ABSTRACT

Title of thesis: ASSESSMENT OF MANGROVE AND SALT MARSH MESOCOSM FUNCTIONAL VALUE USING PERIWINKLE SNAILS, *LITTORARIA ANGULIFERA* AND *LITTORARIA IRRORATA*, AS AN INDICATOR

Stacy Lyn Swartwood, Master of Science, 2004

Thesis directed by: Associate Professor Patrick Kangas
Marine, Estuarine, and Environmental Science Program

Although much research has been conducted on restoration techniques, questions about the functional value of restored and constructed ecosystems remain. Gastropods are a particularly useful indicator organism because they play a vital role at the detrital interface. This study addresses the question of whether the age structure, population density, and distribution of *Littoraria angulifera* in the Smithsonian Institution's Florida Everglades mesocosm in Washington, DC is analogous to that of wild populations. The second phase investigates these same factors, in populations of *Littoraria irrorata* at a reference site on Slaughter Creek and six mesocosm replicates at Horn Point Laboratory in Cambridge, Maryland. Neither the mangrove nor the salt marsh mesocosms were able to support healthy, reproducing populations of periwinkle snails. Salinity, humidity, territory requirements, habitat complexity, precipitation, photoperiod, and tidal variation were identified as potential causal factors for mortality and the absence of evidence of juvenile recruitment to mesocosm populations.

ASSESSMENT OF MANGROVE AND SALT MARSH MESOCOSM FUNCTIONAL VALUE USING PERIWINKLE SNAILS, *LITTORARIA ANGULIFERA* AND *LITTORARIA IRRORATA*, AS AN INDICATOR

by

Stacy Lyn Swartwood

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Master of Science
2004

Advisory Committee:

Associate Professor Patrick Kangas, Chair
Associate Professor William Lamp
Professor Court Stevenson

DEDICATION

For my family.

ACKNOWLEDGMENTS

First and foremost I would like to thank my thesis advisor, Dr. Patrick Kangas for his encouragement, enthusiasm, and patience throughout my academic work and research for this project. I would also like to thank Dr. Court Stevenson for his interest in and support of my work in the Horn Point Laboratory salt marsh mesocosms, and Dr. William Lamp for his understanding and high research standards.

Dr. Walter Adey was a positive and helpful mentor, always available to answer questions about the Everglades mesocosm and his work. Sue Lutz's energy and understanding of the Everglades mesocosm were invaluable. I would also like to thank Luisa Robles-Diaz-de-Leon and David Blersch for their help with the collection of mangrove reference site data collection and constant support, advice, and friendship.

Mr. Benjamin Linthicum and Mr. and Mrs. Peter and Kathy Paul were generous enough to allow me to conduct research on the areas restored on their properties by Dr. Ed Garbisch and his organization, Environmental Concern.

I would like to thank my parents, Jack and Sandra Swartwood, for their endless support and giving me so many wonderful opportunities, including four years roaming the wilds of Kenya as a child. Had they not chosen to live on Sligo Creek Park in Maryland, I would surely not have had the drive to study aquatic biology, nor the intimate knowledge and understanding of aquatic ecosystems derived from spending so much of my childhood in Sligo Creek that has informed so much of my work.

My husband, Benedict Tisa, was a wonderful research assistant and kept me going through the tough periods with his warm love, tremendous sense of humor, pragmatic advice, and delicious meals.

My high school biology teacher, Elaine Goldberg, sparked my interest in the natural world and ingrained in me a firm foundation from which to continue my studies.

Tracie-Lynn Nadeau has been a rigorous scientific sounding board and editor, as well as being a tireless supporter of my work. Rebecca Dils and Jamal Kadri, my mentors during my Fellowships at the US EPA, have given me the opportunity to explore the discipline of Smart Growth and the implications of my research in the wider context of the effects of land use on water quality and aquatic ecosystems.

All of my friends have been sources of strength and joy throughout this project and my life. In particular, Julia Rosenbaum has always been ready with a welcome diversion and words of understanding. Stephan Dix has provided endless empathy and a much needed sanctuary in which to work while he was in Iraq.

Our research was supported by the EPA STAR program as part of the Multiscale Experimental Ecosystem Research Center (MEERC) at the University of Maryland Center for Environmental Science.

THE TORRENT LEAVES

Rise up nimbly and go on your strange journey
to the ocean of meanings where you become one of those.
From one terrace to another through clay banks,
washing your wings with watery silt,
follow your friends. The pitcher breaks.
You're in the moving river. Living Water,
how long will you make clay pitchers
that have to be broken to enter you?
The torrent knows it can't stay on this mountain.
Leave and don't look away from the Sun as you go.
Through him you are sometimes crescent, sometimes full.

– Rumi

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

As human development continues to encroach upon natural habitats, the need to restore and recreate functioning ecosystems becomes increasingly critical. Wetlands and estuaries, in particular, have gained visibility as their numerous functions and values have been documented. The benefits of mangroves, marshes and other wetlands have been recognized to a greater degree in recent decades, as their filtering and flood mitigation capabilities and high levels of biodiversity and production have been documented. According to the US Fish and Wildlife Service, over half (53%) of the wetlands in the continental United States were lost between the 1780s and the mid-1980s (Dahl 1990). In the Southeastern United States, 96% of the commercial fisheries catch depends on the estuary-coastal wetlands system (Feierabend and Zelanzy 1987). Nationwide, approximately 75% of the ocean harvest is dependent on estuaries at some point of its constituent species' life cycle. These vital coastal ecosystems protect the shore against erosion, filter and assimilate pollutants, stabilize bottom sediments, and provide breeding habitat and protection for maturing offspring of birds, mammals, crustacea, and fish populations (Mitsch and Gosselink 2000).

Long and Mason (1983) define salt marshes as, "Areas of alluvial or peat deposits, colonized by herbaceous and small shrubby terrestrial vascular plants, almost permanently wet and inundated with saline waters." Mitsch and Gosselink (2000) define mangrove swamps as, "Subtropical and tropical coastal ecosystem dominated by halophytic trees, shrubs, and other plants growing in brackish to saline tidal waters."

Section 404 of the Clean Water Act (CWA) and the National Wetlands Mitigation Action Plan (December 24, 2002) encourage the preservation and net increase of quantity and quality of wetlands. A policy of "no net loss" was first articulated in the final report of the US EPA National Wetlands Policy Forum, which was published in 1988, and was adopted by the first Bush administration in 1989 and subsequent presidential administrations (Scodari 1997). Towards this end, mitigation banking is becoming more accepted as wetland areas that have been restored, created, enhanced, or in rare cases, preserved, are valuated in terms of credits and set aside to compensate for future effects of development activities on wetlands.

Regulations and restoration programs require assessment of the biological integrity and functional value of restored and constructed sites to guard against an overall loss of function and value. One definition of biological integrity for aquatic environments has been formulated by Karr and Dudley (1981) as, "The ability of an aquatic ecosystem to support and maintain a balanced, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region." Biomonitoring is a key component of ecological assessment, and has been used extensively in stream, lake, and wetland monitoring programs. Indicator organisms such as birds, amphibians, macrobenthic invertebrates, and insects have been used to quantify the functional value of ecosystems. These organisms must be carefully selected to reflect specific and consistent biological responses to human activities.

An effective multimetric index will include organisms that are sensitive to a range of biological stressors, and the index should be capable of identifying human-caused changes in the context of natural variation. By tracking the biota's health, changes in living systems can be detected, particularly ecological risks resulting from human activities. Ideally, when a system has crossed the threshold at which it can support the biodiversity of a fully functioning ecosystem, restoration work is required in order to ensure that the system will be capable of, from a purely pragmatic standpoint, delivering the functions and values we depend on. In extreme cases, ecosystem creation may be required in order to offset impacts from development or to mitigate impacts from existing development in watersheds that fail to meet water quality standards (CWA §303(d) listed waters).

The field of restoration ecology has grown out of attempts to recreate functioning ecosystems in damaged environments and is an essential component of environmental management and stewardship. According to some, the best way to understand a system is to "attempt to reassemble it, repair it, and to adjust it so that it works properly" (Jordan *et al.* 1987). By creating large-scale, self-contained models, or living systems, we can test our understanding of critical ecosystem components and processes.

Research on large-scale model ecosystems, or mesocosms, began in the 1960s and has been applied extensively to wastewater treatment, aquaculture, and environmental impact and ecological risk assessments (Giesy 1980, Odum 1984, Graney *et al.* 1994). Mesocosms are derived from natural systems and are usually controllable environments in which experiments can be easily carried out.

The selection of reference sites is critical as it provides the baseline for evaluating site conditions. Ideally, historical data on the original system that has become impacted or, in the case of this research, created in the form of a mesocosm, is used to designate the desired endpoint (Hughes 1994). Unfortunately, historical data of this nature is rarely available, so reference sites located in a watershed that is free from human modifications and has biological, physical, and chemical characteristics that are analogous to the study site (or system) are often difficult to find. As the goal of many restoration projects is to return a system to its historical conditions, these considerations are critical to determining baseline conditions as well as to establishing the natural variability of an ecosystem, an important factor when considering anthropogenic effects (Karr and Chu 1999).

Against this baseline, the functional value of the mesocosm can be measured, as can the effects of experimental manipulations of the mesocosm. Mesocosms provide excellent opportunities for assessment of our ability not just to restore degraded ecosystems, but to create self-contained, functioning ecosystems for controlled studies. Comparative study of populations of indicator organisms across mesocosms, restored or constructed sites, and reference sites reveals important life history information about organisms and can be used to create new metrics for biological integrity assessments.

Biological measures such as survival of taxa can indicate anthropogenic effects when compared to reference site data along a gradient of conditions that differentiates between human impairment and natural variation. Care must be exercised in selecting indicators, however, as only a few biological attributes provide reliable signals about biological condition (Karr and Chu 1999).

Indicator organisms known to be sensitive to particular pollutants and disturbance regimes have been used to assess water quality and habitat integrity in stream surveys. One of the more popular indexes of biological integrity (IBI), the Ephemeroptera-Plecoptera-Trichopetera index (EPT), uses population counts of benthic macroinvertebrate taxa to determine stream status in the presence of anthropogenic effects. The presence of similar densities of reproducing organisms common to the analogous natural, undisturbed system can also be used to assess the overall value of the work performed to restore or create the system (Karr and Chu 1999).

Gastropods play a vital role at the detrital interface in a variety of wetland systems, as many consume living and decaying plant material. Grazing by gastropods will have obvious effects on preferred plant material, but positive effects for other species are more difficult to ascertain, such as clearing a suitable substrate for barnacle settling. Conversely, some species may require the habitat provided by plants for shelter, and thus would be detrimentally affected by gastropod grazing and shredding behavior (Anderson and Underwood 1997).

In the first phase of this study, populations of the periwinkle snail *Littoraria angulifera* were used to assess how well a Florida Everglades mangrove system at the Smithsonian's Marine Systems Laboratory in Washington, DC functioned as habitat, and how effectively functional processes were emulated. In the second phase, population density and age structure studies were conducted using a second periwinkle snail, *Littoraria irrorata*, to evaluate the efficacy of model marshes at Horn Point Laboratory in Cambridge, Maryland to function as habitat, and to examine how effectively functional processes were emulated. Data from population surveys were used to assess whether or not these constructed marshes perform as surrogates for natural marshes.

CHAPTER II: OBJECTIVES

Constructed ecosystems are becoming more common, and animals serve as excellent indicators of the quality of these habitats. The presence of reproducing organisms common to the analogous natural system can be used to assess the overall value of the work performed to restore or create the system. This research investigates how well two model ecosystems serve as habitat for periwinkle snails by comparing populations in experimental mesocosms to corresponding natural reference site populations.

The specific objectives of this study were to:

1. Investigate the behavior of periwinkle snails in model ecosystems *vis a vis* wild populations, using population density, age structure, and distribution patterns as metrics.
2. Compare population density and structure of captive populations to wild populations in reference sites.
3. Investigate the reproductive capacity of indicator organisms.
4. Determine whether wall effect in marsh mesocosms impacts behavior of gastropod populations.
5. Assess habitat value of model ecosystems.
6. Determine suitability of subject organisms as an indicator for success of restoration and mitigation work.

CHAPTER III: SITE DESCRIPTIONS

MANGROVE

Reference Site

The Florida Everglades is comprised of approximately 13,000 km^2 (5,000 square miles) of subtropical wetlands (Schomer and Drew 1982). Many of the Ten-Thousand Islands are drowned Pleistocene sand dunes (Tabb 1963). Vegetation, fish, and invertebrate stock collections for the Everglades mesocosm in Washington, DC (Adey and Loveland, 991), were taken from the Ten-Thousand Islands area of the Everglades near Everglades City, Florida during the 1987-1988 construction of the mesocosm (Figure 1). This area of the Big Cypress watershed is characterized by a relatively steep elevation gradient, such that all zones – from high salinity at the Gulf of Mexico shore to fresh marsh – can be found in a 50 kilometer (30 mile) wide band. This transect was modeled in the Everglades mesocosm. Tides are an extremely important component of the estuarine Everglades, which experiences a complex diurnal-semidiurnal tide. The average diurnal tide range is 0.7 m (Carter *et al.* 1973). The Ten-Thousand Islands area is indicated on the map of Southern Florida (Figure 2).

Figure 1. Ten-Thousand Islands area of the Everglades near Everglades City, Florida. *Rhizophora mangle* dominate the coastline.

