decomposition and loss of cover (McLeod *et al.* 2011).

In addition to volatilizing the previously stored C, damage to seagrass beds also has the potential to have severe adverse effects on the nutrient cycling within the ecosystem. Tropical seagrass beds in particular have been found to have generally low ambient nutrient concentrations in the water column while having high nutrient concentrations in the pore water. (Stapel *et al* 1996). To maintain the high productivity found in seagrass beds, the roots as well as the leaves participate in nutrient uptake (Stapel *et al op cit*.) Damage to the above ground and below ground biomass can hinder this process, making it difficult for the plant to recover from the initial damage.

Changes to N availability in particular have been found to have adverse effects on plant growth, changing the ratio of above ground to below ground biomass (Hovey *et al* 2011). A previous growth study conducted in the Lower Laguna Madre (LLM) Bay in south Texas show that seagrasses that experience low nutrient availability focus more on building below ground biomass, allowing for more nutrient uptake to offset the limitation (Lee *et al* 2000.). This however would likely hinder C collection as less aboveground biomass would lessen the ecosystem's ability to collect C through lateral transport as mentioned above.

Unfortunately, as coastal populations grow, threats to seagrass ecosystems have increased at alarming rates (Orth *et al.* 2006). Improper recreational and commercial boat operations cause large scars in many of the shallow seagrass beds when the propeller component of their motor strikes the shallow bottom and digs into the sediment. Satellite data show that these scars remain visible for years following the disturbance. Full recovery time is species dependent, and can take as long as 9.5 yrs., causing changes in species abundance as pioneering and opportunistic species fill in gaps more readily than do late successional species (Kenworthy *et al.* 2002). Further, most estimates of recovery is based on above ground biomass and do not take sediment into account. This, coupled with other anthropogenic disturbances such as dredging and degradation of water quality due to poor land use practices, has led to seagrass ecosystems being among the world's most threatened ecosystems (Fourqurean *et al.* 2012). Global estimates of seagrass loss are approximated to be as high as 5% annually, with roughly 1/3 of total seagrass ecosystems destroyed in the last 75 yrs. (Orth *et al. op. cit.*, Duarte *et al.* 2013). Public awareness of the impact of disturbances to seagrass beds is lacking (Orth *et al*. 2006). Current studies fail to address land managers' needs for making informed decisions regarding protection of these natural areas (Duarte *et al. op. cit.*).

Considering that the C sequestration capacity of seagrass is so high, proper management of these ecosystems is of the utmost importance. Studies indicate that if the rate of loss in seagrass ecosystems continues on its current trajectory, there exists the potential to release from sequestration up to 299 Tg of C yr^{-1} (Fourqurean *et al.* 2012). In terrestrial ecosystems, the importance of reducing the C flux associated with disturbance has been recognized, leading to forest conservation efforts by many organizations including the United Nation's initiative of Reduced Emissions for Deforestation and Degradation, which employs financial incentives for forest conservation (Fourqurean *et al. op. cit.*). Unfortunately, this level of recognition and protection does not currently extend to seagrass conservation, mostly likely due to lack of understanding.

As mentioned above, this question of C is of the very important given that as of 2013, the global average of atmospheric CO_2 reached 396 ppm (Dlugokencky and Tans 2014), which was the highest level in the last 800,000 yrs. (Lüthi *et al.* 2008). The rise in global atmospheric C concentration is due to increased burning of fossil fuels and land use changes (Solomon *et al.* 2007, McLeod *et al.* 2011), which, prior to disturbance, C was safely sequestered by natural processes. Given our current dependence on these fuels and our need for space for our expanding population, management efforts need to include not only a reduction in such emissions of C, but also careful management of the ecosystems such as seagrass which sequester C.

Several studies have been conducted recently, following the realization that the destruction of seagrass ecosystems could potentially be weakening the C sink capacity of the biosphere (Nellemann *et al.* 2009, Duarte *et al.* 2010) but the need still exists for more study on the dynamics of C loss in these ecosystems during the post-disturbance successional interval (Duarte *et al.* 2013). Further, the C studies that have been done on seagrass are mostly conducted with the Mediterranean species *Posidonia oceanica*, (L. Delile, 1813) which is very different from many other seagrass species (Lavery *et al.* 2013). Specifically, *Thalassia testudinum* (König, 1805) is the dominant species in many areas of the subtropical United States as it is a late successional species (Kaldy and Dunton 2000), potentially rendering it one of the most important species in terms of C sequestration in these areas. However, with wide variations in the traits important to C accumulation and storage among the 70 + species of seagrass found in the world, there is an urgent need of species-specific studies to avoid generalizing (Lavery *et al.* op cit.).

The goal of this study is to quantify the actual damage to the seagrass ecosystem as a C sink when a T. testudinum bed is damaged by a recreational boat scar and to extrapolate what the loss of seagrass in those areas would do to the C pool. This study will be conducted in the LLM Bay of South Texas and will examine the scarred area based on time from initial scarring event utilizing Google Earth imagery to determine relative age. Given that the recreational boats that we have observed to frequent the LLM typically draft less water than larger recreational or commercial vessels, I hypothesize that the disturbance will be localized to the top 20cm of the sediment layer. Additionally, I hypothesize that samples taken in disturbed areas will show reduced percentages of both organic C and N within the top 20cm of the core when compared to the undamaged control area, with the most dramatic differences between the scar and control samples being in the younger scars. This will progressively become less as the age of the scar increases, eventually reaching pre-disturbance levels when compared to the corresponding control data. This would indicate that the previous processing that had been done by that area in terms of C sequestration was removed and redistributed in the disturbance, likely through a combination of physical transport out of the disturbed area, as well as changes in the area's microbial activity. I also hypothesize that the initial loss of cover caused by the boat strike will result in an increase in the bulk density (BD) due to erosion and reduced accumulation of new material facilitated by loss of cover, both of which will also return to normal over time. These hypotheses will be tested utilizing older scars of relatively known ages to compare the older disturbance with undisturbed space nearby, to determine if, over time, these scars show a change in the level of C when compared to the undisturbed space. This information aims to be useful in future management decisions to provide insight as to the importance of protecting this vital ecosystem and important C sink.

CHAPTER II

MATERIALS AND METHODS

Study Area

This study took place in the Laguna Madre, a barrier island estuary extending from Corpus Christi Bay to South Padre Island on the Texas-Mexico border (Figure 1). Laguna Madre, coupled with the neighboring Laguna Madre de Tamaulipas, is one of only five hypersaline bays (salinity > 35 ppt) in the world (Onuf *et al.* 2007). The Laguna Madre maintains its high salinity due its shallow average depth (1 m) and low rainfall/freshwater input, allowing for higher evaporation than precipitation rates (Onuf *et al.* 1996). Hypersaline ecosystems as a whole are fragile ecosystems (Kjerfve *et al.* 1996). Water turnover time is long, which can lead to a decline in water quality following even modest disturbance (Kjerfve *et al.* op cit.).

Seagrass thrives in the Laguna Madre for a number of reasons. Large land tracts owned by businesses such as King Ranch as well as the protected space provided by Laguna Atascosa National Wildlife Refuge aide in keeping the western shore of the Laguna Madre largely undeveloped, where The Nature Conservancy and Padre Island National Seashore does the same for the eastern embankment (Onuf *et al. op cit*.). The flat land relief surrounding Laguna Madre and low rainfall allow for water clarity adequate for seagrass growth due to low runoff (Onuf *et al.* op cit.). Further, the completion of the Gulf Intercoastal Waterway through the Laguna Madre in 1949 created a permanent connection between the upper and LLM as well as increased flow between the Laguna Madre and the Gulf of Mexico (Onuf *et al.* op cit.).

From an anthropogenic standpoint, South Padre Island and LLM are popular tourist destinations, attracting over 1 million visitors annually (City of SPI Convention and Visitors Bureau). The seagrass beds provide nursery habitat and consequently excellent fishing for the area (Tunnell 2001). Further, LLM supports the only significant population of eastern oysters (*Crassostrea virginica*, Gmelin 1791) south of Corpus Christi, TX (Tunnell *op. cit*.) and is the primary overwintering point for redhead ducks (*Aythya americana* Eyton, 1838), who feed almost exclusively on the roots and rhizomes of the shoal grass (*Halodule wrightii* Ascherson, 1868) found along the shoreline and blended into the *T. testudinum* meadows (Onuf *et al. op cit*.). Previous studies have determined that the total monetary value of seagrass in Texas when considering distribution for shoreline protection, recreational value, and commercial fishery harvest exceeds 12.6 million dollars annually (Dunton, unpub data; CCBNEP, 1995). Expansion pressure from the growing tourism industry, coupled with the island's popularity as a water sport and recreational fishing destination causes a detrimental clash between the needs of the area as an economic driver with the needs of the area ecologically (Orth *et al.* 2006).

Conducting studies in this area is imperative to both the understanding if this area's role in carbon sequestration as well as to the importance of protection. Previous work by Pulich *et al* (1997) in the Redfish Bay/ Harbor Island area near Corpus Christi found that rates of seagrass loss are on the rise, and are largely due to water quality issues as well as mechanical damage by recreational boaters. Land managers are already faced with the task of developing management strategies that work from both an economic as well as an ecological perspective, even though the data do not currently exist to make those decisions responsibly.

Experimental Design

This study was conducted on seagrass ecosystems of the eastern shores of the LLM within the Laguna Madre Bay system in Texas. The Laguna Madre is home to three major species of seagrass; *H. wrightii*, *Syringodium filiforme (*Kützing, 1860), and *T. testudinum* (Onuf *et al. op cit*.). Shoal grass is a superior colonizer, historically dominating the Laguna Madre as it is able to withstand salinities exceeding 60 ppt (Onuf *et al. op cit*.). Following the above mentioned influx of seawater after the channel was completed, the bay experienced a regime shift to increasing cover of *S. filiforme* and eventually to *T. testudinum*, which is the late successional species in the region (Onuf *et al. op cit*.). Fifteen sampling sites (Figure 2) were selected that were selected by primary dominance by turtle grass (*T. testudinum*) with the assumption that this species would be the most influential in terms of long term C cycling in the area because of their late successional status.

