

Oyster Reef Restoration: Impacts on Infaunal Communities in a Shallow Water Estuary

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OYSTER REEF RESTORATION: IMPACTS ON INFAUNAL COMMUNITIES IN A
SHALLOW WATER ESTUARY

by

KATHERINE P. HARRIS

A thesis submitted in partial fulfillment of the requirements
for the Honors in the Major Program in Biology
in the College of Sciences
and in the Burnett Honors College
at the University of Central Florida
Orlando, Florida

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Thesis Chair: Linda Walters, PhD

ABSTRACT

Oyster reefs are important estuarine ecosystems that provide habitat to many species including threatened and endangered wading birds and commercially important fishes and crabs. Infaunal organisms (i.e. small aquatic animals that burrow in the sediment) are also supported by oyster reef habitats. Infaunal organisms are critical to marine food webs and are consumed by many important species that inhabit coastal estuaries. However, over the past century 85% of shellfish reef habitats have been lost, making restoration of these areas vital. Due to their important role in coastal food webs, infauna is hypothesized to be a strong indicator of habitat productivity to document the transition from a dead to a restored and living intertidal oyster reef. Research was conducted in Mosquito Lagoon of the northern Indian River Lagoon system. Three replicate samples were collected from 12 intertidal oyster reefs (four dead, four live, four restored). Samples were collected one-week pre-restoration and one month and six months post-restoration. Infauna was counted and sorted into six taxonomic categories: polychaetes, amphipods, isopods, gastropods, bivalves, and decapods. Results analyze taxa abundance and diversity. Reef infaunal abundance increased following restoration: restored reefs became more similar to live reefs one month after restoration. Six months after restoration restored reefs were also significantly different than dead reefs. Polychaetes were the most abundant type of infauna on all reef types. Amphipod abundance increased the most on restored reefs after restoration, while isopod, bivalve and decapod abundance increased slightly. Live reefs consistently had high infaunal abundance and dead reefs consistently had low abundance, while restored reefs were intermediate. These data suggest restored reefs are more productive than their dead

counterparts, with restoration showing a positive trajectory to impact numerous infaunal species and their associated food webs.

DEDICATION

For my parents, thank you for always supporting and encouraging me to pursue my dreams, I would not be the woman I am today without you both. For my professors, thank you for your dedication and encouragement that inspired my passion for science.

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INTRODUCTION

Oyster Reefs and Restoration:

Oyster reef habitats provide an abundance of ecosystem services that benefit estuaries. *Crassostrea virginica*, the eastern oyster, provides several different categories of ecosystem services. These oysters filter nutrients, sediment, and phytoplankton from the water and are able to impact local water quality (Coen et al. 2007, Grabowski and Peterson 2007). By filtering out excess nutrients and phytoplankton from the water, oysters decrease the effects of eutrophication and allow sunlight to penetrate the water column benefiting submerged plant habitats. Oyster reefs are also considered carbon sinks and are able to sequester carbon from the water, potentially reducing the harmful effects of greenhouse gases (Peterson and Lipcius 2003, Chambers et al. 2018). The reefs help stabilize shorelines; they retain sediment and act as wave breaks to mitigate erosion (Meyer et al. 1997). As important ecosystem engineers, oyster reefs provide habitat to many commercially important fishes and crabs and threatened species of wading birds. Many estuarine animals utilize oyster reefs for foraging and crabs and juvenile fish use the reefs as refuge from predators (Grabowski and Peterson 2007). The monetary profit of ecosystem services provided by oyster reefs and the value of the habitat they provide to commercially harvested fish and crabs averages between \$10,000 to \$99,000 annually per hectare of reef, contributing to the economic value of this habitat type (Grabowski et al. 2012).

In the past century, 85% of shellfish reef habitats have been lost worldwide (Beck et al. 2011). The global loss of oyster reefs is mainly attributed to excessive over-harvesting, exploitation, and habitat loss from anthropogenic use. As ecosystem engineers, the loss of oyster reefs has detrimental effects to estuary ecosystems. The loss of this habitat diminishes the

ecosystem's ability to provide complex habitat to other species and decreases the water quality of the system (Lotze et al. 2006). This then contributes to the decline of commercially important fishes and crabs that depend on oyster reef habitats and could potentially increase eutrophication that depletes oxygen from the estuary (Grabowski and Peterson 2007). Loss of oyster reefs also contributes to increased erosion, which can lead to economic losses from property damage and related repairs.

The loss of the ecosystem services that oyster reefs provide negatively affects human economies. The commercial fishing industry harvests oysters for human consumption, and depleted oyster resources have caused a decline in this industry. A study conducted in Maryland compared commercial oyster harvesting from 1890 to 1991 and found that the annual oyster yield had gone from 550 g/m² of oysters in 1890 to 22 g/m² in 1991 (Rothschild et al. 1994). The cause of this decrease in oyster yield was attributed to decades of overharvesting. Loss of oyster reefs is also economically detrimental in terms of ecosystem services. In one study, it was estimated that oyster reef ecosystem services provide an average annual dollar value of \$10,325 to \$99,421 per hectare depending on the location of the reef (Grabowski et al. 2012). This was based on the economic value oyster reefs provide through water filtration, protection and habitat for juvenile and commercial fish and crustaceans, and prevention of shoreline erosion.