Mesocosm

The mesocosm models a 50 kilometer tract of the Florida Everglades from the Gulf Coast to a fresh water stream, and was housed in a 30.5 meter long, 6 meter tall greenhouse at the United States Soldiers and Airmens Home in Washington, DC (Figure 3 and Figure 4) (Adey and Loveland 1991). The system was built during 1987 – 1998 and was used by the Biosphere 2 project which is located north of Tucson, Arizona for preliminary design research. Biosphere 2, a 1.25 ha (3.0 acres) experimental bioregenerative life support system, was initiated in 1984 and continues to operate today under the auspices of Columbia University as a climate change research center. The Everglades mesocosm operated until November 2000, staffed primarily by volunteers overseen by the Marine Systems Laboratory of the Smithsonian Institution's National Museum of Natural History.

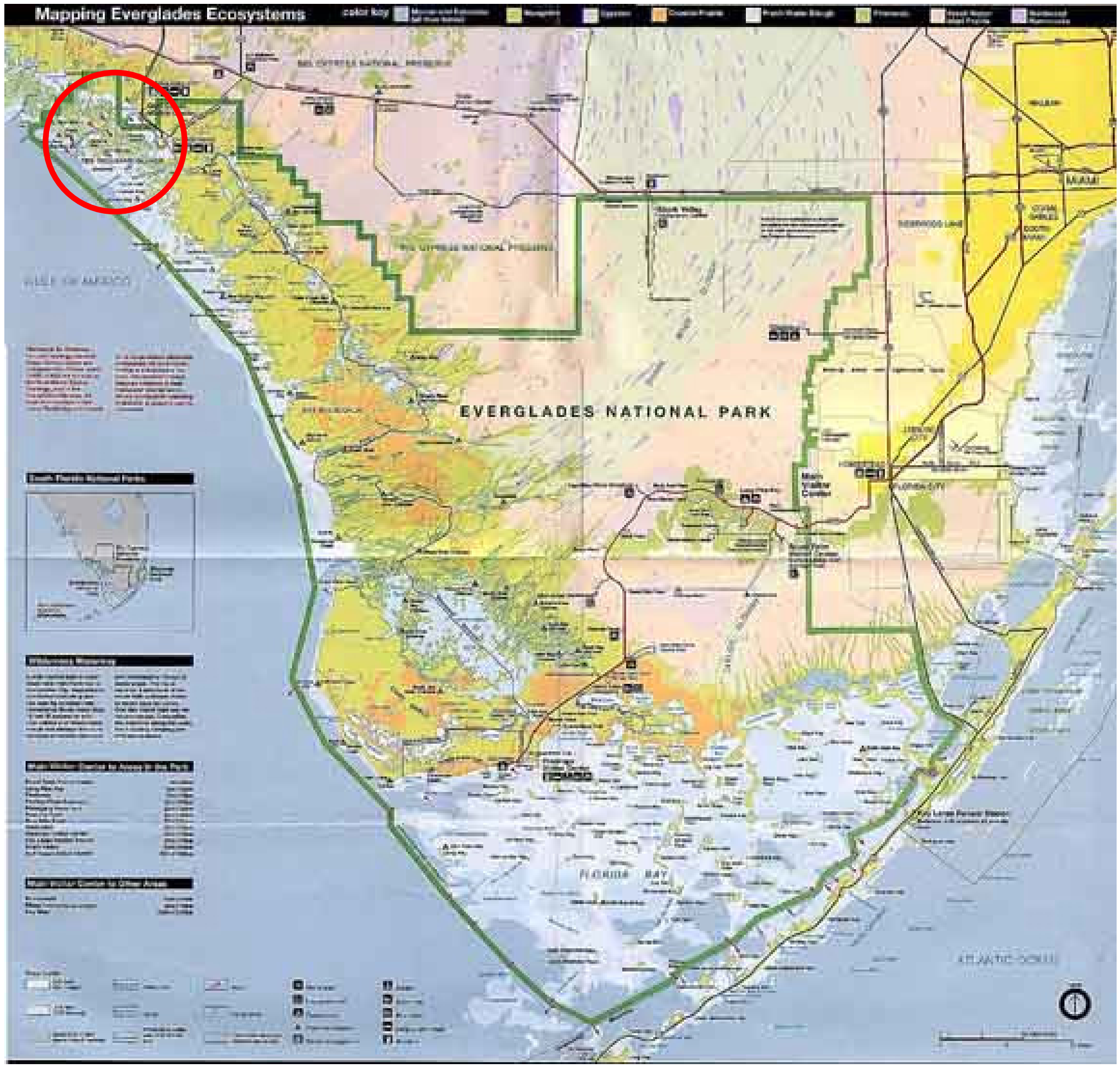


Figure 2. Map of Southern Florida showing Ten Thousand Islands reference site.

> The greenhouse-scale mesocosm...is a 98,500 liter (26,000 gallon), butyl lined, concrete block tank divided into seven connected sections of varying salinity. Each section contains water, algae, animals, sediments and wetland-coastal plants representative of habitats along a transect from the Gulf of Mexico through the Ten-Thousand Islands and into the freshwater Florida Everglades. As in the wild analog, the Gulf Shore and estuary are part of the same dynamic water mass. Here, the estuarine salinity gradient is created by pump-driven tidal inflow interacting through open weir constrictions and against downstream freshwater flow...The freshwater is derived from rain and from reverse osmosis extraction from the Gulf Shore (the equivalent of Gulf or Gulf Stream evaporation and resulting rainfall in the wild). All aquatic organisms, including adult fish, can move freely throughout the entire estuary, and plankton, larval fish and small invertebrates can move from the estuary to the Gulf Shore. All organisms that can survive Discflo™ pumping (including small fish on occasion) can return to the estuary via tidal inflow. The Freshwater system, at times, flows directly into the uppermost estuary and technically all organisms could enter the estuary from fresh water; however the return, for fully aquatic organisms is not possible.... As in the wild, the coastal and lower estuary systems are the largest estuarine components. An algal turf scrubber bank on the coastal unit simulates the much larger Gulf of Mexico interaction. The freshwater component is also proportionally larger in area, but clearly the prairie unit is minimal compared to its role in the wild. (Adey *et al.* 1996)

The system is described in detail in Walter Adey and Karen Loveland's book, *Dynamic Aquaria: Building Living Ecosystems* (1991). An electronic tidal control and gate valve with three stepping motors produced a tidal variation of 66 cm (26 inches). The estuary tanks in the system (tanks 2 – 6) were used as a reservoir, so that spring high tide in the gulf coast section (tank 1) produced a spring low tide in the estuary proper. Precipitation in the form of reverse osmosis (R/O) water was delivered via a sprinkler system at a rate of 0.245 cm (0.1 inch) per day in the dry season (January through May) and 0.762 cm (0.3 inch) per day in the wet season (June through December). The red mangrove tank (unit #2), where this study was conducted, was 4 m x 5.7 m (13'4" x 18'9"), with a surface area of 23.4 m^2 (250 ft^2) (Figure 5).

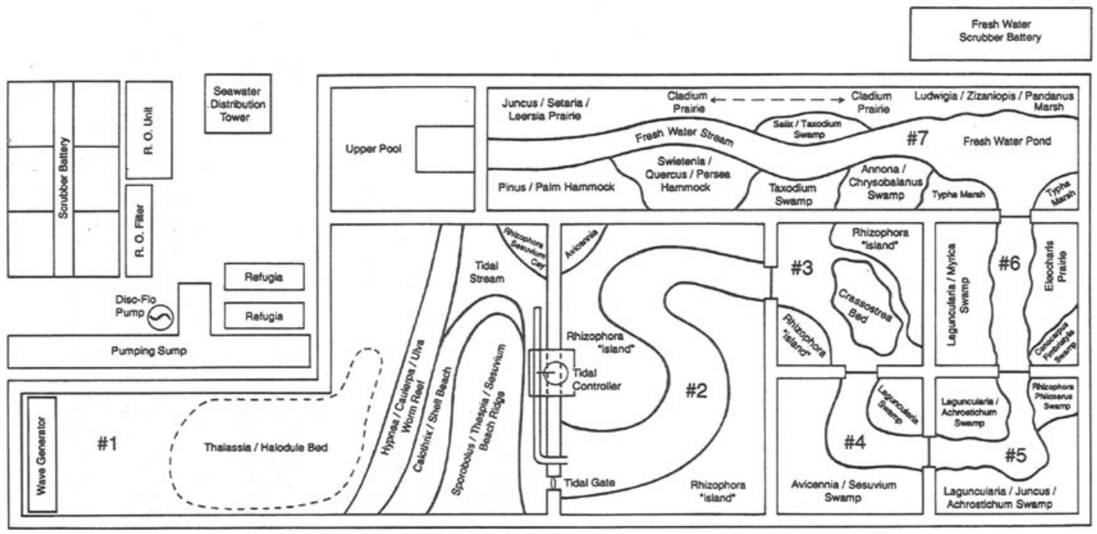


Figure 3. Plan view of the Florida Everglades mesocosm and its critical engineering components (Adey *et. al.* 1996).

Figure 4. Everglades mesocosm greenhouse in Washington, DC.

Figure 5. Interior of Everglades mesocosm, gulf coast (tank 1), red mangrove (tank 2), *L. angulifera*, and freshwater stream (tank 7).

SALT MARSH

Reference Site

The Chesapeake Bay is arguably the most productive estuary in the world (Nixon 1980). At approximately 290 km (180 miles) long and 8-48 km (5-30 miles) wide, it is also one of the largest. The Chesapeake Bay watershed is comprised of approximately 165,759 km^2 (64,000 square miles).

Figure 6. Slaughter Creek reference site.

A natural salt marsh at Slaughter Creek on the north side of the Route 16 bridge to Taylor's Island near Smithville, MD served as the reference site for experiments conducted in the interior salt marsh mesocosms housed at Horn Point Laboratory in Cambridge, MD. Low and high marsh zones were well-delineated with *Spartina alterniflora*, *S. patens*, and *Juncus romereanus* dominating (Figure 5 and Figure 6). Surface salinities in this area range from 10 ppt (spring minimum) to 17 ppt (fall maximum) with an average yearly range at any one point in open water of 4-7 ppt. Tides in the Chesapeake Bay are relatively small, with a maximum of 0.3 to 1.2 m (1-4 feet) (Pritchard 1952, Stroup and Lynn 1963). The general location of the reference site is noted on the map of the Chesapeake Bay (Figure 8).

Figure 7. Slaughter Creek reference site, view of inlet.

Mesocosms

The Horn Point Laboratory interior marsh mesocosms were constructed in 1995 as part of the Multiscale Experimental Ecosystem Research Center to investigate the scale necessary to approximate natural processes in an artificial environment. The mesoscosms, located outdoors, were six m long open tanks constructed of 2.5 mm thick gel-coated fiberglass with an aquatic-terrestrial interface marsh gradient (Figure 8 and Figure 9). Filtered water was pumped in from the Choptank River, and an attempt was made to preserve tidal regimes. There were, however, chronic problems with the pumping equipment and pipes, which produced novel tidal patterns.

Groundwater inflow to the study mesocosms (1, 2, 3, 6, 8, 12) was comprised of R/O water with no added nitrate. The models were designed with 1.5 m^2 of low marsh area. Mesocosms 3, 8 and 12 had low vegetation diversity (*S. alterniflora, S. patens*, and *J. romereanus*). Mesocosms 1, 2, and 6 had high vegetation diversity (*S. alterniflora, S. patens*, *J. romereanus, Schoenoplectus americanus, Eleocharis sp. and Hibiscus sp.*). All vegetation was native and correlated to the reference site. Schmitz (2000) burned portions of the vegetation in Mesocosm 6 during an experiment in 1999 (Table 1). During winter, both groundwater and brackish water inflows were suspended due to subfreezing temperatures. The mesocosms experienced increased exposure, in comparison to reference plots, due to air circulation under the mesocosms. Increased air circulation resulted from a design component incorporated to facilitate adjustments for optimal elevation gradients from the point of groundwater input to the brackish open water zone at the end of each tank. In addition, the long and narrow design of the mesocosms (in order to accommodate the high number of replicates) and the cessation of both fresh and brackish water flows over the winter season may have further exacerbated exposure effects. Mesocosms 1 and 12 would be expected to have greater exposure effects due to their position at each end of the row of mesocosms.

The general location of Horn Point Laboratory is noted on the map of the Chesapeake Bay (Figure 10).

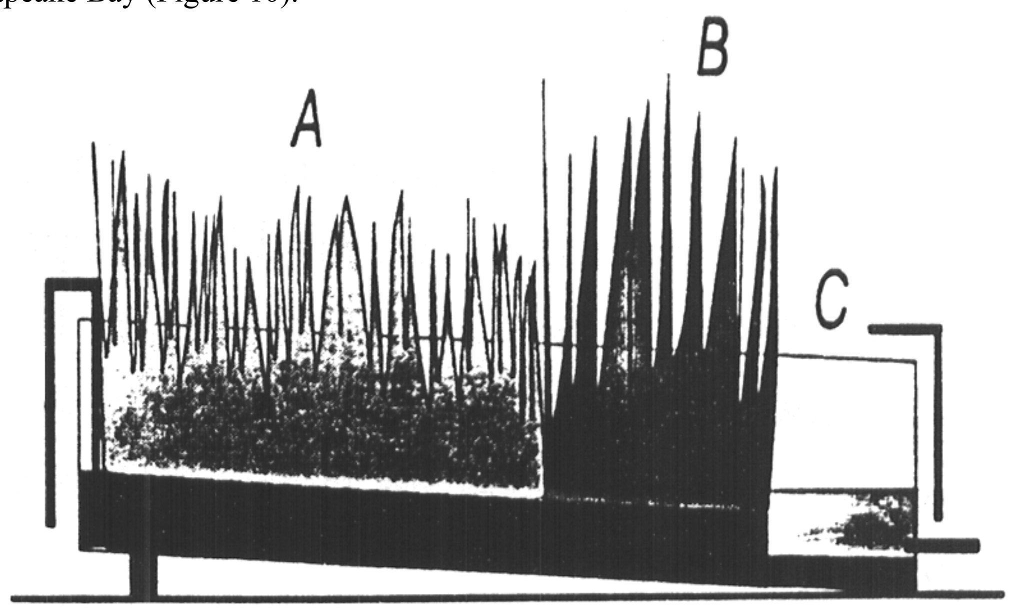


Figure 8. Horn Point Laboratory interior salt marsh mesocosm plan view. A) High marsh ($3.0\ m^2$), B) Low marsh ($1.5\ m^2$), C) Sub-tidal pool ($1.0\ m^2$).