The study's primary objective was to quantify the amount of C stored in the seagrass beds and determine how that C pool is affected by boat scarring over time. Boat scars occur when a vessel is operated in water shallow enough to allow the boat's propeller to come in contact with the sediment, which usually occurs when the water is <1 m when the tide is low (Zieman, 1976). Given that the boat is being propelled forward while in contact with the bottom, a long section of seagrass bed can be disturbed. The level of initial disturbance is a function of water depth (Sargent *et al* 1995) which determines how long of a distance the propeller remains in contact with the sediment and how far down it digs. Fortunately, seagrasses create large, dense mats of roots which, if largely undisturbed, can replace the above-ground materials that were lost in less than 2 years (Macreadie *et al* 2014). Scar damage that extends into root layer however, take more time. Following that initial disturbance, wave action can lead to further sediment loss, deepening the scarred area (Eleuterius 1987) as well as a reduction in the fine sediment within the disturbed space (Zieman *op cit*.).

The original plan for this study included making boat scars of known ages and depths. In the state of Texas however, making a boat scar is a Class C misdemeanor, carrying with it a $500.00 fine. The necessary permits to create these more controlled conditions were not granted and therefore the study was completed using historic scars found utilizing Google Earth imagery ranging from 2005 to 2014. While this method did not allow us to look at initial scar depth, we were able to bin the scars into time spans in which it was created by utilizing the historic imagery of the area. This method was beneficial in that it helped determine that the scars found met our criteria for sampling. To obtain the reflectance necessary for a scar to be visible in Google Earth imagery, the above ground biomass would have had to been removed in the scarring event so that mineral soil was exposed. Further, although the depth was not obtainable from Google Earth, knowing the initial depth was not necessary given that the focus of the study is on stored C changes. No recreational boat would create a scar one meter in depth, which is the target depth of this study, and depending on sedimentation in the area, the amount of lost or gained sediment from scar inception to scar coring would not be comparable among sites anyway.

Initial scar selection was completed during the winter of 2014-2015. Google Earth imagery for the LLM was available for January of 2014, 2011, 2009, 2006, and 2005. This allowed for the creation of bins of age ranges 1-<4 (group 2), 4-<6 (group 3), 6-9 (group 4), and 10+ (group 5) that did not overlap. A fifth bin of 0-1 yrs (group 1) was added using sonar imagery collected 2 weeks apart with the aim of creating a smaller and more new time window than what Google Earth had available. Site selection was done by finding scars in current imagery and tracing back how far into the past imagery the same scar could still be located. The same approach was taken with the site collected from the sonar images, although in this case, the earlier sonar image was simply compared to the later one. A minimum of two GPS coordinates were then collected for each site from within the scar so that the path between the two could be traveled, thus ensuring that the correct scar was located.

A total of six sediment cores were collected from each site; three from the scarred area and three from the surrounding seagrass within three meters of the scar for use as a control. The coring device use to collect the cores was built for this project so that the cores would be longer than those of commercially available corers as well as be able to be kept and frozen. This device is pictured in Figure 3. Collection of these cores was typically done in one day for each site, although some spanned multiple days but never took longer than 5 days. Once collected, the cores were transported back the University of Texas Rio Grande Valley (UTRGV) Coastal Studies Laboratory where they were frozen until subsampled.

Subsampling of the cores consisted of either removing a small plug of sediment from the desired depth location in the core or removing the entire depth location from the core and processing the whole section. The difference in subsampling methods was a product of time management and space. The subsamples done as a small plug were ideal given that we were left with the majority of the core in the event that we needed it again. The problem was that the process was very time consuming and storing frozen cores became constrained as more cores came in. The methods of sub sampling and the calculations involved in correcting for compression as well as the specifics of subsampling are discussed later in this document (Appendix A).

Once subsampled, the samples were weighed, dried at 60° C to a constant weight (from 3.29-331.60 g, depending on subsampling method and compression correction), and weighed again to obtain dry weigh and BD. From there, the samples were homogenized and brought to the UTRGV Brownsville campus, where a portion of the samples were rolled and ran on an elemental analyzer (Costech ECS 4010, Valencia, CA) for total C and N. Another 0.5 g portion of each of the samples was heated in a muffle furnace at 500° C for 4 h to remove the organic content. The dried sample was re-weighed to establish the percent organic content and then re-rolled and ran on the elemental analyzer as an inorganic sample. This established the amount of organic C in the sediment samples as well as compare the elemental analyzer results to the results from the muffle furnace.

Statistical Analysis

Statistical analyses were largely completed utilizing JMP (SAS) and SPSS (IBM). Absolute differences in %Corg, % N, BD, and both C and N pools were tested using 2 separate two way analyses of variance (ANOVA) utilizing treatment as the first factor and either age or depth as the second factor. Post hoc HSD tests were conducted to detail which particular age groups were different.

Given that the greatest damage/differences were expected to be in the top 20 cm, additional tests were conducted on the upper 20cm of the core. These were analyzed as a two way ANOVA using treatment, depth horizon (<20 cm and 20-70 cm) and the interaction of the two factors as parameters for analysis. They were then analyzed again, this time using treatment, depth, and the interaction of treatment and depth. Another set of HSD tests were conducted for each to give homogenous subsets. The categories for analysis in this manner were %C, BD, and C pools. %N and N pools were not analyzed this way given that a few sites were missing N data below 20 cm and would have caused an error in reporting the lower depths.

To account for variations between sites, relative differences between the scar and control samples were established by subtracting the scar from the control (C-S). These were graphed for visual representation as to where the differences lie when taking into account both age group and depth. A one way ANOVA analyzing the effect of depth as well as a two way ANOVA that analyzed both age group and depth were conducted on %C, BD, and the C pool. The N pools and the %N were analyzed using 2 one way ANOVAS, using depth and age group respectively as factors.

CHAPTER III

RESULTS

Organic C Percentage

The percentage of organic C present in the sediment decreased hyperbolically as depth increased, with the greatest change being found in the top 20cm (Figure 4A). A two way ANOVA established that there was a significant difference ($F_{0.05\ (1\ d.f.)} = 6.929$, $p = 0.009$) between the scar and control treatments. Difference in age class we also found to be significantly different ($F_{0.05\ (3\ d.f.)} = 11.619$, $p = <0.001$) although the interaction was not significant ($F_{0.05\ (3\ d.f.)} = 1.294$, $p = 0.275$). A Tukey's HSD post hoc analysis determined that age classes 2, 3, and 5 were one homogenous subset and age class 4 was a separate homogenous subset. A second two way ANOVA found that both treatment ($F_{0.05\ (1\ d.f.)} = 11.2000$, $p = 0.001$) and depth ($F_{0.05\ (11\ d.f.)} = 48.041$, $p = <0.001$) were significant although the interaction of the two factors was not ($F_{0.05\ (11\ d.f.)} = 0.986$, $p = 0.457$). A Tukey's HSD analysis found that the differences in depth were significantly different in the upper layers of the sediment and became increasingly similar as the samples became deeper. In the depth HSD analysis, there were a total of 5 significantly different depth layers. When considering the interaction of treatment and depth, there were 7 layers, with the most significant differences between the depth groups being in the top 20cm.

For further analysis, the samples were grouped into two parts, the first being the area most susceptible to damage (<20 cm) and the other being less likely to sustain damage (20-70 cm). The results showed that there was a significant difference between both treatment ($F_{0.05\ (1\ d.f.)}$ =13.166, p = 0.001) as well as depth layer ($F_{0.05\ (1\ d.f.)}$ =303.664, p = <0.001). There was also a significant difference between the interaction of the two ($F_{0.05\ (1\ d.f.)}$ =4.986, p = 0.026). A Tukey's HSD analysis showed that there was no difference between the scar and control samples at the 20-70 cm depth. When looking at the <20 cm layer however, there was not only a difference from the deeper section, but also a significant difference between the scar and control treatments (Figure 4B). Focusing solely on the 20 cm layer, a second two way ANOVA showed a significant difference between both age group ($F_{0.05\ (3\ d.f.)}$ =12.101, p = <0.001) and treatment ($F_{0.05\ (1\ d.f.)}$ =5.410, p = 0.021), although the interaction was not considered significant ($F_{0.05\ (3\ d.f.)}$ =1.628, p = 0.183). A Tukey's HSD found that the difference in age group specifically was at group 4 (6-9 years) and when considering the interaction of both age group and treatment, there were 4 different connected letter groupings, showing a mix of significant differences between age groupings and treatments.

The relative difference in %C was graphed by age group with the top section of sediment (<20cm) graphed separately from 20-70cm (Figure 4C). The results show little difference in the lower layer of sediment (20-70cm) as indicated by its proximity to zero on the y-axis. The top layer however (<20cm) shows a positive difference, indicating that there is a reduction of %Corg when sampling in a scarred area. This is most pronounced in the younger age groups (1-4 and 4-6). The difference is less in age groups 6-9. The point at which the line reaches zero is where there is no longer a difference between the scarred and control samples. This occurs between the 6-9 and 10+ age groups.

A one way ANOVA of the relative difference between the control and scar treatment (C-S) utilizing depth as a factor found no significant difference between age groups($F_{0.05\ (11\ d.f.)}$ =1.020, p = 0.450) overall. When analyzed by depth group as mentioned above, a two way ANOVA found significant differences between the effects of age group ($F_{0.05\ (3\ d.f.)}$ =5.571, p = 0.003), depth group ($F_{0.05\ (1\ d.f.)}$ =10.192, p = 0.003), and the interaction ($F_{0.05\ (3\ d.f.)}$ =5.800, p = 0.003) of the two.

Organic N Percentage

A two way ANOVA found that there was a significant difference in N percentage between treatments ($F_{0.05\ (1\ d.f.)}$ =3.943, p = 0.048) as well as age groups ($F_{0.05\ (3\ d.f.)}$ =13.981, p = <0.001) (Figure 5A). The interaction ($F_{0.05\ (3\ d.f.)}$ =1.639, p = 0.181) of the two was not significant. A Tukey's HSD analysis of the age groups showed that age group 4 (6-9 years) was different from the others, as was seen in the percent C analysis. A second ANOVA was conducted with treatment and depth (0-20 cm). This analysis found that there were significant differences between treatment ($F_{0.05\ (1\ d.f.)}$ =4.324, p = 0.039) and depth ($F_{0.05\ (3\ d.f.)}$ =20.546, p = <0.001) but no significance in the interaction ($F_{0.05\ (3\ d.f.)}$ =0.298, p = 0.827) of the two.

Analysis of the relative difference between the control and scar treatments showed no significant difference by depth ($F_{0.05\ (3\ d.f.)}$ =0.332, p = 0.802) (Figure 5B). An additional one way ANOVA found that while there is a graphical trend toward a difference in the treatments by age group, it is not statistically significant ($F_{0.05\ (3\ d.f.)}$ =3.170, p = 0.064).