Oyster reef restoration seeks to restore the ecological function and fishery enhancement of oyster habitats (Coen and Luckenbach 2000). Restoration and conservation targets should be based on the main causes of habitat loss, habitat destruction and overexploitation, to restore historical baselines (Lotze et al. 2006). Natural reefs are a priority for conservation, and protected areas have been used effectively to protect these and other endangered ecosystems

(Beck et al. 2011). Restoration of oyster reefs focuses on creating reef habitat from functionally dead reefs by placing shell and other hard substrate to allow for oyster recruitment. Of created oyster habitats surveyed in the Gulf of Mexico, 73% were fully successful with live oysters found on the created reef habitat (La Peyre et al. 2014). Restoration and conservation will be beneficial in recovering historical oyster reef habitats and restoring estuary ecosystems.

The Indian River Lagoon:

The Indian River Lagoon (IRL) system spans 251 kilometers (156 miles) on the east coast of Florida. This broader system consists of three connected lagoons: Mosquito Lagoon, Banana River Lagoon, and the Indian River Lagoon. The five counties that border the IRL benefit economically from this estuary system; recreational and commercial use averages \$7.6 billion annually (Indian River Lagoon Economic Valuation Update 2016).

The IRL is arguably the most biodiverse estuary in North America (Sigua et al. 2000). This high level of biodiversity is due to the many habitat types that are found in this estuary system including oyster reefs, mangrove forests, salt marshes, and seagrass beds (Dybas, 2002). In recent decades the IRL's biodiversity has been affected by a number of issues. One of the main reasons for this decline seems to be caused by poor water quality due to nutrient loading in many parts of the IRL (Sigua et al. 2000). Eutrophication from highly urbanized areas is widespread in the IRL system. Septic tanks and fertilizer nutrients from urban and agricultural areas are top contributors to eutrophication (Lapointe et al. 2015). Septic tank pollution was found to be the main source of nitrogen loading in the IRL system. This excess of nutrients causes harmful algal blooms that negatively impact the biodiversity and commercial and recreational activities of the IRL (Lapointe et al. 2015).

Mosquito Lagoon

Mosquito Lagoon is in the northern most portion of the IRL. Eutrophication is a major issue within this system. Mosquito Lagoon has a large source of septic tank nutrient pollution and a build-up of nitrogen rich groundwater that contributes to algal blooms in this area (Lapointe et al. 2015). Intertidal oyster reefs, a major habitat type in Mosquito Lagoon, are threatened by nutrient loading and nitrogen pollution (**Figure 1**). The influx of nutrients can cause harmful algal blooms that decrease the water quality and limits the growth and recruitment of oysters (Kirby and Miller 2005). Boat wakes are another main threat to oyster reefs in Mosquito Lagoon. Wave motion and sediment loading caused by recreational boat wakes is correlated with an increase in oyster reef dead margins. (Wall et al. 2005; Garvis et al. 2015). Boat wakes create waves that dislodge live oyster clusters and wash them up on the reef above the water level. The oysters die resulting in a margin of dead white shell (**Figure 2**).



Figure 1: Live oyster reefs in Mosquito Lagoon are threatened by harmful algal blooms and boat wakes.



Figure 2: A dead oyster reef in Mosquito Lagoon. Boat wakes dislodge live oyster clusters and wash them up onto the reef. The oysters cannot survive out of water, resulting in a margin of dead white shell. The volunteers pictured here are preparing to restore this reef.

Oyster reef restoration in this area helps restore dead reef margins to living reefs. In Mosquito Lagoon, oyster reef restoration starts with raking down dead reef margins to the water level. Oyster mats, mesh mats zip-tied with disarticulated oyster shell, are laid out on the dead margin and held down with cement weights (**Figure 3**; Garvis et al. 2015). Oyster larvae recruit on the disarticulated shell and a new reef is able to establish. This method of restoration prevents oyster clusters from being dislodged by boat wakes. Restoration of oyster reefs using this method has proven to be very effective. Three and a half years after restoration, restored reefs had equal live oyster densities as natural reefs in Mosquito Lagoon (Birch and Walters 2012).



Figure 3: A restored oyster reef in Mosquito Lagoon. Oyster mats, made of disarticulated oyster shell, are held down with donut weights. This prevents oyster recruits from becoming dislodged by boat wakes.

Infaunal Communities:

Oyster reefs provide habitat to infaunal organisms that hold significant positions in the estuarine food web (Meyer and Townsend, 2000). Infaunal organisms are small, marine organisms that burrow in the sediment (e.g. worms, clams). Many threatened and endangered wading birds and commercially important fishes and crabs depend on infauna as a main food source. On intertidal oyster reefs in the North Inlet Estuary of South Carolina, a species of infaunal amphipods was found to make up 10% of wading birds' diets in the area (Grant 1981). The rest of the wading birds' diets consisted of infaunal polychaetes and bivalves. Juvenile fish in Alaskan estuaries were found to rely on polychaetes, bivalves, and decapods to make up 90%

of their diet (Grabowski 2002). On restored mudflat oyster reefs in North Carolina, increases in juvenile fish abundances were positively correlated with the abundance of infaunal food sources and oyster habitat structure (Grabowski et al. 2005). These studies suggest large infaunal communities are critical to supporting higher trophic level species in coastal estuaries.