Figure 9. Horn Point Laboratory interior salt marsh mesocosms.

Table 1. Description of Horn Point Laboratory interior salt marsh mesocosms used in this study.

Mesocosm	**Description**
Horn Point Mesocosm 1	Low nitrogen groundwater flow, high vegetation diversity
Horn Point Mesocosm 2	Low nitrogen groundwater flow, high vegetation diversity
Horn Point Mesocosm 3	Low nitrogen groundwater flow, low vegetation diversity
Horn Point Mesocosm 6	Low nitrogen groundwater flow, high vegetation diversity, burn history
Horn Point Mesocosm 8	Low nitrogen groundwater flow, low vegetation diversity
Horn Point Mesocosm 12	Low nitrogen groundwater flow, low vegetation diversity

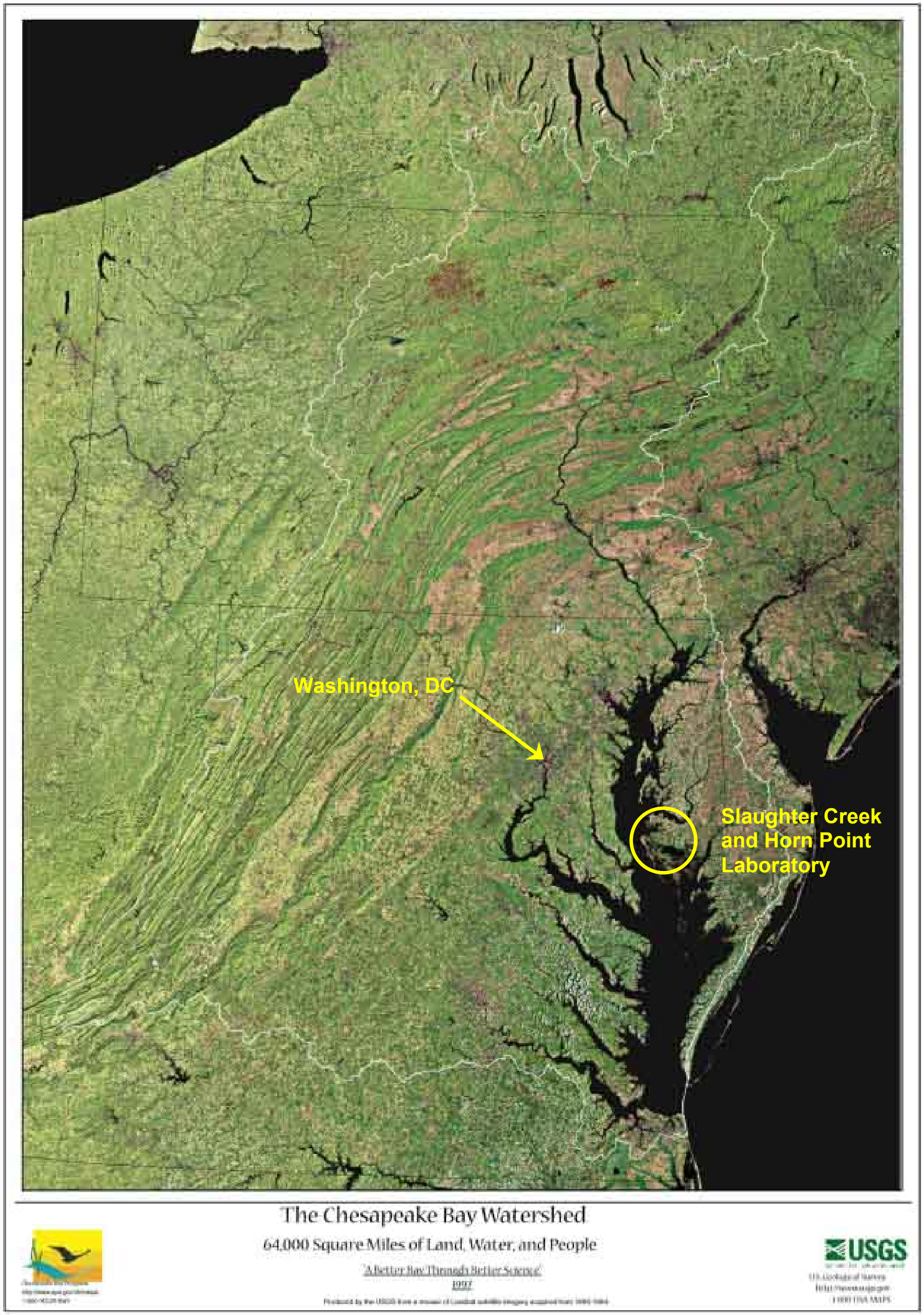


Figure 10. Map of Chesapeake Bay showing Slaughter Creek reference site and Horn Point Laboratory mesocosm site. Washington, DC is referenced for orientation purposes.

CHAPTER IV: LITERATURE REVIEW

MODEL ECOSYSTEMS

As our ability to build model ecosystems at scales that allow for the dynamic processes required for the survival of hundreds of species has improved, the value of these research tools has become increasingly recognized for the purposes of determining the biological, physical, and chemical requirements of individual organisms as well as whole systems (Adey and Loveland 1991). Several definitions of mesosocms have been proposed, based on size and time. One, proposed by Lasserre (1990), defines mesocosms as being larger than 1 m^3 (264 gallons). The systems studied in this research are significantly larger than 1m^3, have operated continuously for several years and are extremely complex.

Results of mesocosm experiments, hopefully, will be applicable to a variety of large scale issues; including prioritization of land acquisition for ecosystem function and value preservation, restoration of damaged ecosystems, creation of ecosystems for purposes of mitigation, and habitat requirements for endangered species. Model ecosystems can also be valuable for developing and testing indicators for biomonitoring, because they aid in defining the fundamental niche requirements of organisms and allow the presence or absence of these organisms to be linked to ecosystem processes and functions.

MANGROVE PERIWINKLE SNAILS

The mangrove periwinkle, *Littoraria angulifera* (Lamarck, 822), inhabits mangrove forests of tropical and subtropical coasts. It is small (< 30 mm), somewhat cone-shaped, and whitish grey. *L. angulifera* occurs from the water line up to seven meters above the high tide mark, on the proproots, leaves and branches of red mangrove trees *(Rhizophora mangle)*. Distribution is affected by physical factors such as salinity and temperature, and biotic factors such as predation, competition, and food availability. According to Gutierrez (1988), *L. angulifera* does not tolerate submersion for extended periods of time (mortality: 51.8% after 7 days, 100% after 17 days), and migrates out of water within 2-3 seconds of submergence.

L. angulifera is dioecious and has been observed to spawn with bilunar periodicity through ten months of the year. Sexual maturity is reached at an average length of 15 mm or approximately two years of age. A minimum of one inch of rainfall appears to be necessary for copulation and spawning. The rate of growth for young snails under natural conditions accelerates until they reach a length of 8 mm, after which the rate of growth decelerates rapidly until they reach a length of 14 mm. A more gradual deceleration in rate of growth has been observed for the remainder of life (Lenderking 1954). Gutierrez (1988) classified individuals smaller than 9.5 mm as juveniles or new recruits, and those larger than 9.5 mm as adults. Based on these observations and data collected in the Everglades mesocosm during this study, it was assumed for my study that individuals under 10 mm length are less than one year old, individuals between 10 mm and 15 mm are one to two years old, individuals between 15 mm and 20 mm are over two years old, and individuals greater than 20 mm are over three years old.

Generic revisions of the Littorinidae were made by Reid in 1986 and 1989. As a result, *Littorina angulifera* has been reclassified as *Littoraria angulifera* (Reid 1996).

SALT MARSH PERIWINKLE SNAILS

The salt marsh periwinkle, *Littoraria irrorata* (Say, 822), ranges from New York to Texas with an apparently large disjunction around southern Florida (Dayan and Dillon 1995), where mangrove swamps replace salt marshes along the coastline. This snail is similar in size and shape to *L. angulifera*, and is closely associated with the vegetation that fringes tidal waters (Paul 1994). Along the southeastern coast of the United States, *L. irrorata* is a significant consumer of *S. alterniflora*. It prefers to feed on dead rather than living plants. A study of *L. irrorata's* diet in Louisiana salt marshes (Alexander 1979) revealed that, in addition to dead *S. alterniflora*, 37% of the individuals consumed marsh sediment, and 4% consumed live *S. alterniflora*. Algal mats were also a significant food source for the periwinkles, and members of the microbial community of food substrates were assimilated.

L. irrorata appears to play an important functional role in salt marshes, particularly during the summer and early fall, as abundant populations (>400 individuals per m^2) ingest up to 100% of dead *Spartina* biomass (Kemp *et al.* 1990). A four-fold greater standing crop of dead leaves was found in the absence of *L. irrorata* as compared to an adjacent populated area. As a result, the authors postulate that the nutrient pulse from seasonal *Spartina* diebacks would be significantly lower when sufficient numbers of *L. irrorata* are present. This organism may also be key in controlling fungal standing crops, as the snail primarily consumes dead *Spartina*, the decaying substratum for fungal growth in cordgrass marshes (Newell and Baerlocher 1993).

Salt marsh periwinkle distribution appears to be primarily limited by habitat availability, competition for habitat and food, and salinity (Stiven and Kuenzler 1979). *L. irrorata* distribution has been observed to be restricted to salinities averaging greater than 15 ppt. At salinities less than 8 ppt, decreased activity and death is observed. However, Paul (1994) has observed healthy, reproducing populations of *L. irrorata* in Chesapeake Bay marshes with average salinities of 10-15 ppt, leading to the suggestion that a higher value of 10 ppt is likely the minimum tolerance range for healthy, reproducing populations of *L. irrorata* in the Mid-Atlantic region (Paul 1998). Salinities in the Horn Point Marsh adjacent to the salt marsh mesocosms range from 8 to 17 ppt (Stevenson, personal communication). Salinities in the Horn Point Laboratory interior salt marsh mesocosms fall to almost zero during the winter as both fresh water and brackish water inputs are suspended and the only source of water is precipitation.

Two mark-recapture experiments in Galveston Bay, Texas demonstrated that *L. irrorata* individuals rarely moved more than 2 meters from their release point over a four-month period of time (Vaughn and Fisher 1992). Hamilton (1978a) found that *L. irrorata* on a Florida barrier beach stayed within 2 to 4 meters of their release point over an 11-month study period. According to Bingham (1969, 1972), *L. irrorata* has been observed to climb vertical grass stalks in the face of an advancing tide and forage on the substratum at low tide. Schindler *et al.* (1994) postulated that this behavior allows escape from predators such as blue crabs *(Callinectes sapidus)*, though Paul (personal communication) counters this theory with the idea that periwinkles migrate vertically to regulate their body temperature.

The organism breeds at midsummer and grows to a length of up to 10 mm during the second summer of life. It is sex determinate (and reaches sexual maturity at a length of 12-14 mm). It grows rapidly from a length of 14 mm to 18 mm, then growth rates decelerate for the remainder of life (Paul, personal communication). Based on these observations and the research in this study, it was assumed for my study that individuals under 10 mm length are less than one year old, individuals between 10 mm and 15 mm are one to two years old, individuals between 15 mm and 20 mm are over two years old, and individuals greater than 20 mm are over three years old.

Generic revisions of the Littorinidae were made by Bandel and Kadolsky in 1982 and Reid in 1986 and 1989. As a result, *Littorina irrorata* has been reclassified as *Littoraria irrorata* (Reid 1996).

PERIWINKLE SNAILS AS INDICATOR ORGANISMS

Several factors make periwinkle snails an ideal candidate for a study of this type. I previously observed *L. angulifera* and mangrove tree crabs in small pockets of *R. mangle* along a stream that ran between the Haulover Marina and ocean shore in October 1998. This suggests that *L. angulifera* is able to survive in red mangrove forest fragments with extreme edge conditions (parking lot and beach), roughly analogous to those found in the Everglades mesocosm. Primary migration patterns in *L. angulifera* tend to be along the vertical axis, making it a good candidate for inclusion in closed systems.

The ecological and environmental importance of *L. irrorata* in procesing *Spartina* sp. detritus has been emphasized by many researchers (Kemp *et al.* 1990). In addition, their role in fungal communities is of interest. Their tendency to remain within two meters of their release point over long periods of time facilitates mark-recapture studies and predation studies, and makes them particularly suitable for incorporation into mesocosms.

CHAPTER V: METHODS

EXPERIMENTAL DESIGN

This research has been designed to investigate how created systems function in relation to reference systems or sites. This methodology is a touchstone of restoration science, as the functional value of restored or created ecosystems can be determined through the use of biological indices (such as the IBI or EPT) or physical assessment (such as hydrogeomorphology).

The Slaughter Creek reference site was selected because it was close to Horn Point Laboratory, relatively undisturbed, and exhibited the vegetative and hydrologic characteristics sought after by the experimental design of the mesocosms. The Everglades reference sites were selected because the source materials for the mesocosm were obtained from this area.