Bulk Density

Sediment BD increased with depth. A two way ANOVA showed that the effects of both treatment ($F_{0.05\ (1\ d.f.)}$ =34.778, p = <0.001) and depth ($F_{0.05\ (11\ d.f.)}$ =59.266, p = <0.001) were significant, with the interaction ($F_{0.05\ (11\ d.f.)}$ =1.762, p = 0.057) of the two factors showed a strong trend toward significance as well. When analyzing the effects of treatment and age group however, both treatments ($F_{0.05\ (1\ d.f.)} = 21.716$, $p = <0.001$) ($F_{0.05\ (3\ d.f.)} = 30.246$, $p = <0.001$)(respectively) as well as the interaction were significant ($F_{0.05\ (3\ d.f.)} = 03.547$, $p = 0.014$) (Figure 6A). A Tukey's post hoc HSD analysis of the interaction between treatment and age group found that scarred areas in age groups 2 (1-<4 years) and 3 (4-<6 years) were similar and that age group 5 (10+ years) and all of the controls had statistically similar BD. Age group 4 (6-9 years) was not similar to any of the other groups.

Analysis of BD by depth grouping (<20 cm and 20-70 cm) revealed that there is significant differences between both treatment ($F_{0.05\ (1\ d.f.)} = 39.962$, $p = <0.001$) and depth layer ($F_{0.05\ (1\ d.f.)} = 426.119$, $p = <0.001$) as well as the interaction of the two ($F_{0.05\ (1\ d.f.)} = 12.528$, $p = <0.001$) (Figure 6B). Post hoc analysis of the interaction shows that there is no difference between the two deeper depth groupings between treatments however both of the <20 cm groupings are significantly different from each other as well as the more deep depth group. Given this finding, a second two way ANOVA was conducted utilizing only the <20 cm depth group with treatment, age group and the interaction as factors. The results showed a statistical significance with both effects ($F_{0.05\ (1\ d.f.)} = 34.779$, $p = <0.001$) ($F_{0.05\ (3\ d.f.)} = 17.502$, $p = <0.001$) (respectively) as well as the interaction ($F_{0.05\ (3\ d.f.)} = 5.303$, $p = 0.001$). Tukey's post hoc analysis of the interaction shows similarities between 3 out of the 4 age groups control treatments and the age group 5 (10+ years) scar treatment. Scar groups 2 and 3 (1-<4 and 4-<6) were significantly different from the controls and age group 5. A third group of statistically similar groups/treatments included both of the age group 4 (6-9 year) treatments as well as the control treatment of age group 3.

A one way ANOVA conducted on the relative difference in BD between the control and scar treatments (C-S) show a differing trend among the depths however the results were not statistically significant ($F_{0.05\ (11\ d.f.)}$ =1.846, p = 0.819) (Figure 6C). A two way ANOVA however showed a statically significant difference in BD between age group ($F_{0.05\ (3\ d.f.)}$ =18.361, p = <0.001) and depth layer (<20cm or 20-70 cm) ($F_{0.05\ (1\ d.f.)}$ =37.428, p = <0.001) as well as in the interaction of the two effects ($F_{0.05\ (3\ d.f.)}$ =6.392, p = 0.001). The post hoc analysis of the interaction shows different groups on a connecting letter report, although the connections span both depth groupings and various age groups.

Organic C Stocks

Two way analysis of the effects of treatment and age group on C stocks showed that while there was a significant difference between age groups ($F_{0.05\ (3\ d.f.)}$ =6.802, p = <0.001), there was no significant difference in the C stocks between treatments ($F_{0.05\ (1\ d.f.)}$ =1.424, p = 0.233) or the interaction of treatment and age group ($F_{0.05\ (3\ d.f.)}$ =0.334, p = 0.801) (Figure 7A). Tukey's post hoc of age group showed two groupings of statistically similar age groups; one including age groups 2, 3, and 4 and the other consisting of groups 4 and 5. A second two way ANOVA utilizing treatment and depth also found that while the effect of depth was significant ($F_{0.05\ (11\ d.f.)}$ =27.572, p = <0.001), the effect of treatment ($F_{0.05\ (1\ d.f.)}$ =1.883, p = 0.170) and the interaction of depth and treatment ($F_{0.05\ (11\ d.f.)}$ =0.928, p = 0.512) were not. Post hoc testing showed statistically similar groupings that included a group that made up the deepest two subsampling depths, two groups that made up the intermediate depths and a final group that included sampling depths 5-20 cm.

When analyzed by age grouping, there was no significant difference between treatment ($F_{0.05\ (1\ d.f.)}$ =0.347, p = 0.556), depth grouping ($F_{0.05\ (1\ d.f.)}$ =2.673, p = 0.102), or the interaction ($F_{0.05\ (1\ d.f.)}$ =2.439, p = 0.119) of the two (Figure 7B). The ANOVA was ran again, using only the data from the <20 cm age group with both treatment and age as factors. This showed a significant difference in age group ($F_{0.05\ (3\ d.f.)}$ =4.919, p = 0.002), however there was no statistical significance to the effect of treatment ($F_{0.05\ (1\ d.f.)}$ =0.373, p = 0.542) or the interaction ($F_{0.05\ (3\ d.f.)}$ =0.778, p = 0.507) of treatment and age group.

Analysis of the relative differences between scarred and control sites (C-S) in terms of the stored C pool showed a significant difference when considering the effect of depth grouping ($F_{0.05\ (1\ d.f.)}$ =5.422, p = 0.025) (Figure 7C), and marginally significant when considering the interaction of depth group and age group ($F_{0.05\ (3\ d.f.)}$ =2.581, p = 0.067). The effect of age grouping alone however was not significant ($F_{0.05\ (3\ d.f.)}$ =0.664, p = 0.579).

The average C stock of the LLM was 70.046Mg/ha when considering the top 92cm of sediment in our control areas. We also found that damage was localized to the top 20cm of sediment, which is where an average of 23.946Mg/ha of the abovementioned C stock is located, accounting for about 34% of the total organic C.

Organic N Stocks

The effect of age group on N stocks was found to be significant ($F_{0.05\ (4\ d.f.)}$ =4.449, p = 0.002) (Figure 8A) with the groups falling into 2 levels in a connected letter report. Age group 4 was in a group with 1 and 3. Age groups 2 and 5 were significantly different from 4 and age groups 1 and 3 were similar to both. The effect of treatment ($F_{0.05\ (1\ d.f.)}$ =0.803, p = 0.371) and the interaction of treatment and age group ($F_{0.05\ (4\ d.f.)}$ =1.379, p = 0.241) were not significant. Analysis of depth and treatment showed a significant difference in the effect of depth ($F_{0.05\ (3\ d.f.)}$ =16.879, p = <0.001), but no significance in the effects of treatment ($F_{0.05\ (1\ d.f.)}$ =0.904, p = 0.342) of the interaction of treatment and depth ($F_{0.05\ (3\ d.f.)}$ =0.394, p = 0.758). An analysis of the relative difference between the scar and control treatments (C-S) found no significant difference between age groups ($F_{0.05\ (3\ d.f.)}$ =0.565, p = 0.653) (Figure 8B).

The average N stock of the LLM in the control treatments was 1.71 Mg/ha when considering the top 20 cm sediment in our control areas (Table 2). The average N stock of the scarred area is 1.63 Mg/ha. This difference represents a 5% loss to the N pool between treatments.

CHAPTER IV

DISCUSSION

This study found that damage to *T. testudinum* caused by improper use of a recreational boat resulted in an increase in BD as well as a decrease in sedimentary %C, %N, and the overall C and N pool when compared to nearby undisturbed sediments. These changes are the result of propeller impact with the sediments redistributing material previously stored in the sediments as well as the resulting lasting effects of the damage. While some of this likely settled back out into the seagrass bed, material continued to be lost well after the initial damage was done. Visually, the center of the depression created by the propeller contained many pieces of shells, indicating that there was erosion of the lighter material from within the scar. This process, facilitated by the lack of cover, leaves the heavier material behind. Serrano et al (2016) found that similar mechanical destruction of seagrass beds in Western Australia caused a loss in the ability of seagrass meadows to sequester C given the loss of above ground biomass.

The simple act of having the organic, muddy material in the water column is a problem in itself as it blocks much needed light from the grasses below. Seagrasses in particular require a large amount of light. Material in the water column reduces light attenuation down to the plant necessary for photosynthetic production (Choice et al 2014). The growth allowed by this production increases above ground biomass leading to more material slowing water. This then allows for the material in the water column to settle out, which clears the water column and leads to the sequestration of suspended C and other material. It becomes a negative cycle however if the water is continually plagued with cloudiness, thus reducing light, which reduces growth (Choice et al 2014).

As noted above, the LLM was found to store an average of 70.046 Mg/ha of organic C within the sediments of *T. testudinum* beds. Unfortunately, propeller damage and the subsequent erosion affecting the top 20 cm of that stored sedimentary C potentially redistributed 1/3 of that C pool. *T. testudinum* has typically been found to be an erosion tolerant species (Cabaço *et al* 2008). Unfortunately, through the removal of aboveground biomass, further collection of organic C into the seagrass bed is inhibited (Serrano *et al op cit*.). Alongi *et al* (2016) published that seagrass beds in Indonesia hold an average of 119.5 Mg/ha in the sediments and that combine with mangroves, Blue Carbon ecosystems there are home to roughly 17% of the stored C in the world (Alongi *et al op cit*.). Fourqurean *et al* (2012) reports values for C pools ranging from around 48.7 Mg/ha in the North Atlantic to 150.9 Mg/ha in the Tropical Western Atlantic (Howard *et al op cit*., Fourqurean *et al* 2012). The variation in these values may be the result of the lack of deep sampling data when it comes to seagrass carbon stores, forcing the mathematical calculation of the C pool to a certain depth utilizing only surficial sediment samples (Fourqurean *et al op cit*).

Changes to the LLM over time could have also potentially impacted the historical capacity of the bay as a C sink. The bottom of the LLM was almost completely covered by seagrass in the 1960's, however sometime between the sampling periods of 1965 and 1974, large spaces became bare, with some areas remaining bare (Onuf *et al op cit*). There was also a regime shift from H. wrightii to S. filiforme, to T. testudinum in the last 30 years. (Onuf *et al op cit*.) These changes have the ability to effect the sequestration ability of the bay as different species sequester C and N at different rates (Lavery *et al op cit*.)