Oyster reefs function as foraging grounds for many important species, and restoration has been shown to increase the complexity of food webs in northern estuaries. In Chesapeake Bay three to five year old restored oyster reefs increased the energy transfer to higher trophic levels in the reef community (Paynter and Rodney 2006). Restoration increased the biomass of prey species that are a primary food source for commercially and recreationally important fish in the area. This demonstrates that mature, restored reefs have the ability to support more complex trophic structures than degraded, non-restored reefs.

Infaunal organisms are strong indicators of oyster reef productivity not only because of their important role in the food web, but because they are typically the first organisms to recolonize a habitat after a disturbance. A study done in Tampa Bay, Florida on short-term faunal recolonization, demonstrated that infaunal habitats were recolonized within hours after removal of these organisms (Bell and Devlin 1983). Within 25 hours the species abundance had returned to the level it was before the removal occurred. If infaunal species are the first organisms to recolonize an oyster reef after the disturbance of restoration, it is likely that these early successional species may facilitate other organisms colonizing the reef soon after.

HYPOTHESES

Several studies have examined the impact of restoration on faunal abundance, but few have assessed the impact of habitat restoration on infaunal abundance (Meyer and Townsend 2000, Hadley et al. 2010). To my knowledge, no studies have been conducted in Mosquito Lagoon to understand how infaunal organisms are impacted by oyster reef restoration. I hypothesize that if restoring dead oyster reefs allows them to function as natural, live reefs and live reefs maintain a high abundance of infauna, then infaunal abundance and diversity will increase over time after restoration. H_0 : Restoration does not impact infaunal abundance or diversity. H_a : Restoration increases infaunal abundance and diversity over time. By comparing infaunal communities for change over time pre- and post-restoration, infaunal communities on restored oyster reefs will become more densely populated than on non-restored, dead reefs. This increase in infaunal abundance will potentially contribute to an increase in other important estuarine species.

RESEARCH METHODS

Infauna Collection

Infaunal organisms were collected from 12 intertidal oyster reefs in Mosquito Lagoon: four dead reefs, four live reefs, and four restored reefs (**Figure 4**). Infaunal samples were collected one week pre-restoration, and one month and six months post-restoration. Three samples were collected per site from the mid-intertidal reef level, sediment and shell was collected. A quadrat was used to maintain an area of 15cm x 15cm on the surface of the reef. Sediment was collected to 15cm deep, obtaining a core sediment volume of 15cm x 15cm x 15cm. The samples were pre-sieved using a bucket with mesh (2 cm diameter) in place of the bottom. The sediment /shell was rinsed with lagoon water to retain all sediment and organisms while large shells were removed from the sample. The sediment was then sieved through a 2000-micron sieve and a 500-micron sieve. All sediment and organisms retained in the 500-micron sieves were kept. Any larger infaunal organisms found in the 2000-micron sieve were also kept. The samples were stored in containers with 200 mL of seawater. 50 mL of a formaldehyde (preservative) and rose bengal (vital stain) mixture was added to the seawater to obtain a seawater to formaldehyde ratio of 4:1. After one week, the samples were sieved a second time through the 500-micron sieve to reduce the amount of sediment retained. The samples were then transferred to 75% ethanol for long-term storage.