The following hypotheses were tested in this work:

1. Based on initial observations that the population of *L. angulifera* in the Everglades mesocosm was less than one-quarter the original size after two years of self-organization, it was expected that the population would continue to decline to zero.
2. The population density of *L. angulifera* in the Everglades mesocosm was expected to be lower than the population densities in the Everglades reference sites.
3. As there was no evidence of juvenile recruitment to the population of *L. angulifera* in the Everglades mesocosm, it was expected to be more concentrated

in the older age classes, while populations in the Everglades reference sites were expected to be more evenly distributed across all age classes.

4. The length-weight relationship for *L. angulifera* individuals in the Everglades mesocosm was expected to be the same as the length-weight relationship for individuals in the Everglades reference sites.
5. The height distribution of *L. angulifera* individuals in the Everglades mesocosm was expected to be the same as the height distribution of individuals in the Everglades reference sites.
6. The Horn Point Laboratory salt marsh mesocosms were expected to support reproducing populations of *L. irrorata* of similar densities to those found in the Slaughter Creek reference site.
7. The age structure of populations of *L. irrorata* in the Horn Point Laboratory salt marsh mesocosms, which initially reflected the age structure in the Slaughter Creek reference site, was expected to be maintained throughout the course of the experiment.
8. The length-weight relationship for *L. irrorata* individuals in the Horn Point Laboratory salt marsh mesocosms was expected to be the same as the length-weight relationship for individuals in the Slaughter Creek reference site.
9. The populations of *L. irrorata* in the Horn Point Laboratory mesocosms with high vegetation diversity were expected to have higher survival rates than the populations of *L. irrorata* in the Horn Point Laboratory mesocosms with low vegetation diversity.

10. The population of *L. irrorata* in the Horn Point Laboratory mesocosm with burn history and high vegetation diversity was expected to have a higher survival rate that the populations of *L. irrorata* in the high vegetation diversity Horn Point Laboratory mesocosms that had not been burned.

11. The population of *L. irrorata* in the reference site was expected to demonstrate a preference for the artificial walls that were placed in the marsh, as was observed in the Horn Point Laboratory mesocosms.

MANGROVE

Initial research consisted of population counts and notation of relative distribution in the Everglades mesocosm from 7/15/97 to 11/18/00. Simple maps (Appendix A) were used to record population distribution. Time, temperature, and weather were also noted. All mangrove prop roots, trunks, and canopy leaves were examined from multiple angles throughout Tank #2 of the mesocosm during each survey.

The second phase of research, a mark-recapture study, utilized the same maps and search of the system. Individuals were marked with nontoxic indelible ink and their height above the sediment and relative distribution noted for each of three surveys. In the final survey on 9/20/98, all individuals in Tank #2 of the Mesocosm were collected, weighed with a manual balance, and measured from tip to base with calipers (General Hardware Manufacturing Company, Model No. 142), after noting their relative distribution.

In November 1999, reference site density and height distribution measurements were taken from multiple reference sites within the source material collection area in the

Ten-Thousand Islands in November 1999. Five plots measuring 4 m^2 meters each and selected for similarity to vegetation density in the mesocosm were surveyed by examining and climbing the red mangrove trees. Four m^2 plots were used in order to facilitate surveys of individual red mangrove trees so that counts could be made accurately. The height of each *L. angulifera* individual above the sediment was noted. In addition, all individuals were collected from two of the plots (#1 and #4), weighed using a Mettler electronic balance, and measured from tip to base with calipers (General Hardware Manufacturing Company, Model No. 142).

A population trend was created for *L. angulifera* based on the data collected in mesocosm from 7/15/97 to 11/18/00. Mesocosm population age structure was also analyzed based on length data collected on 9/20/98. The correlation between length and weight data was calculated based on this data and reference site data collected in Plot #1 and Plot #4 on 11/19/99. The mean height above the sediment in the mesocosm on 8/2/98, 8/17/98, and 9/7/98 was compared to the mean height above the sediment in the reference sites on 11/19/99.

SALT MARSH

In June 1997, the animals in the MEERC marsh were stocked by Karen Sundberg. Populations of *Gammarus mucronatus* (30 individuals per mesocosm), *Palaemonetes pugio* (20 individuals per mesocosm), *Uca minax* (6 individuals per mesocosm), *L. irrorata* (50 individuals per mesocosm), *Geukensia demissa* (5 individuals per mesocosm) , and *Rangia cuneata* (9 individuals per mesocosm) were placed in mesocosms 1, 2, 5, 6, 7, and 10. Based on the selection of *L. irrorata* for inclusion in this earlier work, we assumed that they would be an appropriate species to use in this study.

On May 17 and 19, 2000, all surviving *L. irrorata* from the preceding stocking were removed, measured from tip to base with calipers (General Hardware Manufacturing Company, Model No. 142), and weighed with a Mettler electronic balance. A second survey and removal was conducted in June 2000 prior to restocking mesocosms 1, 2, 3, 6, 8 and 12 with populations of *L. irrorata* reflecting a standard age structure and density for this work.

On 6/20/00, the Slaughter Creek reference site was surveyed using 20 ¼ m^2 plots selected for similarity to mesocosm hydrologic regime and vegetation. On 6/22/00 and 6/23/00, six mesocosms were stocked with periwinkle populations reflecting the age structure and density of the reference site plots. The mean number of snails per ¼ m^2 reference plot on 6/20/00 was 8.85. As the mesocosms were designed with 1.5 m^2 tidal salt marsh per tank, they were stocked with 8.85 per ¼ m^2 x 1.5 m^2 (area of tidal marsh habitat in mesocosm design) = 53.1 snails per tank, rounded down to 53 (Figure 36). Individuals were collected from south side of the Route 16 bridge at the reference site and another nearby salt marsh, divided into standard populations reflecting the age structure in the reference site, marked with nontoxic indelible paint and glitter nail polish, and placed in mesocosms 1, 2, 3, 6, 8, and 12. The periwinkles were introduced in a random pattern, then allowed to self-organize over the growing season. Length-weight correlations for the six mesocosm populations ranged from R^2=0.8868 to R^2=0.9126. The length-weight correlation for all Slaughter Creek reference site plots was R^2=0.9551. Based on these correlations, length was used exclusively to determine age structure for future surveys. Population surveys were conducted at the end of the year 2000 growing season and throughout the year 2001 growing season. Surveys were not performed during the winter season as *L. irrorata* breeds during the summer and hibernates over the winter, so immigration and/or emigration is not expected.

The ¼ m^2 reference site plots were selected based on degree of disturbance and similarity of vegetation density and tidal regime to Horn Point Laboratory mesocosms (Figure 11). Population surveys were conducted during the growing season in 20 individual ¼ m^2 plots per collection date from June 2000 to November 2001.

Figure 11. Typical Slaughter Creek ¼ m^2 reference site plot, with clumps of *Spartina alterniflora*.

In order to test for wall effects observed in the marsh-mesocosms, in July 2001, 1x2 meter rectangles of plastic board were placed upright in the reference site at Slaughter Creek in order to mimic the walls of the mesocosms (Figure 12). The cost of using the same coated fiberglass that the mesocosms were constructed from was prohibitive, so an alternative material was identified. The plastic board used was not as smooth as the coated fiberglass, but it was similarly light in color and sufficiently strong and flexible to withstand extreme weather conditions in the reference site. Data was collected on *L. irrorata* utilization of the walls and the area directly adjacent to the base of the walls at the end of the year 2001 growing season and throughout the year 2002 growing season.

Figure 12. Artificial walls (1x2 m) in Slaughter Creek reference site (11/15/02).

CHAPTER VI: RESULTS

MANGROVE

The red mangrove tank (unit #2) in the mesocosm was stocked with 200 *L. angulifera* collected from the Ten-Thousand Islands area of the Everglades on May 10, 1995. Population densities in the five 4 m^2 reference site plots that were surveyed in November 1999 ranged from 10 to 54 with a mean of 34 per 4 m^2. The red mangrove tank is 4 m x 5.7 m (13'4" x 18'9"), with a surface area of 23.4 m^2 (250 ft^2), yielding space for 5.85 4 m^2 reference plots. Based on the mean reference site population density and this multiplier, one would expect to find a relatively stable population of 34 *L. angulifera* x 5.85 plots = 199 individuals per 23.4 m^2. This value is remarkably similar to the population size that was established in the mesocosm in 1995. Population counts began on July 15, 1997 and document a steady decline over 31 collections to 0 individuals in November 18, 2000 when the mesocosm was dismantled (Figure 13). The decline in population through November 2000 clearly indicates that the mesocosm failed to provide at least one resource gradient critical to the maintenance of a healthy *L. angulifera* population.

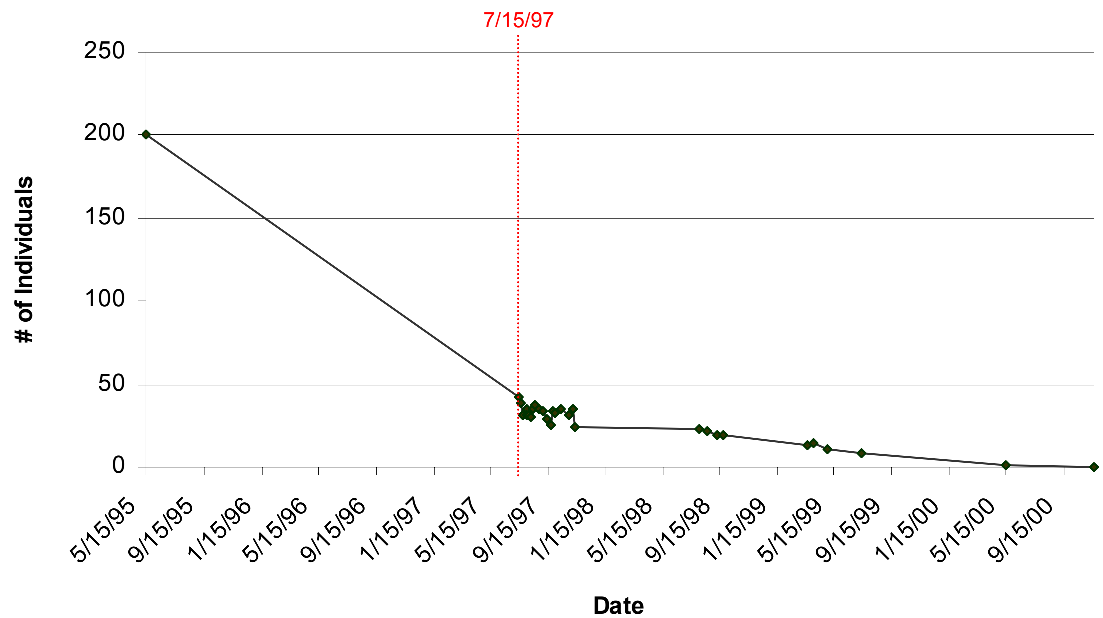


Figure 13. *L. angulifera* population trend in Everglades mesocosm, 1995-2000.

At the end of the summer of 1998, three mesocosm surveys were taken to document the height distribution of individuals. Approximately twice as many individuals were found between 50 and 75 centimeters above the sediment than in the 25–50 cm height class and 75–100 cm height class. These three height classes comprised 85% of the mean population height across the three surveys. Individuals were not found in the 0-25 centimeter range, presumably due to the fact that, according to Gutierrez (1988) *L. angulifera* cannot tolerate submersion for extended periods of time and migrates out of water in response to tidal inundation (Figure 14 and Table 2). The individual height distributions from each survey and a summary of all three surveys can be found in Table 2.

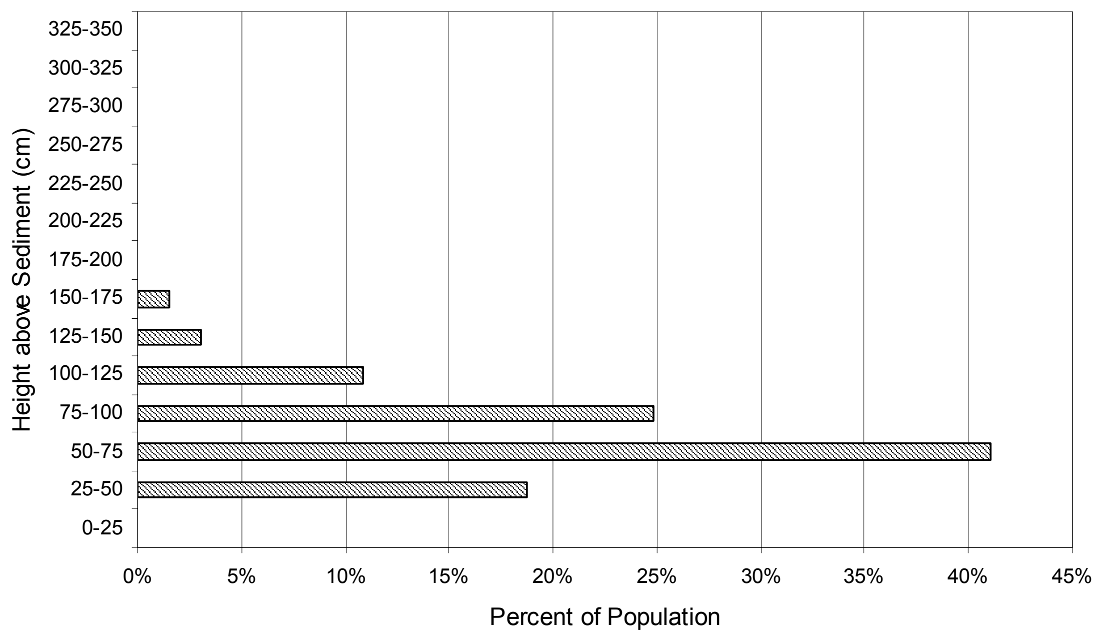


Figure 14. Mean height distribution of *L. angulifera* in Everglades mesocosm, measurements taken 8/2/98, 8/17/98, 9/7/98.