The shallow nature of large quantities of these C pools mean that propeller scars alone have the ability to easily redistribute a large quantity of previously sequestered C. Further, the depth of damage is a function of the position and width of the propeller as well as the depth of the water and the topography of the bottom that the propeller comes into contact with. Given that the LLM bay has an average depth of less than 3 ft., this puts large areas at risk.

The difference in N pools between treatments illustrates the need for continued studies on the fate of stored N following mechanical damage in these shallow waters. While there is a growing body of work concerning C pools in seagrass, information on the N pool is lacking. It has been found though that seagrass very influential in terms of the N cycle. A study publish in 1998 found that seagrass moved large quantities of N into material that degraded at a lesser rate than free N, thus reducing it's availability to phytoplankton and macro algae that could cause harmful booms in the presence of that quantity of N (Risgaard-Petersen *et al* 1998). By allowing these pools to be redistributed, they are made available again, potentially facilitating increased algal and phytoplankton activity.

Upwards of 50% of N uptake comes from the roots (Alongi *et al* 2008). Damage to the top 20cm of the sediment means that there is the potential for extensive root damage given that the first 20 cm of the below ground space includes the majority of the root structure of the plant. Root loss is devastating to the plants ability to take up nutrients, given that pore water has more nutrients than are found in the water column (Stapel *et al* 1996). The increased bulk density stemming from the erosion that damaged areas experience would tend to decrease pore water, thus lessening the available nutrient rich water to the seagrass.

In the case of this research, all scars utilized in the statistical analysis were garnered using Google Earth satellite data. In the case of the 0-1 year scars however, the damage may have not been deep enough to have damaged the root structure, thus not creating the same issues as seen in the Google Earth scars. The two sonar scans done to find the scars were two weeks apart, with all areas being sampled 2 weeks or less from the second scan. Therefore none of the scars sampled were more than a month old for this age group. Even still, all three of the scars showed regrowth of the above ground biomass, with the scar only being recognizable as a scar by the shorter, more epiphyte free blades that filled the space. If this was in fact the case that the below ground root structure was not damaged, then this area would recover much more quickly having regained its cover. A study conducted in Florida came to similar conclusions. Less severe (shallow scars) recovered in less than three months from initial inception (Fonseca *et al* 1998). Given these findings, the 0-1 age group was determined to have been too dissimilar from the rest of the scars and removed from the analysis.

CHAPTER V

FUTURE WORK

As discussed above, there is a dramatic difference in outcome depending on the depth of damage. While some scars remain easily visible for 10+ years, others are nearly healed in a month. And while our results point to a healed environment after a time, it is important to remember that the "healed environment" we speak of is in terms or the parameters we looked at; C, N, and bulk density. These scars were all visible scars, both to satellite imagery as well as to the human eye when snorkeling over it to find the correct scar. The landscape is changed. The habitat in terms of the food and cover that the seagrass provides has changed. With the exception of the 0-1 year scars, all others had very sparse if any seagrass growing in the scar. The space was instead full of shells. Some scars had *H. wrightii or Halimeda (Lamarck 1813)* inhabiting the scarred space, neither of which provide the same cover that *T. testudium* does. And while growth of any kind seems to be a step in the right direction, it's a slow process.

Even more alarming is how often this occurs. Any tidally influenced body of water can be challenging to navigate given the fluxuations in water depth. Further, given that the seagrass provides such important ecosystem services, it is often sought out by anglers for the abundance of fish that frequent the seagrass beds. This has the potential however to cause repeated damage, making it more difficult for these areas to recover.

The information presented here is initial base work. Prior to this, no work of this kind had been done in the LLM. We learned several things about the bay, the legality of sampling, and our initial question that would be useful to take in to consideration for future work.

In terms of repeating this experiment, it would be useful to do more replicates at each an age group. The variability we experienced in the bay made comparison difficult when only using three replicates of each age group. The flip side of that however, is that coring to a 92 cm depth is a difficult and labor intensive process. It is also dependent on good weather and tides. Adding more sites would require more help to complete in a timely manner.

The impact of the variability in the bay could be lessened if the original plan of creating the scars ourselves and monitoring them from the scar inception could be carried out. This would allow us to control scar size, depth, and location, eliminating much of the variation. Unfortunately as mentioned earlier, causing a propeller scar is a class C misdemeanor and carries fines with it. At the time of this study, we were unable to secure permission from Texas General Land Office and Texas Parks and Wildlife to complete that portion of the original experimental design. This is understandable as at the time the experiment was proposed to them, there was no data available for the LLM to support the need for a study that would cause that sort of damage. Moving forward with the work presented here however, we feel that these entities might be more interested in allowing such work to be conducted.

This study would have also greatly benefitted from smaller time windows. Using Google Earth to locate scars was inexpensive and relatively simple however we were bound to the dates that Google Earth had for satellite imagery. This imagery needs to be very clear to be useful in identifying scars and unfortunately that was not always the case. Cloud cover, fog, and wind driven waves made several time frames unusable which resulted in long and uneven age groupings.

Using sonar imagery would be beneficial in that we could get the exact date of the scan as well as complete scans at regular intervals to create even age groupings. Further, these scans could be used to quantify damage over a time period as well as length of time that an area remains visibly scarred. As mentioned earlier, the scans that we completed for the 0-1 age group were timed too close together. If more scans had been done over a longer time scale however, this would have been far superior to our Google Earth method.

It is our hope that the information found in this manuscript will be useful and informative to members of the scientific community, the public, and to policy makers. Seagrasses provide so many ecosystem as well as economic services to areas all around the world. Its protection is essential to the seagrass's ability to continue to provide those services to us now, as well as in the future.

REFERENCES

Alongi, D.M., Murdiyarso, D., Fourqurean, J.W., Kauffman, J.B., Hutahaean, A., Crooks, S., Lovelock, C.E., Howard, J., Herr, D., Fortes, M. and Pidgeon, E., 2016. Indonesia's blue carbon: a globally significant and vulnerable sink for seagrass and mangrove carbon. *Wetlands Ecology and Management*, *24*(1), pp.3-13.

Cabaço, S., Santos, R. and Duarte, C.M., 2008. The impact of sediment burial and erosion on seagrasses: a review. *Estuarine, Coastal and Shelf Science*, *79*(3), pp.354-366.

City of South Padre Island Convention and Visitors Bureau. *About South Padre Island* http://www.sopadre.com/about/

Chambers, J.Q., Higuchi, N., Tribuzy, E.S. and Trumbore, S.E., 2001. Carbon sink for a century. *Nature*, *410*(6827), pp.429-429.

Choice, Z.D., Frazer, T.K. and Jacoby, C.A., 2014. Light requirements of seagrasses determined from historical records of light attenuation along the Gulf coast of peninsular Florida. *Marine pollution bulletin*, *81*(1), pp.94-102.

Dlugokencky, E., and Tans, P., 2014. Trends in Atmospheric Carbon Dioxide. *NOAA/ESRL* www.esrl.noaa.gov/gmd/ccgg/trends/

Duarte, C.M., and Chiscano C.L., 1999. Seagrass Biomass and Production: A Reassessment. *Aquatic Botany*, 65(1–4), 159–174.

Duarte, C.M.; Kennedy H.; Marbà N., and Hendriks I., 2013. Assessing the Capacity of Seagrass Meadows for Carbon Burial: Current Limitations and Future Strategies. *Ocean & Coastal Management*, 83(2013), 32–38.

Duarte, C.M.; Marbà N., Esperança G.; Fourqurean, J.W.; Beggins, J; Barron, C., and Apostolaki, E.T., 2010. Seagrass Community Metabolism: Assessing the Carbon Sink Capacity of Seagrass Meadows. *Global Biogeochemical Cycles*, 24(4)

Eleuterius, L. N. 1987. Seagrass ecology along the coasts of Alabama, Louisiana, and Mississippi. Preceedings of the Symposium on Subtropical-tropical Seagrasses of the Southeastern United States. Durako, M.J., Phillips, R. C., and Lewis III, R. R.,(eds). St. Petersburg Fl. Mar. Res. Pub. 42, Fonseca, M.S., Kenworthy, W.J. and Thayer, G.W., 1998. Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters.

Fourqurean, J.W.; Duarte C.M.; Kennedy H.; Marbà N.; Holmer, M.; Mateo, M.A.; Apostolaki, E.T.; Kendrick, G.A.; Krause-Jensen, D.; McGlathery, K.J., and Serrano, O., 2012. Seagrass Ecosystems as a Globally Significant Carbon Stock. *Nature Geoscience,* 5(7): 505–509.

Fourqurean, J.W., Kendrick, G.A., Collins, L.S., Chambers, R.M. and Vanderklift, M.A., 2012. Carbon, nitrogen and phosphorus storage in subtropical seagrass meadows: examples from Florida Bay and Shark Bay. *Marine and Freshwater Research*, *63*(11), pp.967-983.

Greiner, J.T.; McGlathery K.J.; Gunnell J., and McKee B.A., 2013. Seagrass Restoration Enhances "Blue Carbon" Sequestration in Coastal Waters. In: Just Cebrian, (ed.), *Public Library of Science ONE*, 8(8), e72469.

Howard, J; Hoyt, S.; Isensee, K.; Telszewski, M., and Pidgeon, E., (eds.) 2014. *Coastal Blue Carbon: Methods for Assessing Carbon Stocks and Emissions Factors in Mangroves, Tidal Salt Marshes, and Seagrasses.* Conservation International, Intergovernmental Oceanographic Commission of UNESCO, International Union of Conservation of Nature. Arlington, Virginia USA.

Kaldy, J.E., and Dunton, K.H., 2000. Above and Below Ground Production, Biomass, and Reproductive Ecology of *Thalassia testudinum* (turtle grass) in a Subtropical Coastal Lagoon. *Marine Ecology Progress Series,* 193. 271-283.

Kennedy, H.; Beggins J.; Duarte, C.M.; Fourqurean, J.W.; Holmer, M.; Marbà N., and Middleberg, J.J., 2010. Seagrass Sediments as a Global Carbon Sink: Isotopic Constraints. *Global Biogeochemical Cycles,* 24(4)

Kenworthy, W.J.; Fonseca M.S.; Whitfield P.E., and Hammerstrom K.K., 2002. Analysis of Seagrass Recovery in Experimental Excavations and Propeller-Scar Disturbances in the Florida Keys National Marine Sanctuary. *Journal of Coastal Research*, Special Issue No. 37, pp. 75–85.