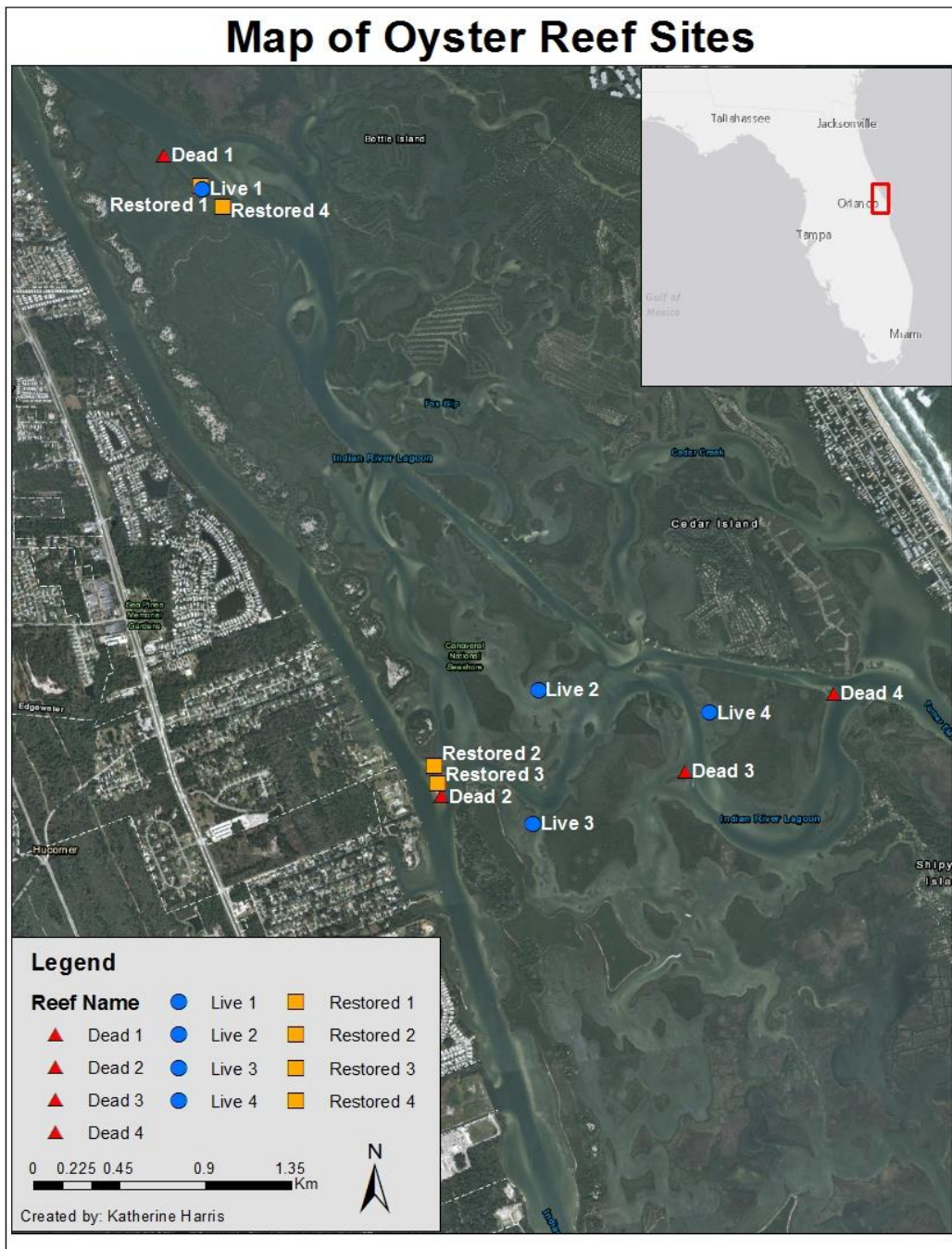


Figure 4: Map of the 12 oyster reef sites where infauna samples were collected in Mosquito Lagoon on the east coast of Florida.

Infauna Processing

Infaunal organisms were sorted from the sediment samples using a dissecting microscope. The organisms were counted to assess infaunal abundance per sample and sorted into one of the six taxonomic categories: polychaete, amphipod, isopod, bivalve, gastropod, or decapod. Infaunal organisms that did not fit into one of these categories were rare and were not included in the subsequent analyses. Sorted infaunal organisms were stored in scintillation vials with 75% ethanol.

Data Analysis

A two-way ANOVA with interaction (Reef Type x Time) was used to compare the reef type and time for the total abundance of infauna. A Tukey HSD posthoc test was then used to compare the total abundance between the different reef types and different sample collection times. Both of the tests were run in the program R.

One-way ANOVAs were used next to look at smaller changes between the different treatments over time. Reef types were compared for significant change over time, then t-tests were used to assess during which collection time periods these changes occurred. These tests were performed in Excel.

RESULTS

The mean (\pm SE) total number of infauna is shown for the three reef types: live, restored, and dead (**Figure 5**). These values were compared across the three collection periods: pre-restore, one-month post, and six months post restoration. The graph indicates that infaunal abundance increased on restored oyster reefs following restoration. From pre-restore to one-month post restoration, restored reefs show an increase in infauna by about 230 organisms (**Figure 5**). A two-way ANOVA with interaction (Reef Type x Time) tested the significance of these results. The interaction between reef type and time was found to be significant ($F(8, 96) = 9.83, p < 0.0001$).