Table 2. Height distribution of *L. angulifera* in Everglades mesocosm, percentage of population, measurements taken 8/2/98, 8/17/98, 9/7/98.

Height above sediment (cm)	8/2/98	8/17/98	9/7/98	Mean
0-25	0%	0%	0%	0%
25-50	13%	27%	16%	19%
50-75	48%	23%	53%	41%
75-100	26%	27%	21%	25%
100-125	13%	9%	11%	11%
125-150	0%	9%	0%	3%
150-175	0%	5%	0%	2%
175-200	0%	0%	0%	0%
200-225	0%	0%	0%	0%
225-250	0%	0%	0%	0%
250-275	0%	0%	0%	0%
275-300	0%	0%	0%	0%
300-325	0%	0%	0%	0%
325-350	0%	0%	0%	0%

In November 1999, five 4 m^2 reference plots in the Ten-Thousand Islands area of the Florida Everglades were surveyed. Individuals were found at significantly higher levels above the sediment than in the mesocosm, and much more evenly distributed across a wider range of heights, from 25 to approximately 350 cm (Figure 15). The individual height distributions from each reference field plot and a summary of all five reference field plots can be found in Table 3.

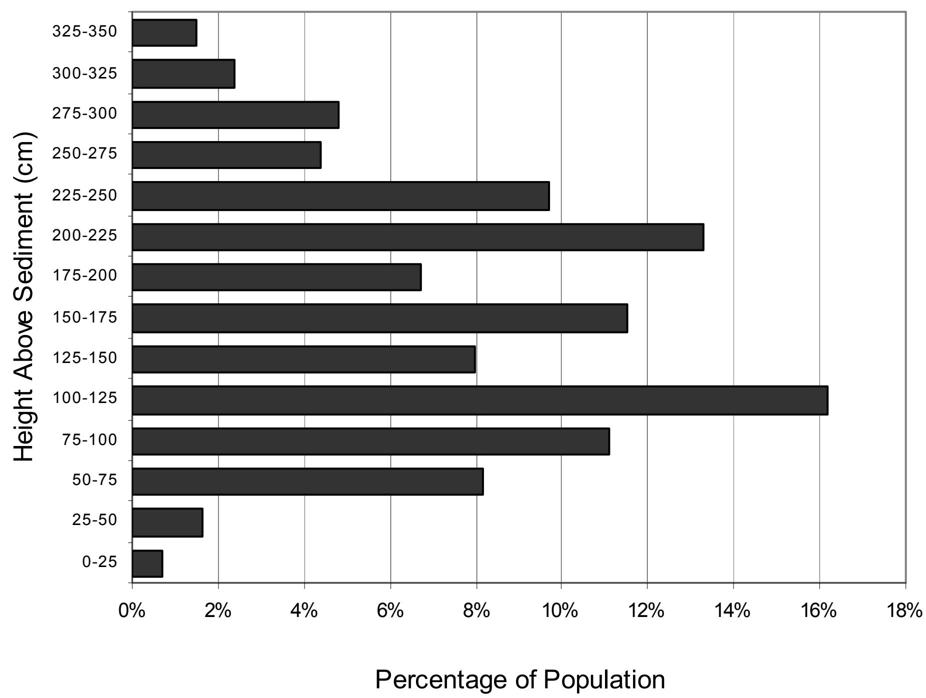


Figure 15. Mean height distribution of *L. angulifera* in five Everglades reference field plots, 11/99.

Table 3. Height distribution of *L. angulifera* in Everglades mesocosm, percentage of population, measurements taken 11/19/99.

Height Above Sediment (cm)	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Mean
0-25	0%	3%	0%	0%	0%	1%
25-50	3%	3%	0%	2%	0%	2%
50-75	3%	21%	7%	0%	10%	8%
75-100	6%	24%	15%	11%	0%	11%
100-125	11%	10%	2%	37%	20%	16%
125-150	8%	0%	5%	17%	10%	8%
150-175	19%	10%	12%	6%	10%	12%
175-200	6%	10%	12%	6%	0%	7%
200-225	11%	7%	15%	4%	30%	13%
225-250	8%	0%	15%	6%	20%	10%
250-275	11%	3%	0%	7%	0%	4%
275-300	6%	7%	10%	2%	0%	5%
300-325	3%	0%	7%	2%	0%	2%
325-350	6%	0%	0%	2%	0%	1%

Height above sediment was measured in three separate mesocosm surveys (8/2/98, 8/17/98, and 9/7/98) and five different reference site plots in the Ten-Thousand Islands area of the Florida Everglades (11/19/99). The mean height of individuals in the reference plots was 164.84 cm, more than double that of the overall mesocosm survey mean of 74.50 cm (Figure 16). Temporal pseudoreplication in the Everglades mesocosm data is recognized as a potential problem. Standard error for the Everglades mesocosm data points ranged from 4.571 to 7.507 in the mesocosm. An ANOVA of these three data points showed no significant difference ($p=0.3758$). Standard error for the reference data points ranged from 8.836 to 19.443. An ANOVA of these five data points indicated that there was significant difference between plots 1 and 2 and between plots 2 and 3 ($p=0.0020$). An ANOVA of all eight data points indicated that there was a significant difference between one or more of the sampling points ($p<0.0001$).

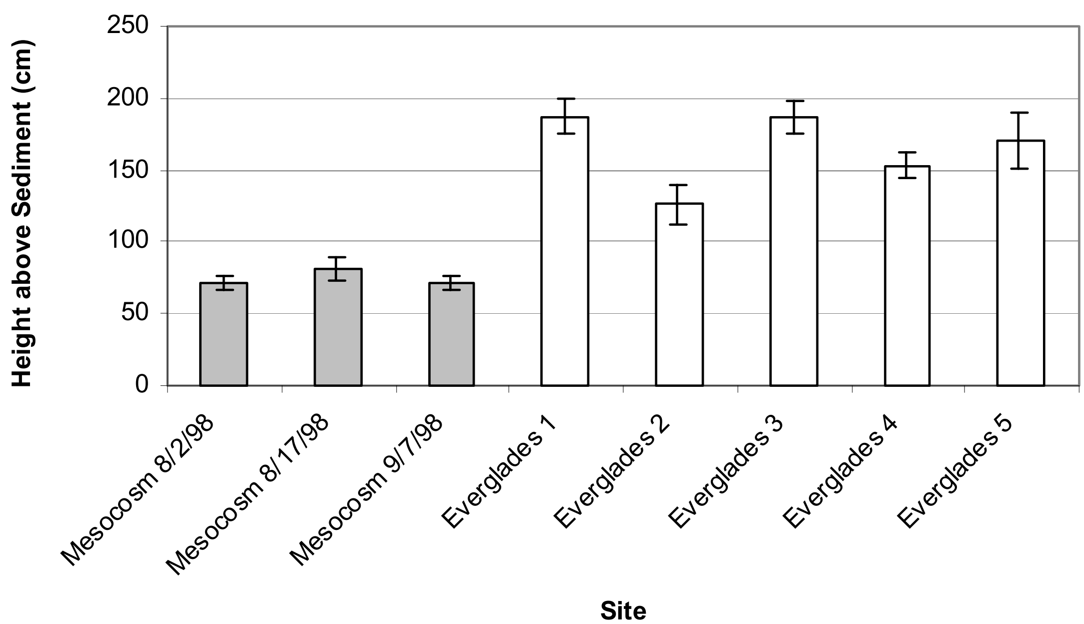


Figure 16. Comparative mean height distribution of *L. angulifera* in Everglades mesocosm (8/2/98, 8/17/98, 9/7/98) and field plots (11/99), error bars indicate standard error.

On September 20, 1998 all individuals were collected from the mesocosm. Length and weight measurements were taken, with an R^2 correlation of 0.75 (Figure 17). This correlation is significant and corroborates the data used to justify the use of length measurements alone to determine population age structure in salt marsh populations. The slope of the regression was 0.2309.

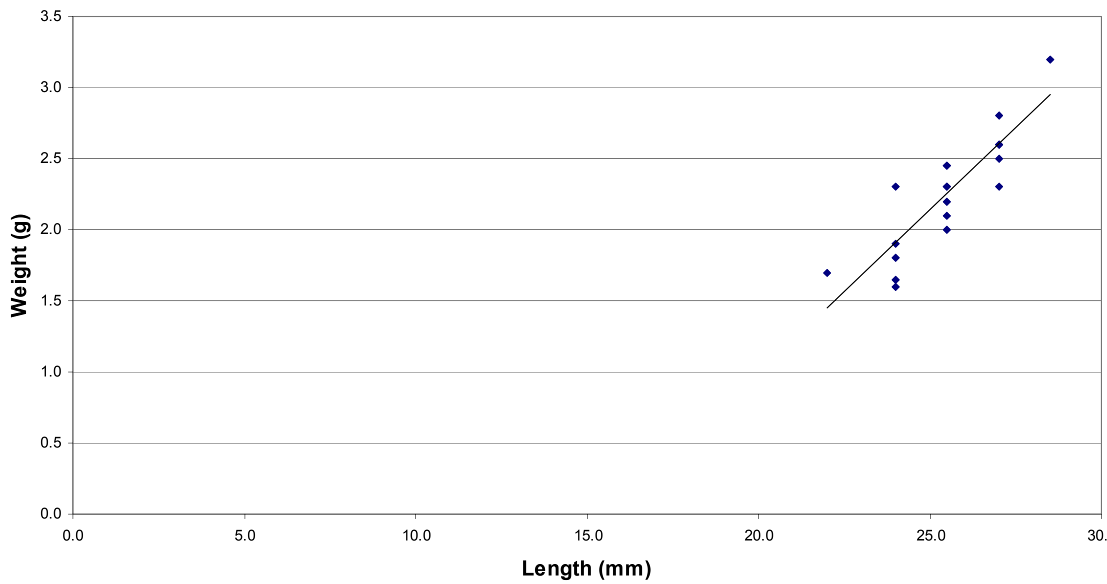


Figure 17. Length-weight correlation of *L. angulifera* individuals in Everglades mesocosm, 9/20/98 (R^2 = 0.75, y=0.2309x - 3.6326).

On November 19, 1999 length and weight measurements were taken at two reference site plots in the Florida Everglades. The R^2 correlations of 0.78 (Plot #1, Figure 18) and 0.86 (Plot #4, Figure 19) further support the use of length to determine population age structure in salt marsh populations. The slopes of the length-weight regressions were 0.1153 (Plot #1) and 0.1477 (Plot #4).

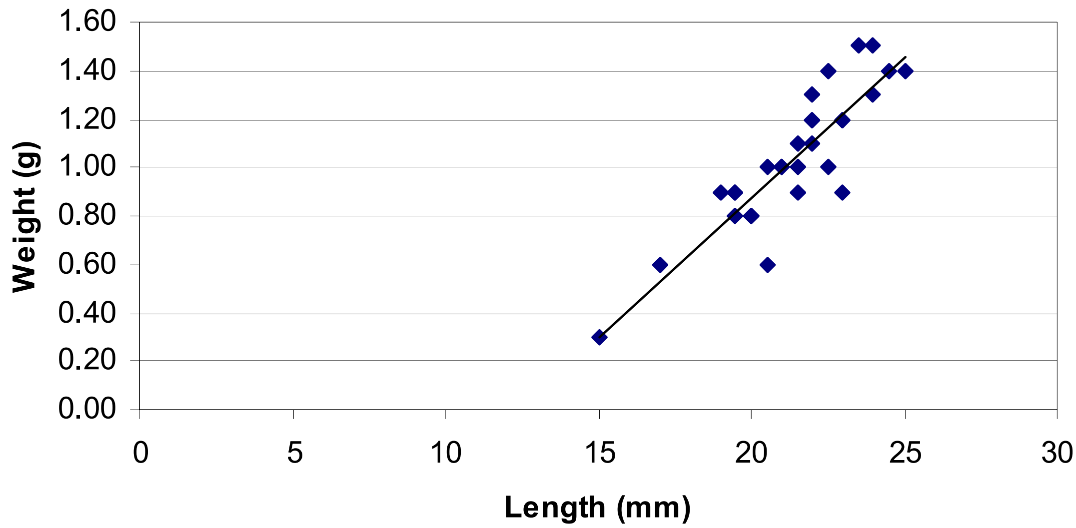


Figure 18. Length-weight correlation of *L. angulifera* individuals in Everglades reference field plot #1, 11/19/99 (R^2 = 0.78, y=0.1153x – 1.4268).

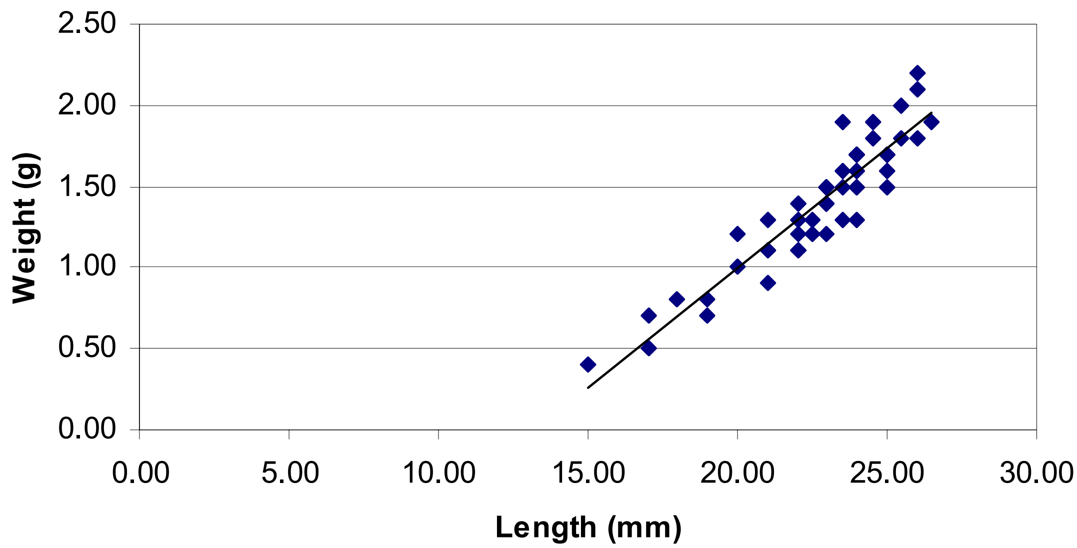


Figure 19. Length-weight correlation of *L. angulifera* individuals in Everglades reference field plot #4, 11//19/99 (R^2=0.86, y=0.1477x – 1.9571).