Kjerfve, B.; Schettini, C.; Knoppers, B.; Lessa, G., and Ferreira, H., 1996. Hydrology and Salt Balance in a Large Hypersaline Coastal Lagoon. *Estuarine, Coastal, and Shelf Science*, 42(6), 701-725

Lavery, P. S.; Mateo M.A.; Serrano O., and Rozaimi M., 2013. Variability in the Carbon Storage of Seagrass Habitats and Its Implications for Global Estimates of Blue Carbon Ecosystem Service. In: Valentine, J.F., (ed.), *Public Library of Science ONE,* 8(9), e73748.

Lo Iacono C.; Mateo M.; Gracia E.; Guasch, L.; Carbonell, R.; Serrano, L.; Serrano, O., and Danobeitia, J., 2008. Very High-Resolution Seismo-Acoustic Imaging of Seagrass Meadows (Mediterranean Sea): Implications for Carbon Sink Estimates. *Geophysical Research Letters,* 35(18)

Lüthi D.; Le Floch M.; Bereiter B.; Blunier, T.; Barnola, J.; Siegenthaler, U.; Raynaud, D.; Jouzel, J.; Fisher, H.; Kawamura, K., and Stocker T.F., 2008. High-resolution Carbon Dioxide Concentration Record 650 000-800 000 Years Before Present. *Nature,* 453(7193), 379-82.

Macreadie, P.I.; Baird M.E.; Trevathan-Tackett S.M.; Larkum A.W.D., and Ralph P.J., 2014. Quantifying and Modelling the Carbon Sequestration Capacity of Seagrass Meadows: A Critical Assessment. *Marine Pollution Bulletin*, 83(2), 430–439.

Macreadie, P.I., York, P.H., Sherman, C.D., Keough, M.J., Ross, D.J., Ricart, A.M. and Smith, T.M., 2014. No detectable impact of small-scale disturbances on 'blue carbon'within seagrass beds. *Marine biology*, *161*(12), pp.2939-2944.

McLeod, E.; Chmura, G.L.; Bouillon, S.; Salm, R.; Bjork, M.; Duarte, C.M.; Lovelock, C.E.; Schlesinger, W.H., and Silliman, B.R., 2011. A Blueprint for Carbon: Toward an Improved Understanding of the Role of Vegetated Coastal Habitats on Sequestering CO2. *Frontiers in Ecology and the Environment,* 9(10), 552-560.

Montagna, P. A, Holt, S. A., Ritter, C., Herzka, S., Dunton, K. H. 1998. Characterization of Anthropogenic and Natural Disturbance on Vegetated and Unvegitated Bay Bottom Habitats in the CCBNEP Study Area. CCBNEP Publication 25A

Morton, R. A., White, W. A., 1997. Characteristics of and corrections for core shortening in unconsolidated sediments. *Journal of Coastal Research* 13, 761-769

Nellemann, C. and Corcoran, E. eds., 2009. *Blue carbon: the role of healthy oceans in binding carbon: a rapid response assessment*. UNEP/Earthprint.

Onuf, C L.; Handley, L.; Altsman D., and DeMay R., 2007. Laguna Madre. Handley, L., Altsman, D., and DeMay, R., (eds.) *Seagrass Status and Trends in the Northern Gulf of Mexico*: *1940–2002.* http://www.arlis.org/docs/vol1/234196545/lagunamadre.pdf

Onuf, C.P., 1996. Seagrass responses to long-term light reduction by brown tide in upper Laguna Madre, Texas: distribution and biomass patterns. *Marine Ecology Progress Series*, *138*, pp.219-231.

Orth, R.J.; Timjb C.; Dennison, W.C.; Duarte, C.M.; Fourqurean, J.W.; Heck Jr., K.L.; Hughes, A.R.; Kendrick, G.A..; Kenworthy, W.J., and Olyarnik, S., 2006. Ecosystem-Based Management. *BioScience,* 56(12), 987-996

Pulich, W., Blair, C. and White, W.A., 1997. *Current status and historical trends of seagrasses in the Corpus Christi Bay National Estuary Program study area*. Texas Natural Resource Conservation Commission.

Riesgaard-Petersen, N., Dalsgaard, T., Rysgaard, S., Christensen, P. B., Borum, J., McGlathery, K. Nielsen, L. P. 1998. Nitrogen balance of a temperate eelgrass Zostera marina bed. *Marine Ecology Progress Series*. Vol. 174, 281-291

Sargent, J. F., Leary, T. J., Crewz, D. W., Kruer, C. R. 1995. Scarring of Florida's seagrasses: assessment and management options. FMRI Tech Rep. TR-. Florida Marine Research Institute, St. Petersburg, FL. 37

Serrano, O., Ruhon, R., Lavery, P.S., Kendrick, G.A., Hickey, S., Masqué, P., Arias-Ortiz, A., Steven, A. and Duarte, C.M., 2016. Impact of mooring activities on carbon stocks in seagrass meadows. *Scientific reports*, *6*.

Solomon, S. ed., 2007. *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC*(Vol. 4). Cambridge University Press.

Stapel, J., Aarts, T.L., van Duynhoven, B.H., de Groot, J.D., van den Hoogen, P.H. and Hemminga, M.A., 1996. Nutrient uptake by leaves and roots of the seagrass Thalassia hemprichii in the Spermonde Archipelago, Indonesia. *Marine Ecology Progress Series*, *134*, pp.195-206.

Tunnell Jr., J. 2001 Protect the Laguna Madre. Corpus Christi Caller Times. http://www.nps.gov/pais/naturescience/laguna.htm

Waycott, M., Duarte, C.M., Carruthers, T.J., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck, K.L., Hughes, A.R. and Kendrick, G.A., 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences*, *106*(30), pp.12377-12381.

Zieman, J. C. 1976. The ecological effects of physical damage from motor boats on turtle grass in southern Florida. Aquatic Botany. 2:127-139

APPENDIX

APPENDIX A

FIGURES AND TABLES

Figure 1: Study area: Lower Laguna Madre, Cameron Country TX

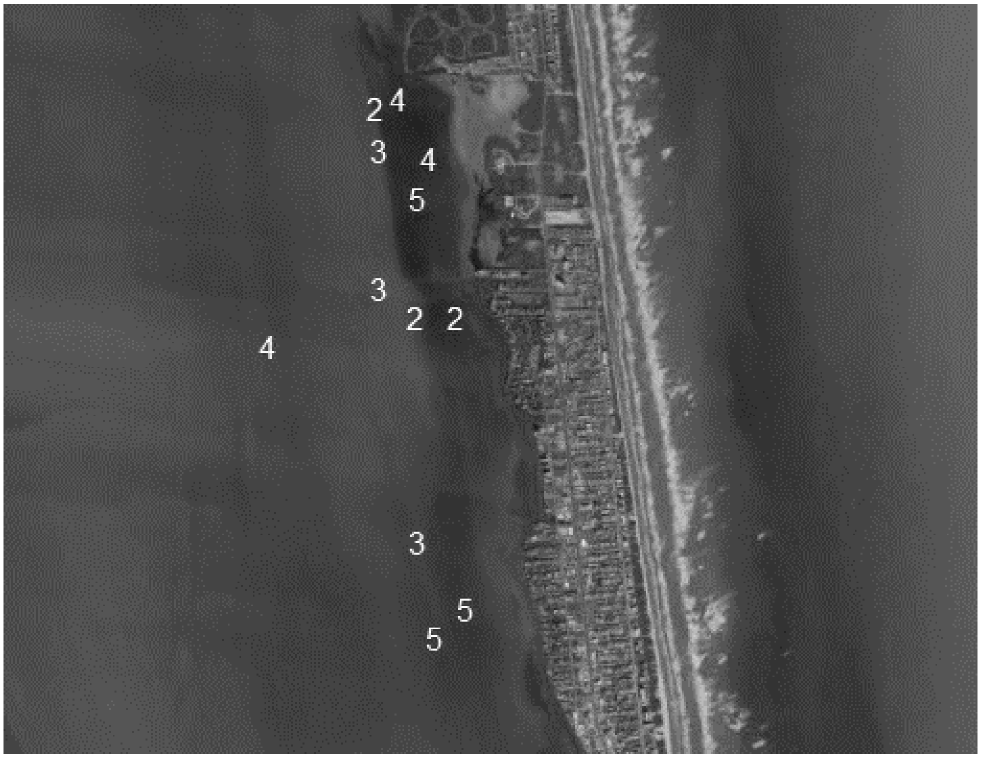

Figure 2: Sampling collection sites in the Lower Laguna Madre. Numbers represent the age grouping of the scar.

Figure 3: Parts of the sediment corer. The zip ties through the liner are not necessary, but are helpful in pulling the liner free of the corer barrel.

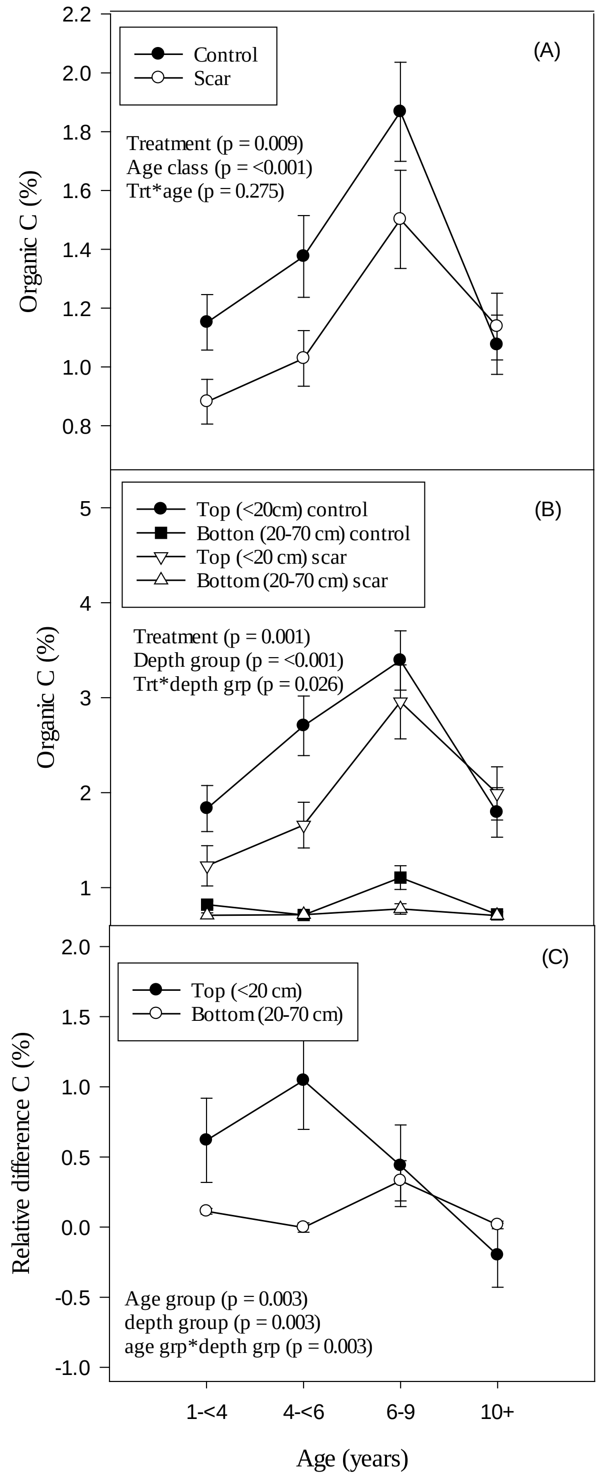

Figure 4: %C graphs by treatment, depth group, and relative difference. Panel (A) depicts mean %C by age group and treatment. Panel (B) shows the % organic C separated by depth layer. Panel (C) shows the relative difference (C-S) between the depth groups and across the designated age groups. Zero on the Y-axis indicates no difference in the control and scar treatments at the age group. A positive value shows a higher %C in control treatments.