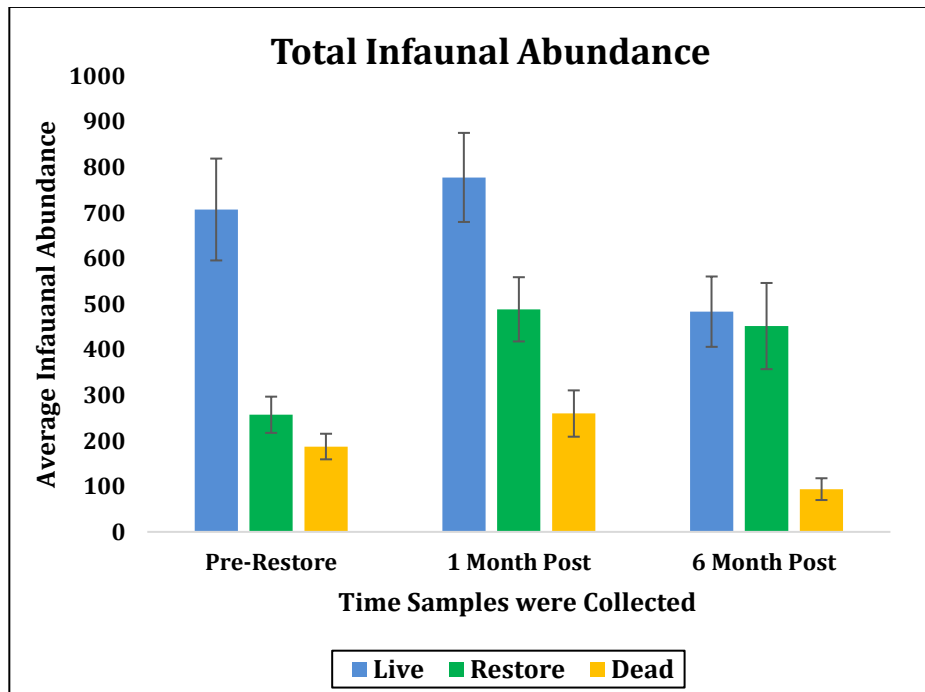


Figure 5: Mean (\pm SE) of total infaunal abundance from pre-restoration, one-month and six-month post restoration. $N = 108$ cores (15cm x 15cm x 15cm of sediment collected per core).

A Tukey HSD test, based on the two-way ANOVA, was used to understand differences in abundance between different reef types and collection times. The results of this test confirmed some expected comparisons. Before restoration dead reefs had significantly less infauna than live reefs ($F(8, 96) = 9.83, p < 0.0001$) and restored reefs were also significantly less than live reefs ($F(8, 96) = 9.83, p = 0.001$). Furthermore, dead reefs and restored reefs were not significantly different from each other ($F(8, 96) = 9.83, p = 0.8768$). This suggests that before restoration, restored and dead reefs had significantly similar infaunal abundance, while live reefs had significantly higher abundance.

When comparing the restored reefs to live and dead reefs, the Tukey HSD test showed there were significant changes seen following restoration. As stated previously, pre-restoration restored and live reefs were significantly different, but one month and six months after restoration these reef types were no longer significantly different (1 month restored : 1 month live, $p = 0.3590$; 6 month restored : 6 month live, $p = 0.999$). Furthermore, by six months post-restoration restored reefs were significantly different than dead reefs (6 month restored : 6 month dead, $p = 0.02143$). The results of this test supports the hypothesis that following restoration infaunal abundance on restored reefs increased and became more similar to infaunal abundance on live reefs.

One-way ANOVAs were used next to look deeper into the data and compare the different treatments for changes over time. Restored reefs were expected to show significant change over time, however the one-way ANOVA showed that changes in restored reef abundance were not significant overall ($F(2, 33) = 2.996, p = 0.06375$). T-tests were then used to compare changes in abundance for the different collection times on restored reefs. This test showed that there was

a significant increase in average infaunal abundance from pre-restoration to one month post-restoration ($F(2, 33) = 2.996, p = 0.0091$), but no significant change from one month to six months post-restoration ($F(2, 33) = 2.996, p = 0.7582$). These results also support the hypothesis that infaunal abundance increased following restoration.

One-way ANOVAs were also used to compare changes over time for live and dead reefs. The live reef ANOVA showed that there was no significant change over time overall ($F(2, 33) = 2.536, p = 0.0945$). However, there is a decrease in live reef abundance seen from the one month to the six month collection periods. A t-test was used to test this decrease and was found to be significant ($F(2, 33) = 2.536, p = 0.0272$), but this did not affect the significance of the one-way ANOVA. The dead reef ANOVA showed a significant change in abundance over time ($F(2, 33) = 5.262, p = 0.0104$). T-tests comparing dead reef collection times show a significant decrease in infaunal abundance occurred from the one month to the six month collection time ($F(2, 33) = 5.262, p = 0.0073$).

Polychaetes were the most abundant type of infaunal organism found on all reefs (**Figure 6**). Polychaetes also consisted of more species within this taxa category. Some of the common polychaetes identified to the family level include: Nereididae, Opheliidae, Hesionidae, Syllidae, and Spionidae (**Table 1**). These infaunal polychaetes were typically less than two centimeters in length. Polychaetes in the family Eunicidae were much larger at five to eight centimeters in length. Eunicidae was not very abundant on oyster reefs, there were typically only three to five of this taxa found in a sample, if at all. However, these polychaetes were larger than the other infaunal organisms and they are worth noting. Eunicidae was mainly found on live oysters reefs and was found on some restored reefs following restoration.