The population age structure of the mesocosm on 9/20/98 was comprised entirely of individuals over 20 mm in length (Figure 20). The age structure of the mesocosm population reveals a lack of juvenile recruitment, which is confirmed by the steady population decline. The age structure of two reference plots surveyed on November 19, 1999 was dominated by the 20-25 mm age class, but was also comprised of individuals in the 15-20 mm age class (Figure 21 and Figure 22). Surveys were conducted along the coastal fringe due to accessibility considerations. *L. angulifera* may settle in more protected areas and migrate to coastal fringe mangrove trees after they have reached a critical size.

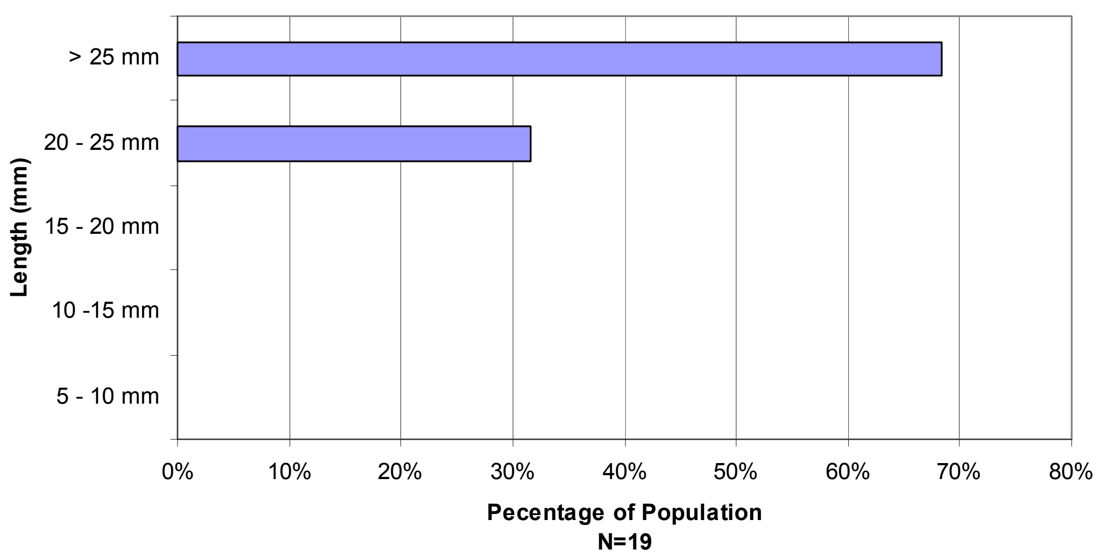


Figure 20. Age structure of *L. angulifera* population in Everglades mesocosm, 9/20/98.

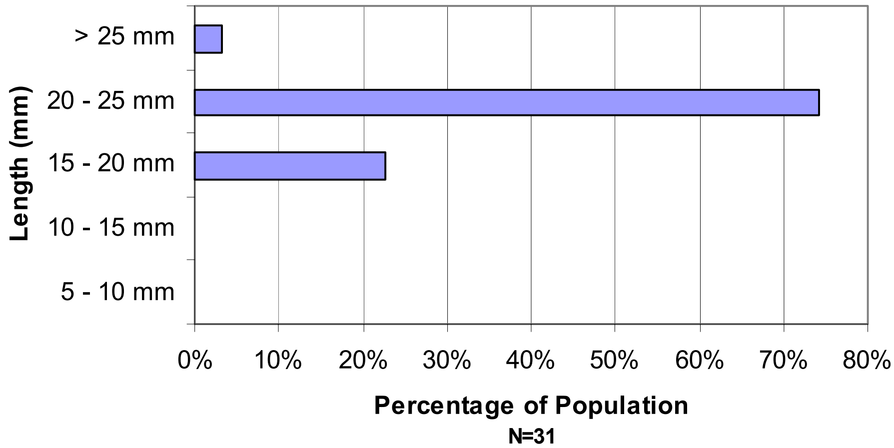


Figure 21. Age structure of *L. angulifera* population in Everglades reference field plot #1, 11/19/99.

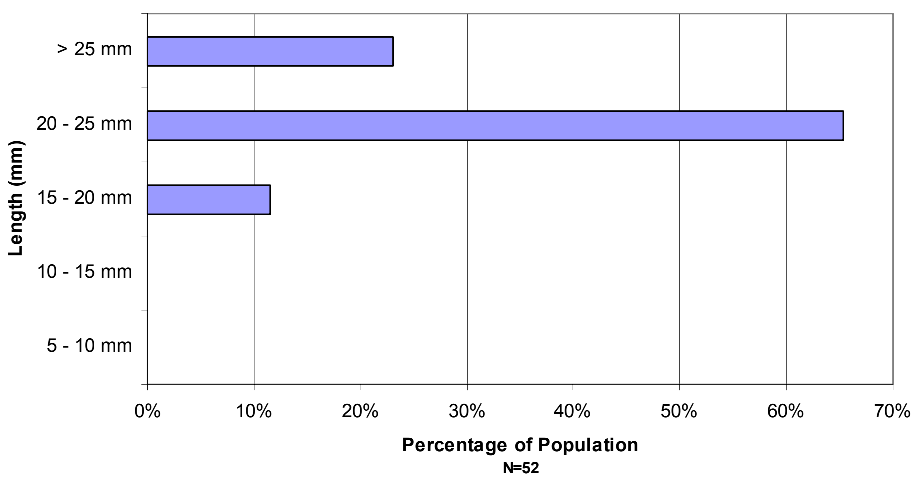


Figure 22. Age structure of *L. angulifera* population in Everglades reference field plot #4, 11/19/99.

SALT MARSH

The mean population density of reference site plots at Slaughter Creek reference site ranged from 8.85 per ¼ m^2 at the beginning of the study period in June 2000 to a high of 21.00 per ¼ m^2 at the end of the second field season in November 2001 (Figure 23). Standard error ranged from 2.42 to 3.45, and an ANOVA of the survey data indicated that there was a significant difference between one or more of the sampling dates ($p=0.0251$). There appears to be attrition over the winter and a steady gain in population over the field season. The mortality rate over the 2000-2001 winter season may have been somewhat lower than one might find during normal winter seasons due to unusually mild weather conditions.

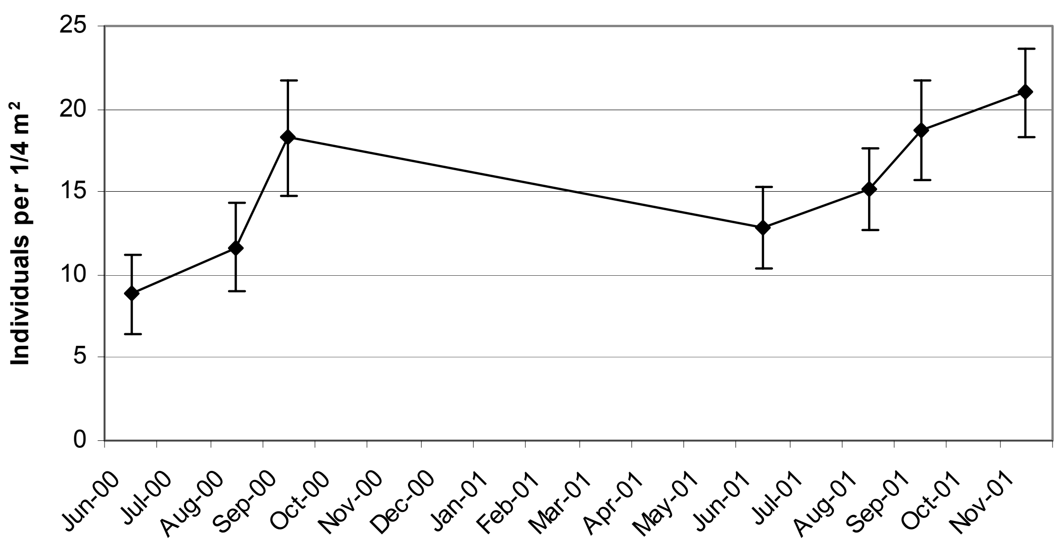


Figure 23. Slaughter Creek reference site *L. irrorata* population density per ¼ m^2, 20 plots per survey, June 2000 – November 2001 (error bars indicate standard error).

The mean length of *L. irrorata* individuals collected at the Slaughter Creek reference site over the course of the study was correlated to season. At the beginning of the first season the mean length was 15.9 mm, while at the beginning of the second season, the mean length was 16.6 mm. The primary factor contributing to this difference was most likely the unusually mild 2000-2001 winter. At the end of the 2000 season the mean length was 16.2 mm, while at the end of the 2001 season the mean length was 18.0 mm (Figure 24). Standard error ranged from 0.416 to 0.787. The dip in mean length during the 2001 season may reflect predation by blue crabs, *Callinectes sapidus*, on intermediate age classes (Paul 1988). The blue crab harvest in the Chesapeake Region (bay and oceanic landings or Maryland and Virginia) was 24% lower in 2000 than 1999, and remained at the same level in 2001 (National Marine Fisheries Service data).

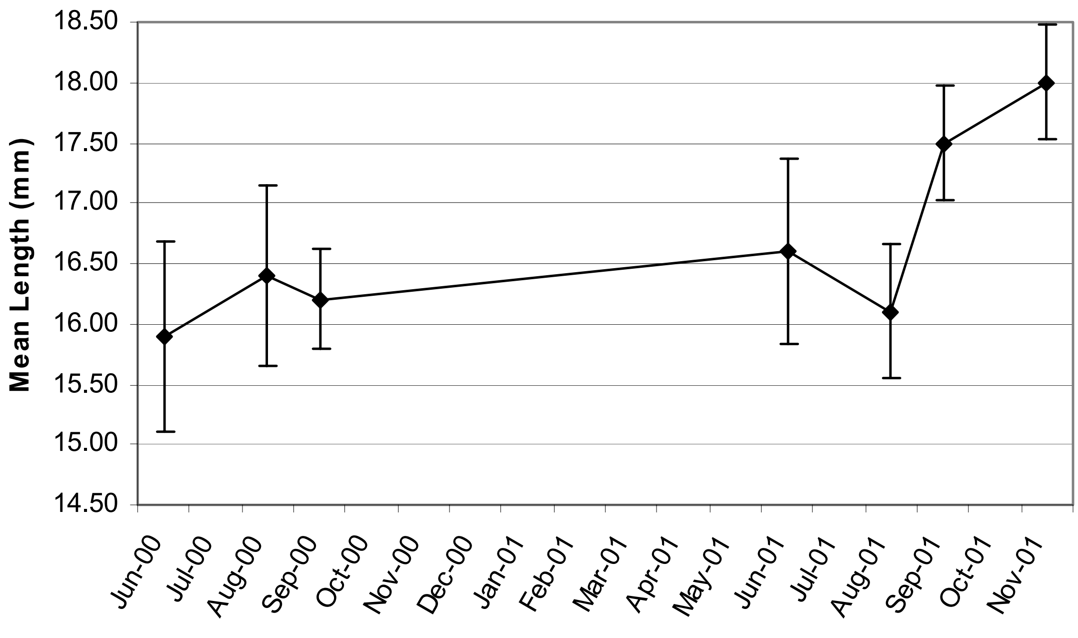


Figure 24. Slaughter Creek reference site *L. irrorata* population mean length (mm), 5 plots per survey, June 2000 – November 2001 (error bars indicate standard error).

In June 2000, length and weight measurements were taken at the Slaughter Creek reference site plots and in each of the newly stocked Horn Point mesocosms. The second order polynomial R^2 of 0.99 was only slightly higher in the reference site (Figure 25) than the range of 0.96 to 0.98 in mesocosm populations (Figure 26).