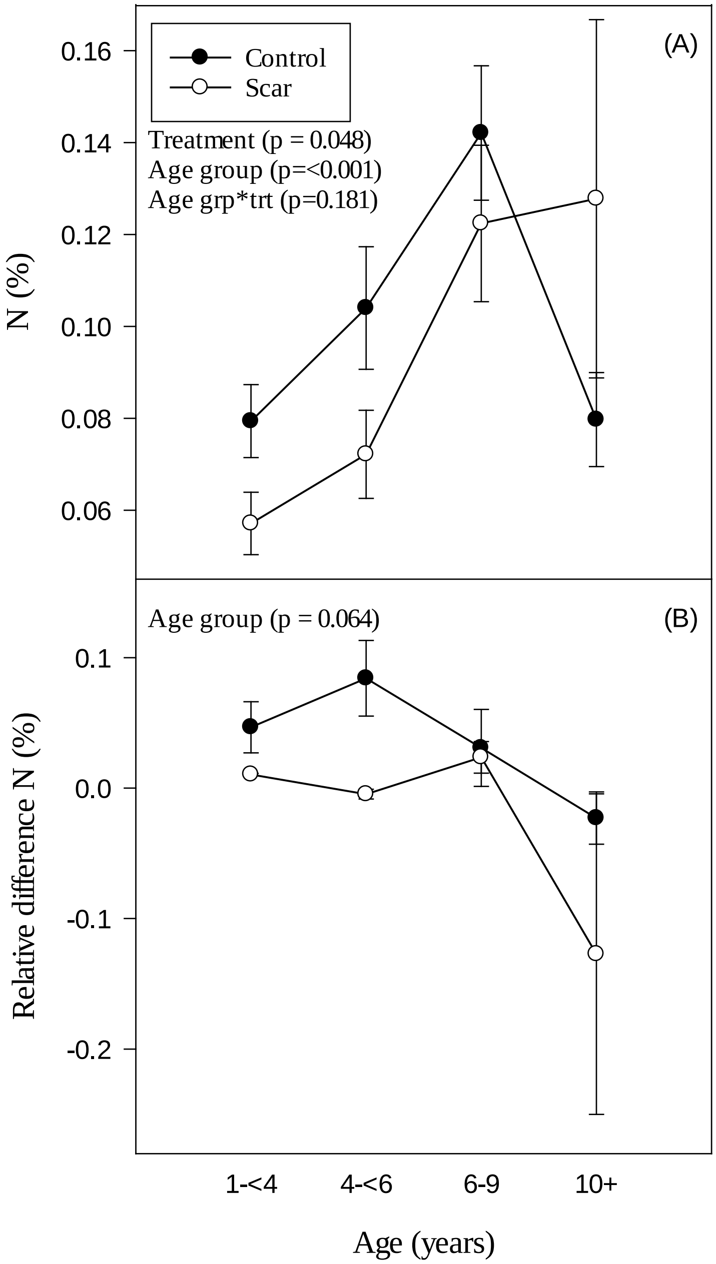

Figure 5: %N Graphs by Treatment and Relative Difference. Panel (A) depicts mean %N by treatment over the age groupings. Panel (B) shows the relative differences between the treatments (C-S), separated by depth grouping (<20 cm and 20-70cm), and spanning over the four age groupings. Positive values in panel (B) indicate that there was a higher %N in control samples than in scar samples. The difference between the treatments becomes less as the graphed values approach zero.

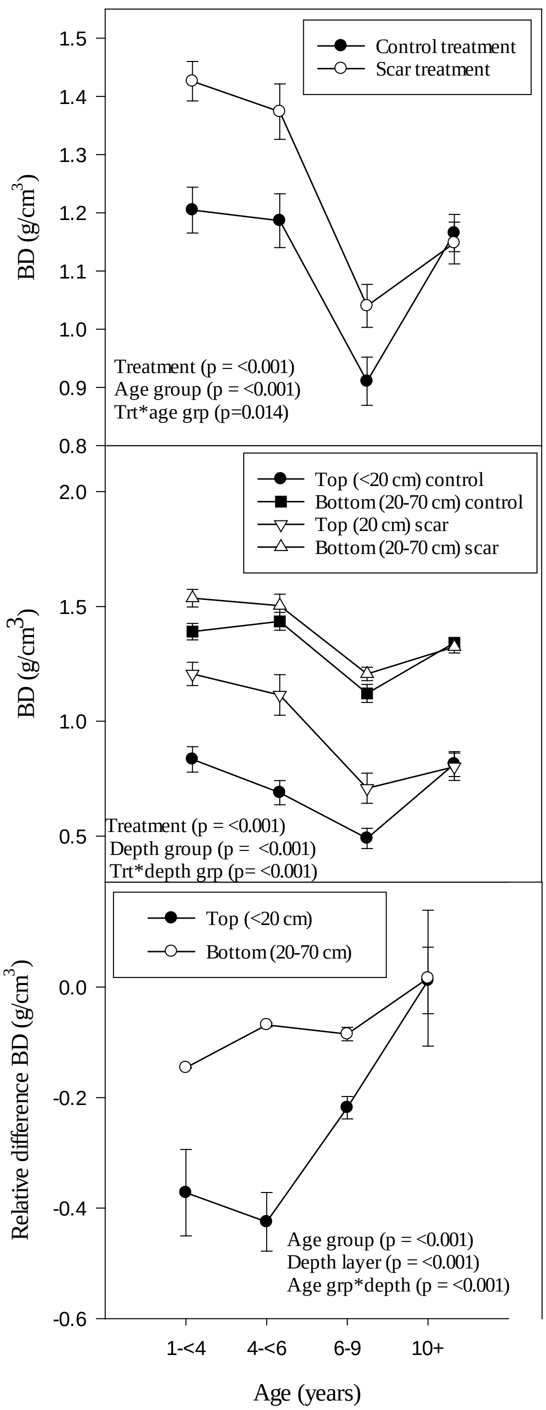

Figure 6: Bulk density graphs by treatment, age group, and relative difference. The top panel is the overall mean BD by age group, while the middle panel shows BD by depth layer (<20 cm and 20-70 cm) and age group. The bottom panel shows the relative difference between treatments (C-S) across the age groups. A negative value indicants that the samples collected from within the scar have a higher BD than the control samples. Points near a zero on the Y-axis indicate that there is no difference between scar and control treatments at that point.

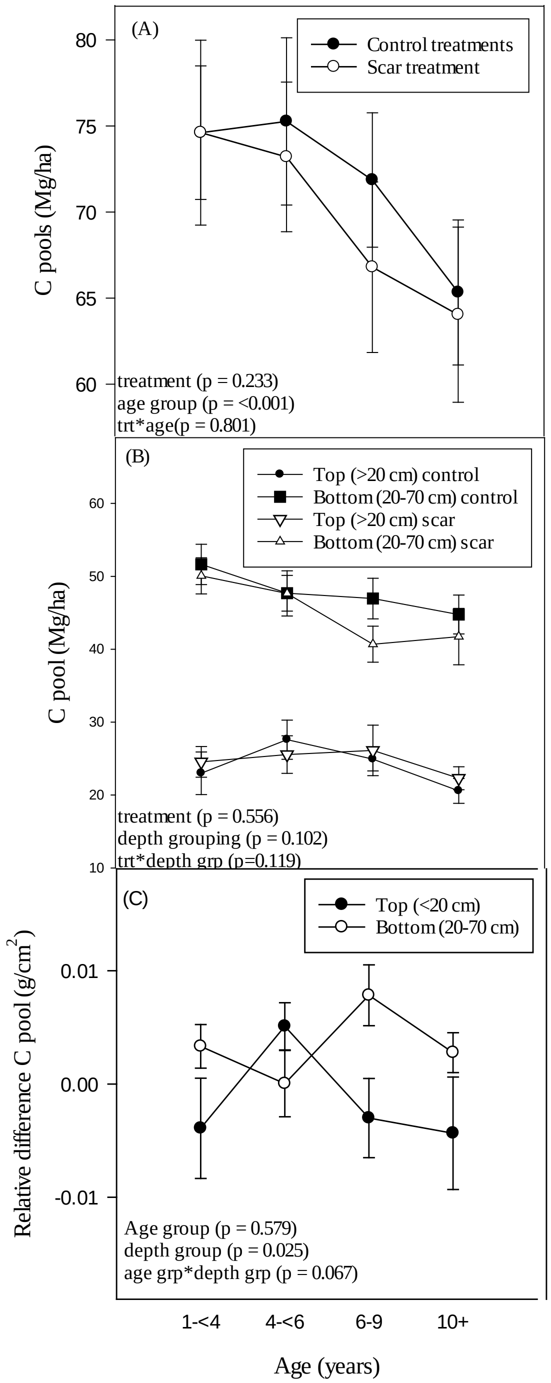

Figure 7: C pools graphed by treatment, age group, and relative difference. Panel (A) shows the mean stored C pool by treatment across the age groups. Panel (B) shows the same mean C pool across age groups however it divided by depth grouping (<20 cm and 20-70 cm) as well. The bottom panel shows the relative difference between the two treatments (C-S) across the age groups. A negative value indicants that the samples collected from within the scar have a higher BD than the control samples. Points near a zero on the Y-axis indicate that there is no difference between scar and control treatments at that point.