The results suggest there is an increase in amphipod abundance by about 100 organisms on restored reefs one month after restoration and slight increases in isopod, bivalve, and decapod abundance (**Figure 7**). Gammaridae and Ampithoidae were common infaunal amphipod families identified on oyster reefs (**Table 1**). A few Corophiidae and Caprellidae amphipods were also identified. The most common isopod species found were *Harrieta faxoni* (family: Sphaeromatidae) and *Amakusanthura magnifica* (family: Anthuridae). There were a few different species of bivalves, but bivalves mainly consisted of species in the Tellinidae family. The main gastropod species found were mostly likely of the Vitrinellidae family. Only two species of decapods were found and identified, the porcelain crab *Petrolisthes armatus* (family: Porcellanidae) and the Atlantic mud crab *Panopeus herbstii* (family: Panopeidae), these were most common on live reefs and restored reefs following restoration.

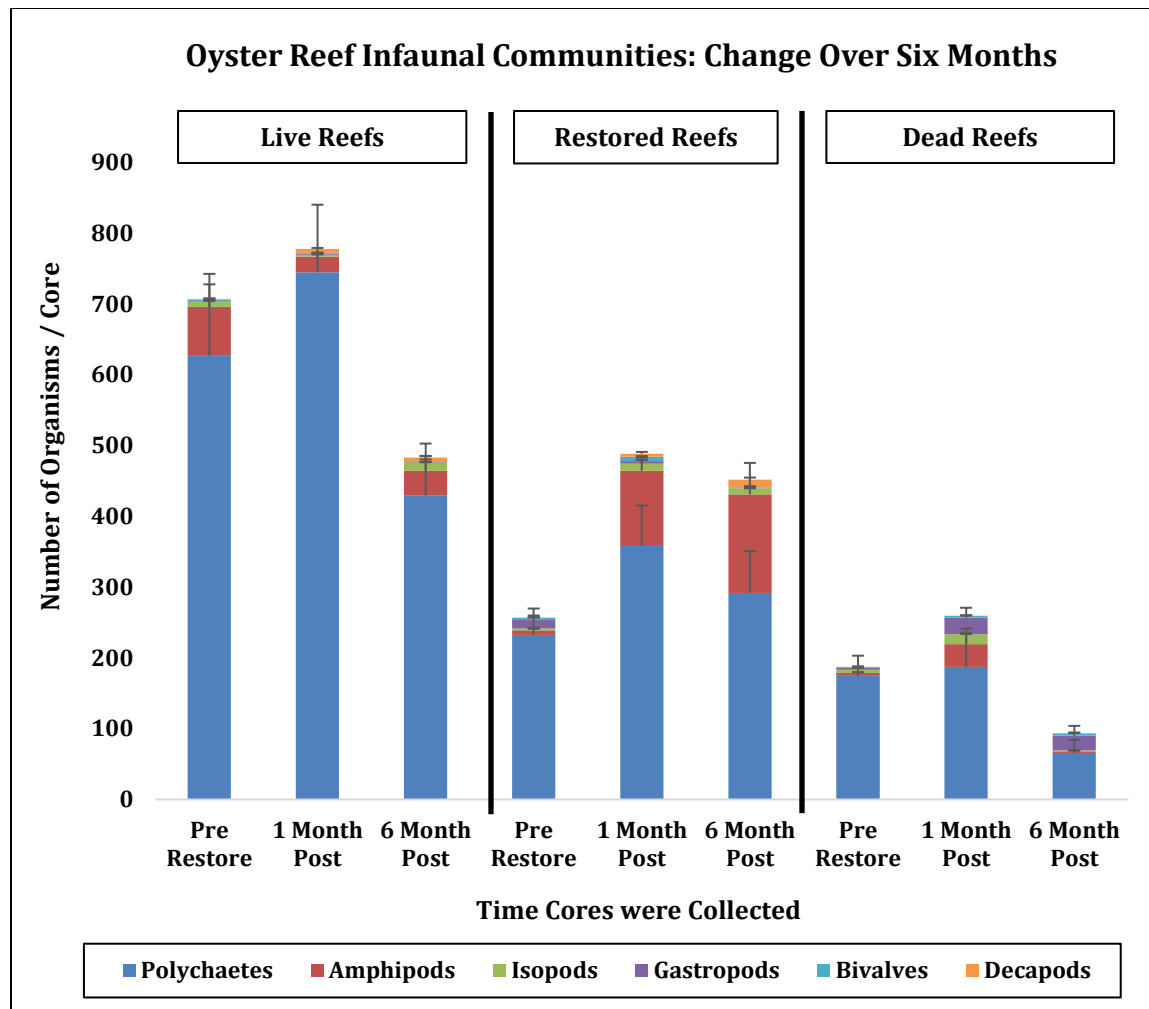


Figure 6: Mean (+ SE) for infaunal diversity and abundance on oyster reefs pre-restoration, one-month and six-months post restoration. N = 108 cores (15cm x 15cm x 15cm of sediment collected per core).

Table 1: Restored oyster reef's average number of infauna per core with the identified infaunal families and species found on restored reefs following restoration.