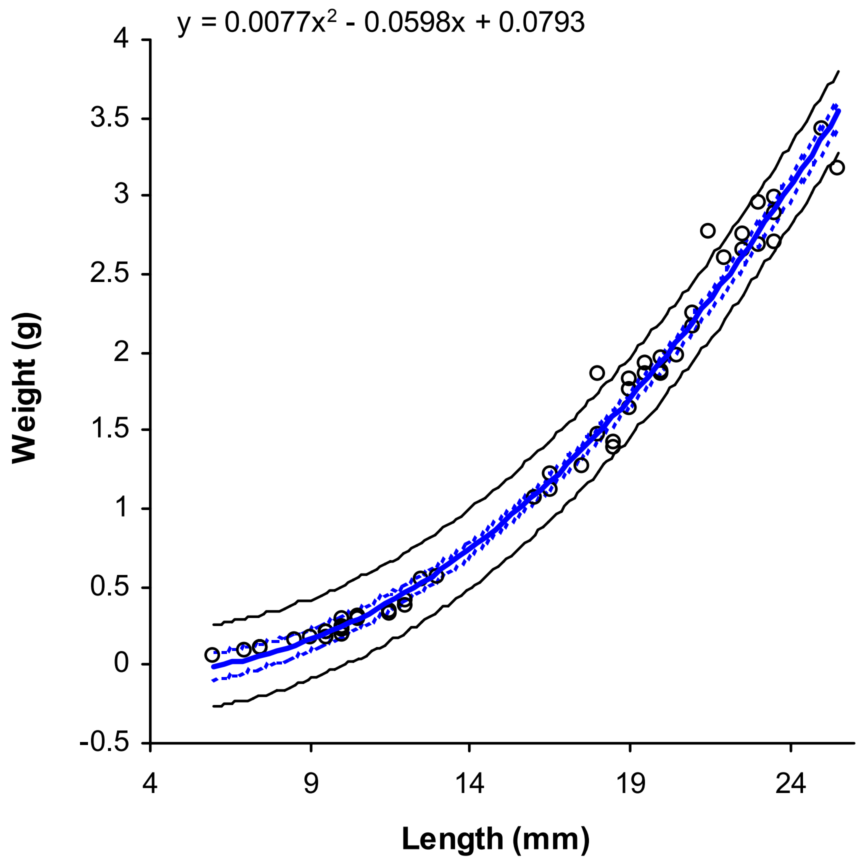


Figure 25. Length-weight second order polynomial regression of *L. irrorata* individuals in Slaughter Creek reference sites, June 2000 (R^2=0.99).

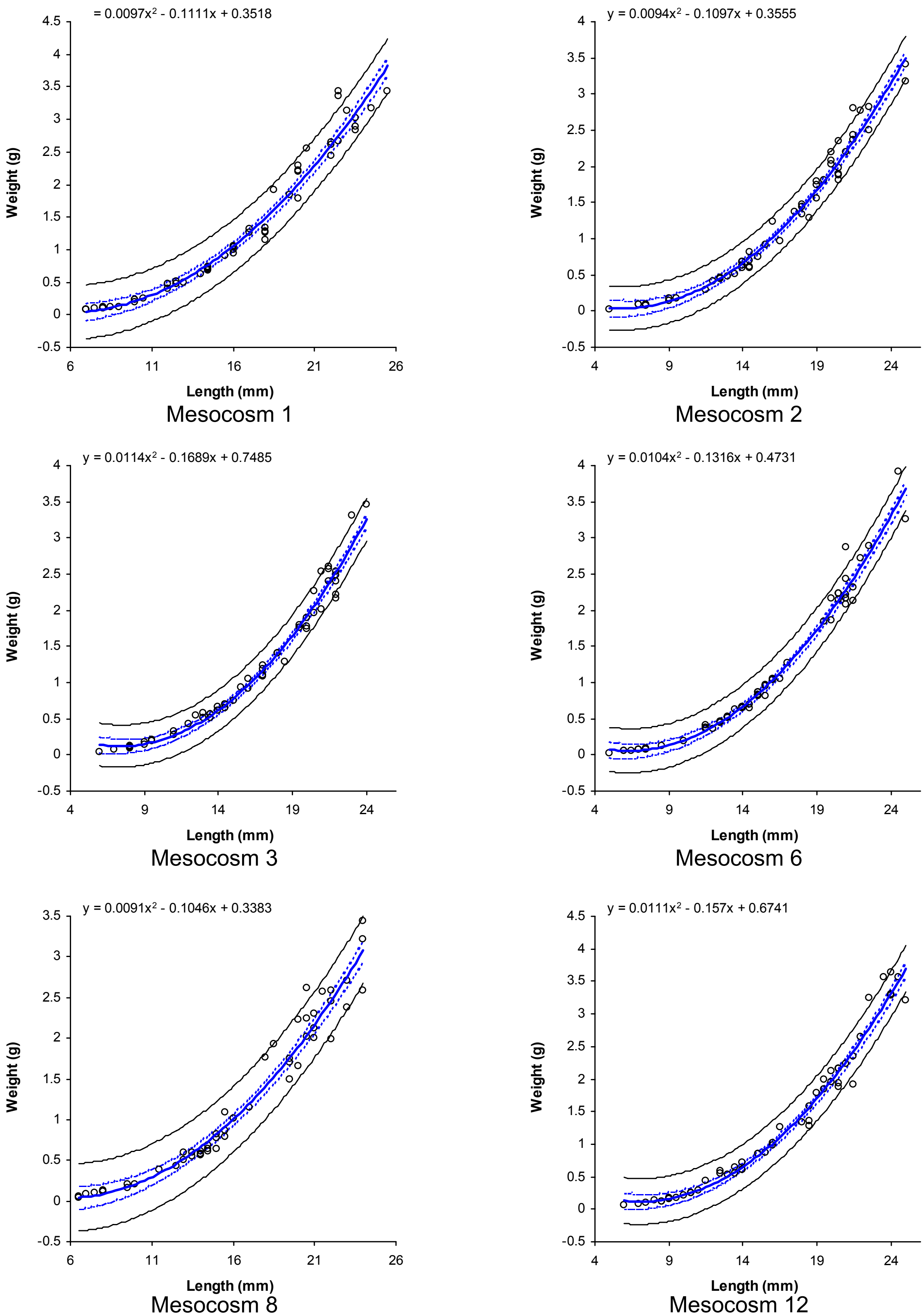


Figure 26. Length-weight second order polynomial regressions of *L. irrorata* individuals in Horn Point mesocosms, June 2000.

The population density trends in the mesocosms over the course of the 2000 season were remarkably similar. The initial density in all mesocosms was 8.85 per ¼m^2. End of season densities ranged from 5.50 to 6.50 per ¼ m^2. The average survival rate across all six mesocosms was 69%. Individuals were observed on the outer edge of the mesocosm and marked individuals were found dead on the ground outside the mesocosms, in addition to those found dead in the mesocosms. The mean density in 20 reference site plots, in contrast, rose from 8.85 ¼ m^2 at the beginning of the season to 11.65 per ¼ m^2 at midseason and 18.25 per ¼ m^2 at the end of the season, an increase of 206% (Figure 27)

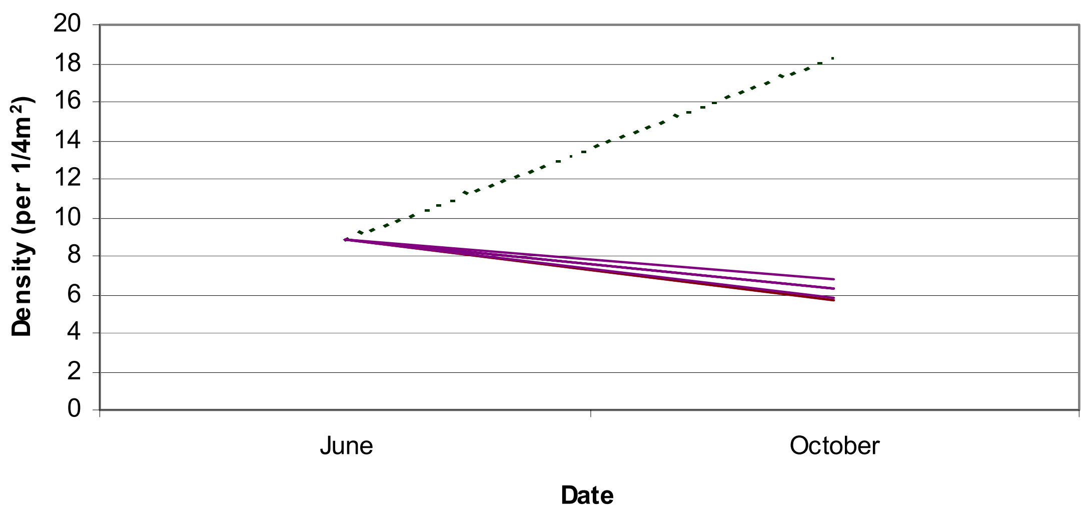


Figure 27. *L. irrorata* population density trend in Slaughter Creek reference site (broken line) and Horn Point mesocosms (solid lines), June 2000 - October 2000.

The population density in the mesocosms at the beginning of the 2001 season ranged from 1.17 per ¼ m^2 to 5.67 per ¼ m^2. At the end of the season, the population density in the mesocosms ranged from 0.50 per ¼ m^2 to 3.33 per ¼ m^2. The average survival rate across all six mesocosms was 56%. The mean density in 20 reference site plots, in contrast, rose from 12.85 ¼ m^2 at the beginning of the season 21.00 per ¼ m^2 at the end of the season, an increase of 163% (Figure 28)

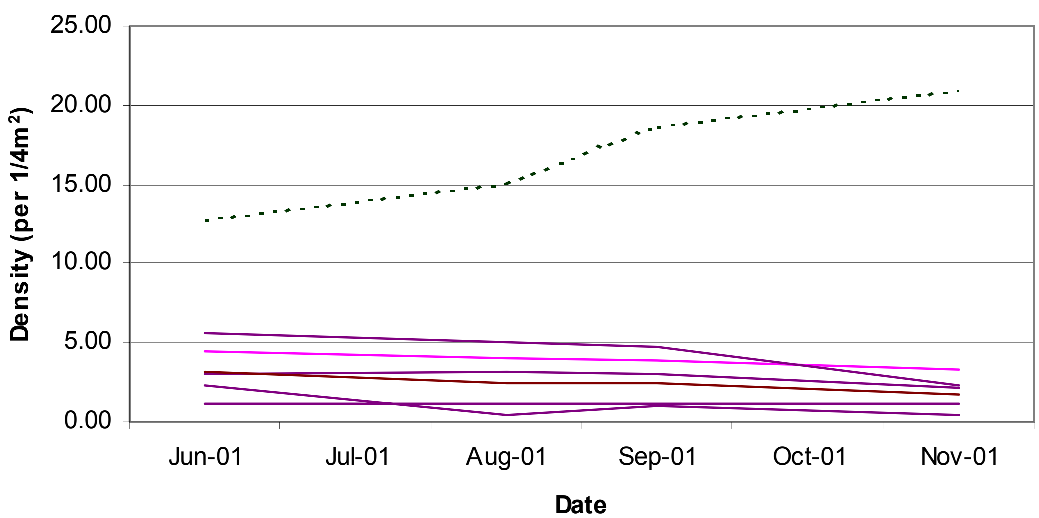


Figure 28. *L. irrorata* population density trend in Slaughter Creek reference site (broken line) and Horn Point mesocosms (solid lines), June 2001 – November 2001.

The mean population in reference site samples rose from 8.85 per ¼ m^2 at the beginning of the 2000 season to 21.00 per ¼ m^2 at the end of the 2001 season, for an increase of 237%. In contrast, the population density in the mesocosms fell to as low as 0.50 per ¼ m^2 in Mesocosm 8 at the end of the 2001 season (Figure 29). The overall survival rate across all six mesocosms during the two-year study period was 21%.

Mesocosms 1 and 12 would be expected to have the highest mortality rates due to increased exposure. The highest mortality rate, however, was observed in Mesocosm 8.

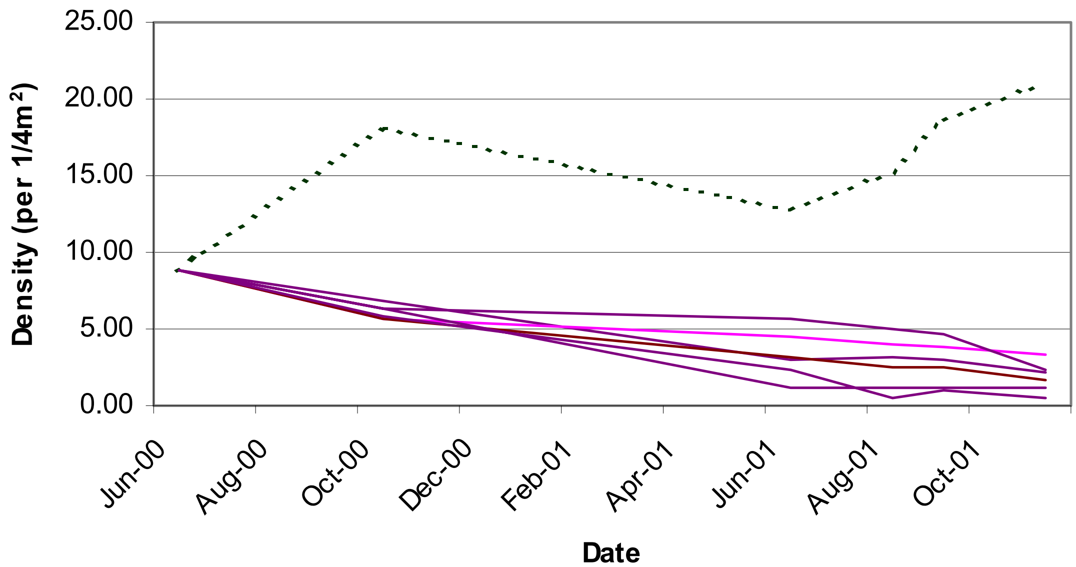


Figure 29. *L. irrorata* population density trend in Slaughter Creek reference site (broken line) and Horn Point mesocosms (solid lines), June 2000- November 2001.

Over the course of the two-year study period, the mean population density in the mesocosms fell from 8.85 per ¼ m^2 to 1.86 per ¼ m^2. The mean population density at the end of the study period ranged from 0.50 per ¼ m^2 to 3.33 per ¼ m^2 (Figure 30).