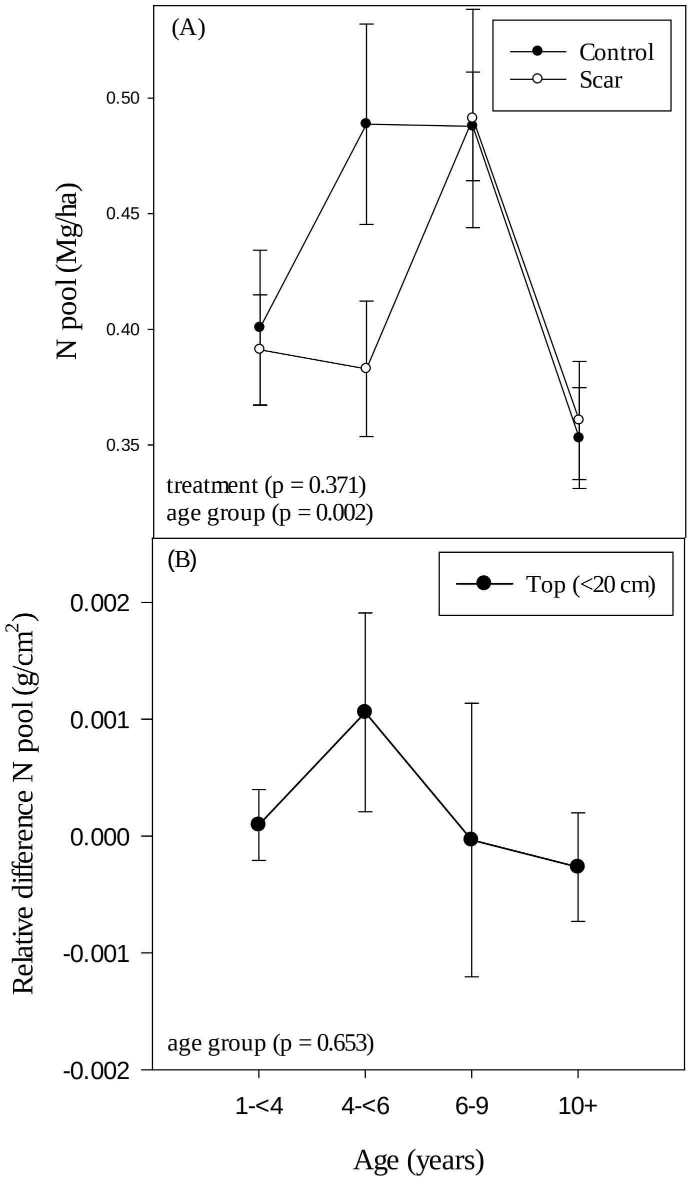

Figure 8: N pool by treatment and relative difference. Panel (A) shows the N pool separated by treatment while panel (B) show the relative difference between the two treatments. Positive values indicate that there was more N in the control samples than the scarred samples. The difference between the treatments becomes less as the graphed values approach zero.

Table 1: C pool totals by age group, treatment, and depth. "All" is the mean of all age groups.

Treatment	Age group	Mean C pool (Mg/ha)	SE C pool (Mg/ha)
C	All	71.77204675	2.306568588
C	2	74.61586796	5.368278364
C	3	75.27125316	4.858394683
C	4	71.86594385	3.902795419
C	5	65.33512202	4.210520176
S	All	69.66675436	2.317761563
S	2	74.61756057	3.879379341
S	3	73.20791362	4.34300718
S	4	66.80005938	4.957130141
S	5	64.04148389	5.090373715
Treatment	**Depth (cm)**	**Mean C pool (g/cm^2)**	**SE C pool (g/cm^2)**
C	5	0.066988562	0.004134201
C	10	0.063249768	0.004305979
C	15	0.055423714	0.002866243
C	20	0.054442749	0.002599893
C	25	0.052711585	0.002573874
C	30	0.054007561	0.002580563
C	35	0.052623568	0.00215571
C	40	0.055167603	0.002558691
C	45	0.051601682	0.002047739
C	50	0.04854815	0.002175183
C	60	0.087785209	0.004365094
C	70	0.077608796	0.003510286
S	5	0.060470869	0.003448234
S	10	0.067297353	0.004228007
S	15	0.061375404	0.003509244
S	20	0.05713744	0.003335868
S	25	0.052397154	0.002809724
S	30	0.051468054	0.00237725
S	35	0.051415994	0.00217127
S	40	0.047574954	0.002265004
S	45	0.047208744	0.002172788
S	50	0.043126235	0.002174717
S	60	0.082574153	0.004007585
S	70	0.076753227	0.00510804

Table 2: N pool totals by age group, treatment, and depth. "All" is the mean of all age groups.

Treatment	Age group	Mean C pool (Mg/ha)	SE C pool (Mg/ha)
C	All	1.71048253	0.087224667
C	2	1.602602671	0.204376137
C	3	1.95486671	0.302459205
C	4	1.951216786	0.152475955
C	5	1.333243955	0.119263627
S	All	1.625721344	0.097543699
S	2	1.564470298	0.169582247
S	3	1.531565021	0.172525638
S	4	1.964740887	0.357095219
S	5	1.44210917	0.165237095
Treatment	Age group	Mean N pool (g/cm^2)	SE N pool (g/cm^2)
C	5	0.005283092	0.000309102
C	10	0.004870177	0.000274769
C	15	0.003839482	0.000229101
C	20	0.003373564	0.00019081
S	5	0.004839694	0.000296868
S	10	0.004563506	0.000305712
S	15	0.003902987	0.000275261
S	20	0.003343002	0.000213664

APPENDIX B

SEDIMENT CORER DESIGN

Background

Traditionally, sediment cores are taken to depths much less than one meter. This is likely because cores to deeper depths are difficult to collect. In the case of seagrass however, less than a meter is insufficient when considering carbon stores. Seagrass meadows can produce carbon stores that are several meters thick, although the first meter is considered the most important when studying disturbance as it is the most easily lost (Fourqurean et al 2012). Work done to a meter depth is considered to be the better estimate of the total carbon store within an area, and are the measurements that are relied on most heavily when calculating total sequestered carbon (Fourqurean et al 2012). This work sought to provide carbon storage information that would be found useful to a broad range of seagrass research and therefore was done to 1 meter depth. .

Most of the handheld core collection equipment has handles sticking out the sides in the shape of the letter "T" and are designed to be twisted down into the sediment manually. This type of corer is useful in shallow water and with a small desired sample, however is difficult to force in when working in water that is more than waist deep. Further, manually pulling up a core that is more than 18 inches is nearly impossible. This designs is also constructed from steel in most cases, making it susceptible to corrosion when working in marine environments. Given these limitations, this type of corer would not work for this application.

Another available option is a version with an attached slide hammer that drives the corer down into the sediment. While this is much easier to drive in, the size of the core collected is still limited by the ability to remove it from the sediment. This style is also constructed from steel, which makes it heavy prior to having a sample inside of it. Corrosion is also a huge issue for this unit. The top of the corer is threaded to allow for the liner to be removed. While attempting to use this device in salt water, this threading corroded to the point that it sealed itself.

Given these limitations with commercially available coring devices, the goal of this portion of the project became to design a coring device that can take long cores, can save the sample in a liner, can be easily driven in, and can be removed from the sediment. The new coring unit needed to be able to withstand saline water as well as still be handheld. Additionally, it needed to be inexpensive enough to be a viable option for student research.

Corer Design

One of the key differences in this corer design versus the other styles available is that ours is built from PVC. This eliminated the need for expensive steel manufacturing and made parts readily available at any home improvement store. Further, PVC doesn’t rust, which is a major concern when working in marine environments. The corer also is designed such that it includes a liner so that the sample can be saved for future processing.

The corer barrel was constructed from PVC water pipe so that the interior diameter is 7.62 cm. This barrel must be longer than the selected core liners so that the interior can also fit a spacer that prevents the liner from being forced up into the top section. This spacer is discussed later. A thin ring of PVC was screwed into the inside of the bottom of the barrel so that a small lip is created for the liner to rest on. The end of the corer barrel was then sharpened to a pointed edge using a bench grinder. Hose clamps were attached near the top of the corer barrel so that a chain could be attached, creating the loop used to pull the core up from the sediment.

The upper section of the corer was constructed using a 15 cm piece of the same water pipe used for the barrel. This connects to a PVC reducer fitting, which connects to a smaller diameter piece of PVC pipe. The lesser diameter allows for the corer to be driven in using a post pounder. These pieces are not glued together, as this section of the corer will wear after several uses. By leaving them unglued, damaged parts can easily be replaced.

The two sections of the corer are connected using a PVC female-female connector that has been cut through lengthwise. This allows for easy attachment and removal. The connector is kept closed during coring with a hose clamp.

Figure 2: top of the corer. Notice the coupling piece is cut lengthwise so that it is easily removed. All of these pieces are not glued. The interior of the lower coupling tends to crack and the top pipe will become damaged from pounding. Not gluing them makes them easily replaceable.

A spacer is required to prevent the core liner from being forced upward inside the core barrel and into the top section. If this is to occur, the core liner becomes very difficult to remove and in many cases, impossible to cap for storage. The spacer was constructed of a piece of 5 cm PVC connected on one end with a coupler. This coupler was ground down to fit into the interior of the core barrel, but not allow enough space for the liner to fit beside it. The other end has a 5 cm diameter rubber connecter, tightened with a hose clamp. This rubber connecter does not actually connect two pieces, but can be adjusted up and down to fill the space in between the core liner and the top of the corer.

Core liners are most easily obtained from an office supply company such as Uline. The liners are actually clear plastic shipping tubes that come in various diameters and lengths. For this corer, 7.62 cm diameter and 91.44 cm length were chosen. Shipping tubes were chosen due to their cost effectiveness. In the case of this study, the cores were to be kept indefinitely and the liners were to be sacrificed when the cores were subsampled. While it is possible to order PVC in many different interior and exterior diameters, the shipping tubes fit nicely and were considerably less expensive. Another advantage is that the cores can be color coded by the caps. Uline in particular offers several different colors for the vinyl caps.