Polychaetes	Amphipods	Isopods	Gastropods	Bivalves	Decapods
325/core	123/core	9/core	2/core	4/core	7/core
Nereididae	Gammaridae	Sphaeromatidae (<i>Harrieta faxoni</i>)	Vitrinellidae	Tellinidae	Porcellanidae (<i>Petrolisthes armatus</i>)
Opheliidae	Ampithoidae	Anthuridae (<i>Amakusanthura magna</i>)		Nuculidae (<i>Nucula proxima</i>)	Panopeidae (<i>Panopeus herbstii</i>)
Hesionidae	Corophiidae				
Syllidae	Caprellidae				
Spionidae					
Eunicidae					

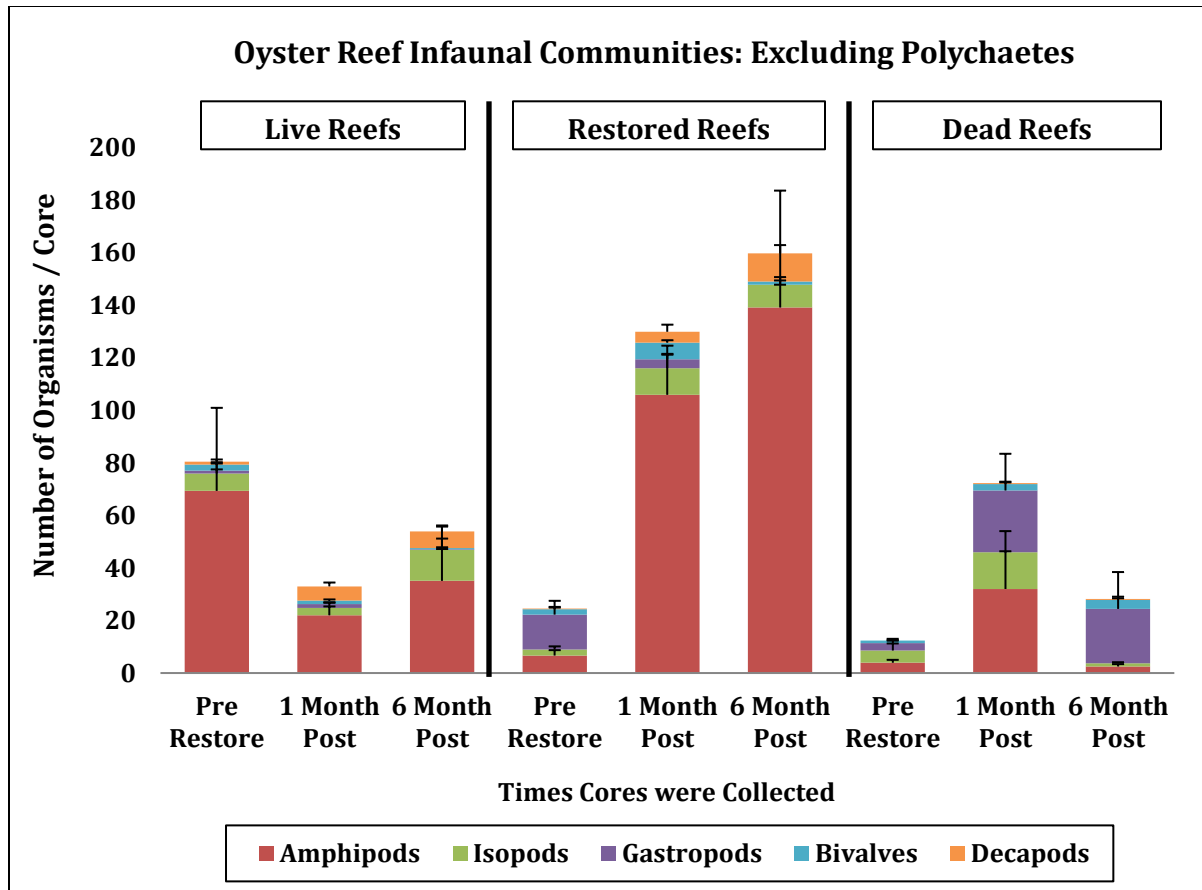


Figure 7: Mean (+ SE) for infaunal diversity and abundance excluding polychaete taxa. N = 108 cores (15cm x 15cm x 15cm of sediment collected per core).

DISCUSSION

With the global loss of oyster reef habitats, oyster reef restoration is vital to restore ecosystem services, prevent economic losses, and provide habitat to important estuarine species (Beck et al. 2011). Infaunal organisms are a key food source in this ecosystem for many commercial, recreational, and endangered species (Meyer and Townsend, 2000). Based on infaunal organisms importance in the food web, infauna may also play an important role in habitat recovery after restoration and they are known to be strong indicators of habitat productivity. Even so, few studies have researched the direct impacts of oyster reef restoration on infaunal communities. This study focuses on the impact of oyster reef restoration on infaunal abundance and diversity and documents the change in infaunal communities on restored oyster reefs in Mosquito Lagoon, Florida.

Infaunal abundance does increase following restoration on restored oyster reefs. The data in this study supports the expectation that live reefs have high infaunal abundance; this expectation was made based on other studies of infaunal communities (Grabowski et al. 2005). Live oyster reefs are also known to support many important estuarine species and contribute to higher complexity in the estuarine food web (Paynter and Rodney 2006). Following restoration, restored oyster reefs significantly increased in infaunal abundance. By one month after restoration restored and live reefs no longer had significantly different infaunal abundances. This data supports the hypothesis that restoration increases infaunal abundance and allows restored reefs to function more similarly to live reefs.

A large primary food source is important to support larger species and support a more complex trophic structure (Paynter and Rodney 2006). With an increase in infaunal abundance it is likely that restored reefs will be better able to support other estuarine species. Many species of wading birds are known to depend on infauna as part of their diet including the white ibis, Roseate spoonbill, American oystercatchers, plovers, gulls, and some species of egrets. Increased infaunal abundance gives wading birds a larger food source and could allow restored oyster reefs to support more species of birds.

Of the main infaunal families found on oyster reefs in Mosquito Lagoon the polychaete families: Nereididae, Spionidae, and Eunicidae (**Figure 8**); amphipod families: Gammaridae and Corophiidae; and bivalve family: Tellinidae are cited as important food sources for wading birds (Goss-Custard et al. 1977; Goss-Custard et al. 1991; Skagen and Oman 1996). These studies focus on birds in the Charadriiform order including plovers, terns, oystercatchers, and sandpipers. All of the listed infaunal families were found on restored reefs following restoration. Nereididae and Gammaridae were some of the more common infaunal organisms on restored reefs and may contribute the most to wading bird diets. This demonstrates that restoration allows restored reefs to provide an important food source to wading birds in Mosquito Lagoon.



Figure 8: Polychaete families Nereididae, Spionidae, and Eunicidae (respectively) are important food sources for wading birds.

Amphipod abundance increased by approximately 100 organisms on restored reefs following restoration. Isopod, bivalve, and decapod abundance also increased slightly on restored reefs, while gastropod abundance decreased. Dead reefs suggest higher gastropod abundances than restored and live reefs one month and six months after restoration. Gastropods may prefer a certain quality of dead reefs or have less competition on dead reefs and are therefore more abundant on this reef type. This may be the reason for the decrease in gastropod abundance on restored reefs following restoration. Live reefs do not have high abundances of any infaunal taxa except polychaetes. It is possible that over time restored reefs may follow this trend and show a lower abundance of amphipods as restored reefs become more similar to live reefs.

The largest significant increase in infaunal abundance on restored reefs occurred one month after restoration. This increase in abundance is not wholly surprising as infaunal species are typically the first organisms to colonize oyster reefs after a disturbance like restoration (Bell and Devlin 1983). This increase in abundance was expected to continue, however at the six month collection period there was a decrease in infaunal abundance across all reef types. Based on other studies of infaunal communities, this decrease is most likely due to seasonal changes in infaunal communities. The six-month samples were collected in January and other studies note a decrease in abundance corresponding with winter months (Zajac and Witlatch 1982). This decrease in abundance was significant on dead and live reefs when comparing one month to six month abundance. Restored reefs had the smallest decrease in abundance at the six-month time period, only decreasing by about 50 organisms. This decrease was not significant for restored reefs ($F(2, 33) = 2.996, p = 0.7582$), although it is unclear if this has any correlation to the restoration efforts.

The data in this study covers infaunal abundance to six months after restoration. This is a short time period compared to other studies of oyster reef restoration projects (Meyer and Townsend 2000; Paynter and Rodney 2006). To better understand the changes to the infaunal communities after restoration more long-term data should be included in the future. One-year post-restoration samples have been collected but have not yet been sorted. Adding this data set will allow for a more complete understanding of how infaunal communities change over time after restoration.

This study attempted to research the changes in infaunal diversity following restoration. However, the taxa categories used here were too broad to study diversity effectively. More in-depth research on species diversity would make this study more thorough and would be more important in understanding community interactions than the higher taxa diversity used here (i.e. polychaetes, amphipods). With polychaetes being the most common infaunal organism, it would be especially important to look at changes in species diversity comprising this taxa category. There may be distinct differences in the polychaete species found on different reef types. This would show a wider range in infaunal diversity and would better show how infaunal diversity is impacted by restoration.

This study is part of a larger, ongoing project researching how oyster reef restoration impacts may different aspects of the estuary ecosystem. Data on infaunal communities can be incorporated into other restoration related studies in the future. Current research is focusing on the impact of restoration on wading birds, fish, and crabs. Infaunal community data can be combined with these studies to understand how changes to infaunal communities may be affecting these other species. These data could explain fluctuations in abundance of these other

organisms, as birds, fish, and crabs will potentially be more abundant on reefs with higher infaunal abundance.

This study suggests that restoration positively impacts infaunal communities by increasing infaunal abundance on restored oyster reefs following restoration. Six months after restoration, restored reefs were more productive with higher infaunal abundance than their non-restored, dead reef counterparts. Given more time, restored reef infaunal communities may become very similar to or indistinguishable from live reef communities. Restoration has also allowed restored oyster reefs to function as a foraging ground to important species of wading birds by providing a habitat to infaunal organisms that make up a large part of the birds' diets. At six months after restoration, restoration has impacted and increased numerous infaunal species and shows a positive trajectory to impact their associated food webs.

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