Prior to taking the corer in the field, it helps to mark the corer barrel where stopping points are needed. The most important is the top of the liner. To do this, a liner was laid next to the core barrel and lined up such that the bottom of the liner is even with the top of the lip in the bottom of the barrel. This gives a view of how high up the barrel the liner actually reaches. This was marked with permanent marker and then again with a thin strip of duct tape. When coring in water, the bottom sediments stir up easily. The tape allows for the “stop” mark to be seen as well as felt if the water is turbid. If the corer is driven in beyond this “stop” point, you could potentially lose the top of your sample and compression calculations work be incorrect. Compression is discussed later.

The liners can sometimes be troublesome to get out. To combat this, we have found that simply putting two small holes in the top of the liner and threading a zip tie from the inside out through each gives you "handles" for use during removal. Since the zip ties do not actually need to connect, they can be removed once the core liner is free of the barrel and the liner can be easily capped.

Removing the corer from the sediment cannot be done by hand as is possible with other, shorter core types. We found that using a 6' fiberglass ladder with a hand winch attached to the top was the easiest and most efficient way of drawing the cores up. A small piece of plywood was cut to the size of the top of the ladder and attached. A winch was then attached to the underside of the apex of the ladder, drilling through the hole in the ladder and into the board. The positioning of the winch needs to be such that the strap and hook hang down in between the ladder legs and the handle sticks out the back ladder where there is more available space. Given that most bottom sediment in the water is soft, the ladder was fitted with two 6" wide boards that run between each of the bottom "feet" on the ladder. This adds stability as well as keeps the ladder from being drawn down into the soil when the core is being pulled up.

Core Collection

The corer is most easily assembled out of the water. The liner with two zip ties goes in the corer barrel. The spacer goes in next with the zip ties ran up the center. The top portion is placed over the corer barrel and the hose clamp on the connector gets tightened down. The corer can then be driven into the sediment with the post pounder, taking care not to drive it in further than the "stop" mark on the core barrel.

To remove the core, the open ladder is placed in the water over top of the corer. The top portion of the corer and the spacer are removed and a 7.62 cm diameter rubber cap is placed over the open core barrel. This is secured tightly with a hose clamp. The winch line from the ladder is then brought down into the water and attached to the chain on the corer barrel. The core can then be drawn up with the winch.

Figure 3: Drawing the core up. The rope seen in the picture was replaced with a length of chain attached to the coring barrel with a hose clamp.

Upon removal, the core is taken to the boat where the cap is removed and excess water is allowed to drain out. Care must be taken in this step to ensure that the sediment is not stirred up and released with the water. At this point, there is no longer suction in the core barrel and the core will begin to slide out the bottom if not laid on an angle. The core liner and sample are pulled out of the core barrel by the protruding zip ties just enough that the core liner can be capped. Then the entire liner/sample can be removed from the barrel and the lower end capped. The core is then transported back to the lab and frozen in an upright position for future subsampling.

Compression

Given the pore space in the desired sediments, compression occurs during core collection. In the case of coring in wet environments, this compression can be significant and will alter the results if not taken into consideration. The simplest manner of measuring compression would be to measure down the hole from which the core was taken and then compare that to the sample that was collected in the core. Unfortunately, when working in wet environments, the hole does not always stay intact and the core has the potential to crack and leave portions of the sample in the hole. Further, different sediments have different pore spaces and therefore different compression percentages. To account for this, subsampling of the core must be done based on the location of a given sediment depth based on the compression, not the location in the core liner.

For the purposes of this lab's work, compression was calculated as an average of 4 compression measurements taken during core collection. The core barrel was marked on the exterior to denote the places where the core liner is 25%, 50%, and 75% into the sediment. Measurements were done to determine how much of a measuring stick would protrude out of the top of the core barrel in the event that a sample was in the corer up to the given mark and experienced no compression. During core collection, when each one of these markings reached the sediment, the top of the corer and the spacer were removed. A measuring stick was put into the corer until it reached the sample. The number at which the measuring stick hit the top of the core barrel was notated. The "no compression" mark is subtracted from the field measurement, and then divided by the actual distance up the core an uncompressed sample would be. This gives the core compression at that point in the coring process.

When subsampling the core, the compression percentages are used to determine where on the actual core a sample needs to be taken from to account for the compression. For example, if you are taking subsamples from a core that experienced 20% compression, then you would take your first “10 cm” sample at a location 8cm from the top of the core. The next “20cm” subsample would be at 16cm, etc.

Subsampling Frozen Cores

It is not necessary to freeze the cores. We have found however, that freezing them aides in making a more precise subsample, as the loosely consolidated sediments in aquatic and marine environments is difficult to work with. Frozen cores allow for more easy calculations of both volume and bulk density, as well as prevent mixing of layers during the subsampling process.

Frozen cores can subsampled using a hole saw bit, a piece of the PVC that makes up the corer barrel, a drill bit, a hammer, a nail and a filet knife. The top of the core is marked with indelible ink so that the distances for subsamples can be measured from the same location each time.

A hole saw bit has a pilot bit inside of the cylinder that aides in keeping the cylindrical bit in place and guiding into the desired surface. This pilot bit however needs to be removed if the intention is to calculated bulk density. Prior to removal, the bit is used as purchased to drill a hole is a small piece of the same PVC used to create the core barrel. It is helpful to drill this hole at the desired distance from the edge of the PVC so that easy compression corrections can be done. For example, we wanted to sample every 5cm with a hole saw bit that measured 3 cm across. Therefore, our “no compression” hole was 1 cm from the edge of the PVC. That way, we could line it up with our starting point and just drill, no measuring needed. Our next hole was drilled with the PVC lined up 1 cm from the edge of the first hole. That put our second hole right in the middle of the 6-10cm section of the core. The same piece of PVC can be used to make templates for 15% compression 20% compression, etc. Once the subsample is removed, the ends of the plug can be shaved flat with the filet knife. The diameter and height can be measured to calculate volume. This will be needed for eventually calculating bulk density.

A more time efficient method of subsampling is to use a table saw. The cores can be cut down the length of them creating two long, semi-circular halves. One should be labeled and saved for future analysis. The other can then be cut along its width, creating small half circle subsamples. These cuts need to be made in accordance with the compression calculations as mentioned above. Bulk density would be calculated the same as well, with the exception being that trimming of the subsample will not be necessary and the volume calculation will need to be divided in half, as the subsample is half of a cylinder.

Advantages and Disadvantages of this Design

One of the major advantages of this corer design is its cost effectiveness. The entire device can be constructed for around 100.00 from materials purchased in a local home improvement center. It only takes about a day to construct and does not require more than a moderate level of construction skill. The liners and caps can be purchased for about 7.00 a piece and are also easily obtained.

The fact that this corer is constructed from PVC is a benefit when working in marine environments. Most commercially available corers are designed using steel, which rusts almost immediately when exposed to salt water. They are also heavy, which is cumbersome when working in the water. When designed from PVC, the corer only weighs about 4lbs without sediment and will not succumb to rust.

Another major advantage is that the cores are collected in liners, which can be saved. Most handmade corers do not have any sort of liner system so you only have what you subsample in the field. By saving the sample in a liner, this core can be subsampled many times and used to reference back to if questions arise during data analysis. While there are commercially available models that include liners, they are smaller in diameter and fit into a core barrel made of steel which suffers corrosion issues as mentioned above. Further, the liners for these commercially available models are hard plastic, making subsampling more difficult and liner replacement more costly.

The largest disadvantage observed is that it is possible to lose part of the core to suction when removing it from the ground. This is a problem with all long cores and can be solved by having some means of closing off the bottom before pulling out the core barrel. Commercially available units have an inverted rubber cap that allows material up through the corer but closes in on itself when the sediment attempts to fall back out. This has been found to have little success in wet environments however and disturbs the sides of the core, given that the sediment in wet environments is poorly consolidated. Ideally, something that remains out of the way during core collection, but can be triggered to close off the bottom prior to core barrel removal would best, although currently such a mechanism doesn't exist.

Another disadvantage of the corer is that the core must be tipped to the side when removing the core liner. Once the cap is removed so that the liner can be accessed, the suction is gone, therefore allowing the sample to slide out the bottom if held vertically. This allows for mixing of the very top layer of sediment. Unfortunately, even if the core was held up high and something was pushed up through the bottom of the corer to hold the sample in place, the water and associated top, loose layer would still penetrated down along the sides of the sample, creating more mixing of layers. This disadvantage was accounted for in our study but subsampling frozen cores that could be trimmed. The sediment plugs removed from the core liner and cut even on the back of the plug well as trimmed from the front, so that any mixing caused by the water movement within the liner during removal is trimmed off. By taking just that interior piece and binning the locations, we can account for much of the variation caused by tipping the core.

Recommendations for Improvement

We recommend that the breakage issues be addressed in future versions of this corer. Core collection is difficult work, no matter how many advantages a design may have. Retrieving a broken sediment core after all the efforts to collect it is a waste of research time and very disappointing. As mentioned above, the corer barrel needs some means of closing off the bottom on demand so that the core can be drawn up without losing any parts of the collected sediment.

Another useful modification would be to allow for the core liner to be removed from the bottom of the core barrel versus the top. This would alleviate the mixing issue as the core would not need to be tipped. If the liner could be released from the bottom, the liner cap could go on right away, keeping all of the sample safely inside with no mixing. Unfortunately, the lip that is built into the bottom of the core barrel to hold the liner in is necessary while removing the core barrel from the sediment. Further, it takes the brunt of the force as the core barrel is driven into the ground, thus mandating that the lip is strong and immobile.

BIOGRAPHICAL SKETCH

Alison Shepherd
645 6th rd. Newtonville, NJ 08346
Alison.shepherd01@utgrv.edu
Alishep04@gmail.com

Alison Shepherd completed her Masters in Biology at the University of Texas Rio Grande Valley. She holds bachelor's degrees from both Rowan University in communications as well as Stockton University in marine science. She has a great deal of volunteer experience with many wonderful organizations including Rutgers University, the Jacques Cousteau National Estuarine Research Reserve, Texas Marine Mammal Stranding Network, and Sea Turtle Inc., to name a few. She just recently completed a temporary project with Conserve Wildlife New Jersey and is currently working for New Jersey Fish and Wildlife.

Born and raised in southern New Jersey, Alison credits her father, Albert Shepherd for her love of the outdoors and her mother Christine Konyn-Shepherd for her passion to look out for the world's creatures. Through her coursework and volunteer experiences, Alison has been blessed with the opportunity to stay close to nature while utilizing all of her degrees. This helps her connect with and educate the public on environmental issues as well as the beauty and processes around them. Alison hopes to continue this in the future and work to help bridge the gap between the science and the public.