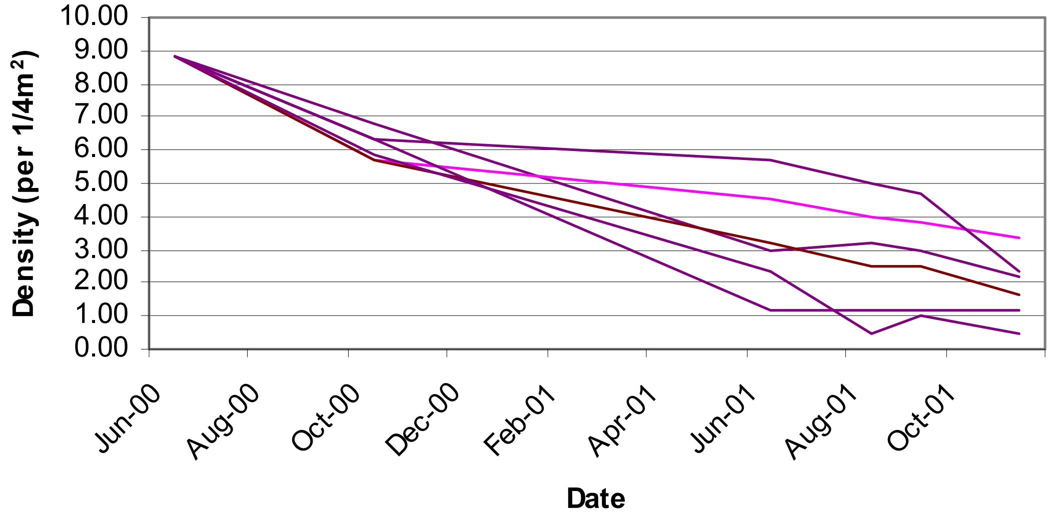


Figure 30. *L. irrorata* population density trend in Horn Point mesocosms, June 2000-November 2001.

The change in *L. irrorata* population density (survival) across all mesocosms during the first season was remarkably similar, ranging from 62% to 74%. Reference site plots, in contrast, had a mean change in population density of 270% (Figure 31).

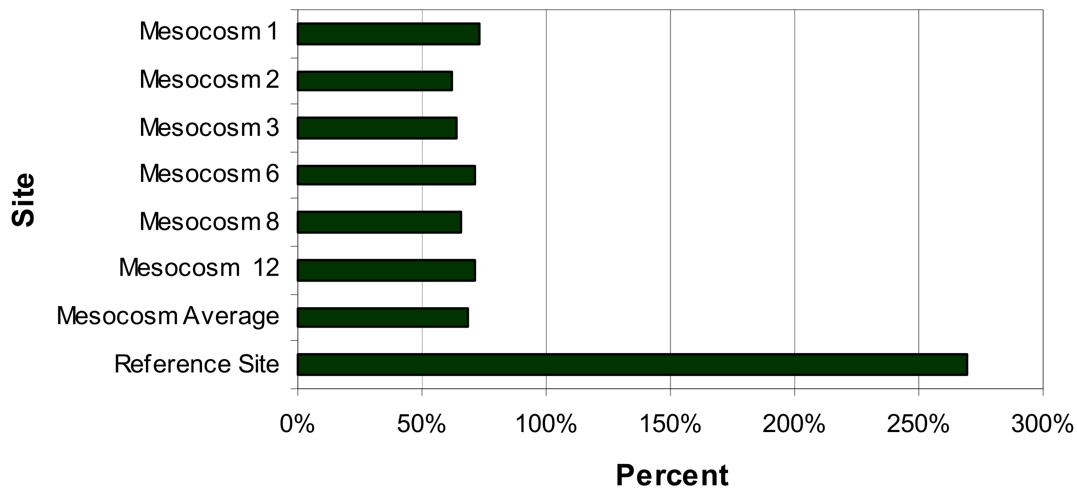


Figure 31. Change in *L. irrorata* population density in Slaughter Creek reference site and Horn Point mesocosms, June 2000 - October 2000

During the second season, the change in population size in the mesocosms varied significantly, ranging from 21% to 114%. The high end of the range is Mesocosm 12, with a total of 7 individuals at the beginning of the season and 8 individuals at the end of the season. It does not appear that this increase in population was due to recruitment, and the most reasonable explanation is human error, as some individuals may have been missed in the dense vegetation during sampling at the beginning of the season. The lowest survival rate was in Mesocosm 8. The mean change in reference site population density was 185% (Figure 32).

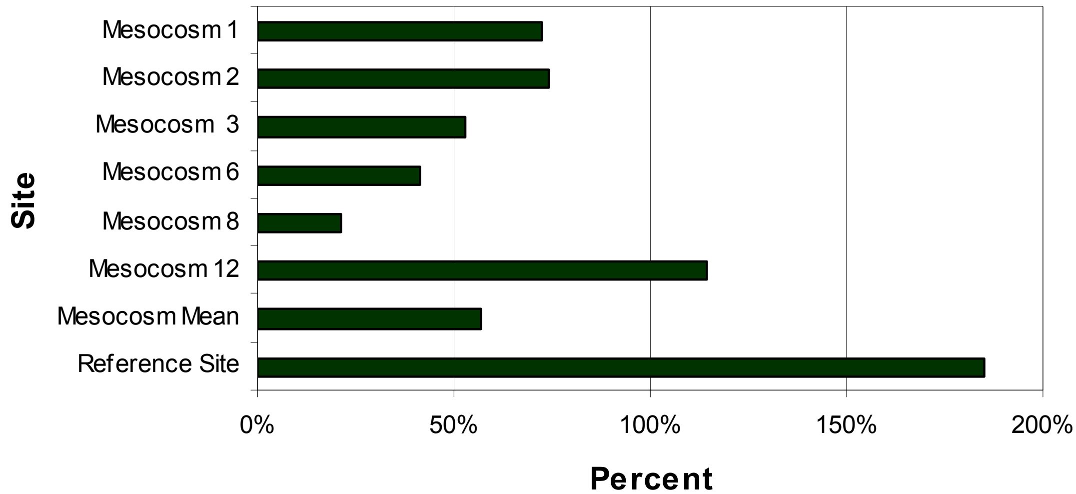


Figure 32. Change in *L. irrorata* population density in Slaughter Creek reference site and Horn Point mesocosms, June 2001 - November 2001.

The survival rate in mesocosms for the two-year study period ranged from 6% to 38%. The mean change in reference site population density during the same period was 230% (Figure 33).

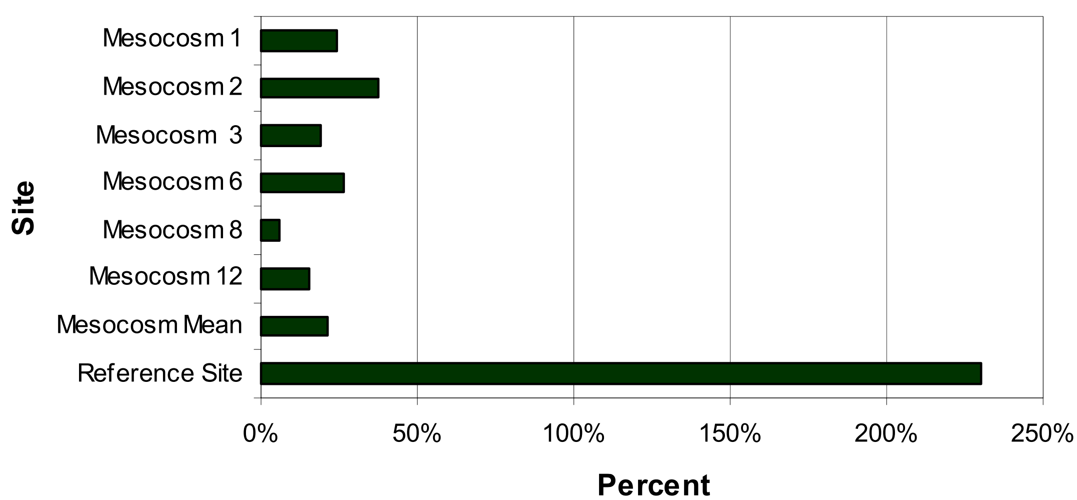


Figure 33. Change in *L. irrorata* population density in Slaughter Creek reference site and Horn Point mesocosms, June 2000 - November 2001.

On 6/22/00 and 6/23/00, mesocosms 1, 2, 3, 6, 8 and 12 were stocked with *L. irrorata* populations of 53 individuals each reflecting the age structure of the reference site plots surveyed on 6/20/00 (Figure 34 and Table 4). Individuals were collected from the south side of the Route 16 bridge at the reference site and another nearby salt marsh.

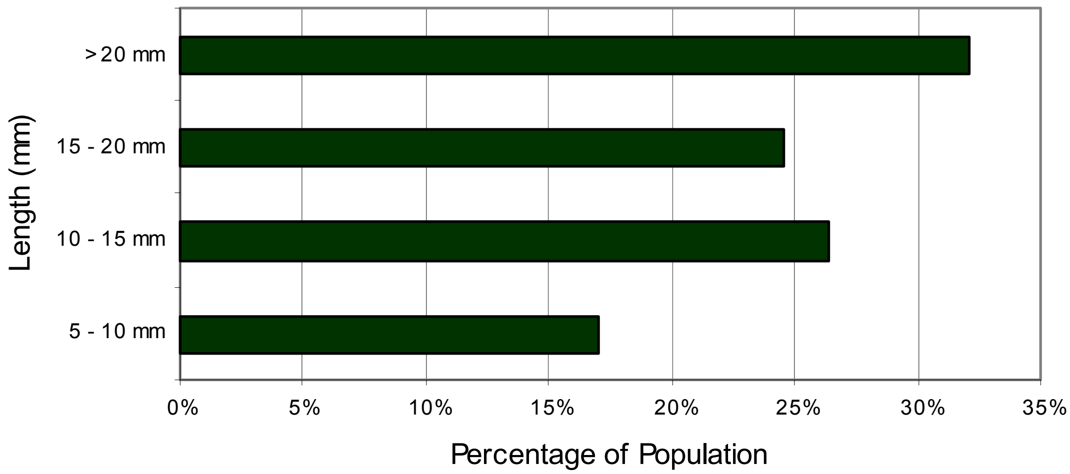


Figure 34. *L. irrorata* population age structure in Horn Point mesocosms, June 2000.

At the end of the first season, the population age structure in the mesocosms was significantly different from that in the reference site. Although the age structure was identical at the beginning, the smallest age class declined a great deal more in the mesocosms than it did in the reference site. Three factors may have contributed to this difference: a higher rate of mortality; a higher rate of growth, leading to greater recruitment into larger age classes; or sampling error due to denser vegetation. The second age class, 10-15 mm, increased in the reference site the end of the season after losses at mid season, but decreased in the mesocosms. The third age class, 15-20 mm, increased at a higher rate in the mesocosm than in the reference site. The primary factor contributing to this difference was higher survival rates due to lack of predation in the mesocosms in concert with recruitment from smaller age classes. The fourth and largest age class, >20 mm, remained essentially steady throughout the season in the reference site, but in the mesocosms showed either higher survival rates, or significant recruitment from smaller age classes, or both (Figure 35 and Table 4).

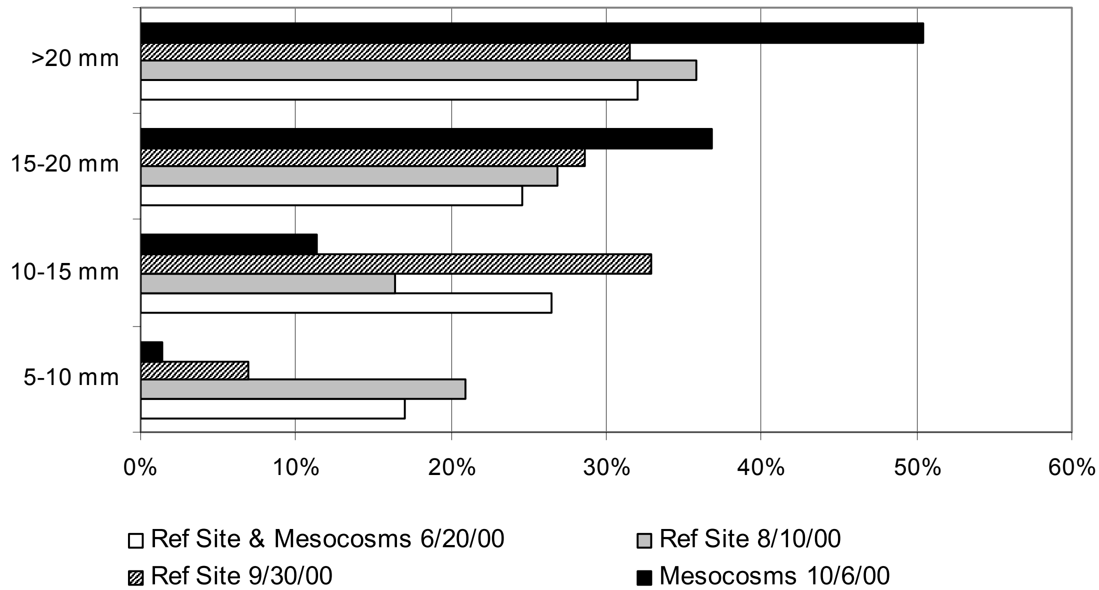


Figure 35. Change in *L. irrorata* population age structure over the course of the first field season in Slaughter Creek reference site and Horn Point mesocosms, June 2000 – October 2000.

Table 4. Change in *L. irrorata* population age structure in Slaughter Creek reference site and Horn Point mesocosms, percentage of population, June 2000 – October 2000.

Length (mm)	Ref Site & Mesocosms 6/20/00	Ref Site 8/10/00	Ref Site 9/30/00	Mesocosms 10/6/00
5-10 mm	17%	21%	7%	1%
10-15 mm	26%	16%	33%	11%
15-20 mm	25%	27%	29%	37%
>20 mm	32%	36%	31%	50%

The population age structures in the individual mesocosms were similar, with the exception of Mesocosm 2, which had greater representation of the 15- 20 mm age class than the > 20 mm age class (Figure 36).

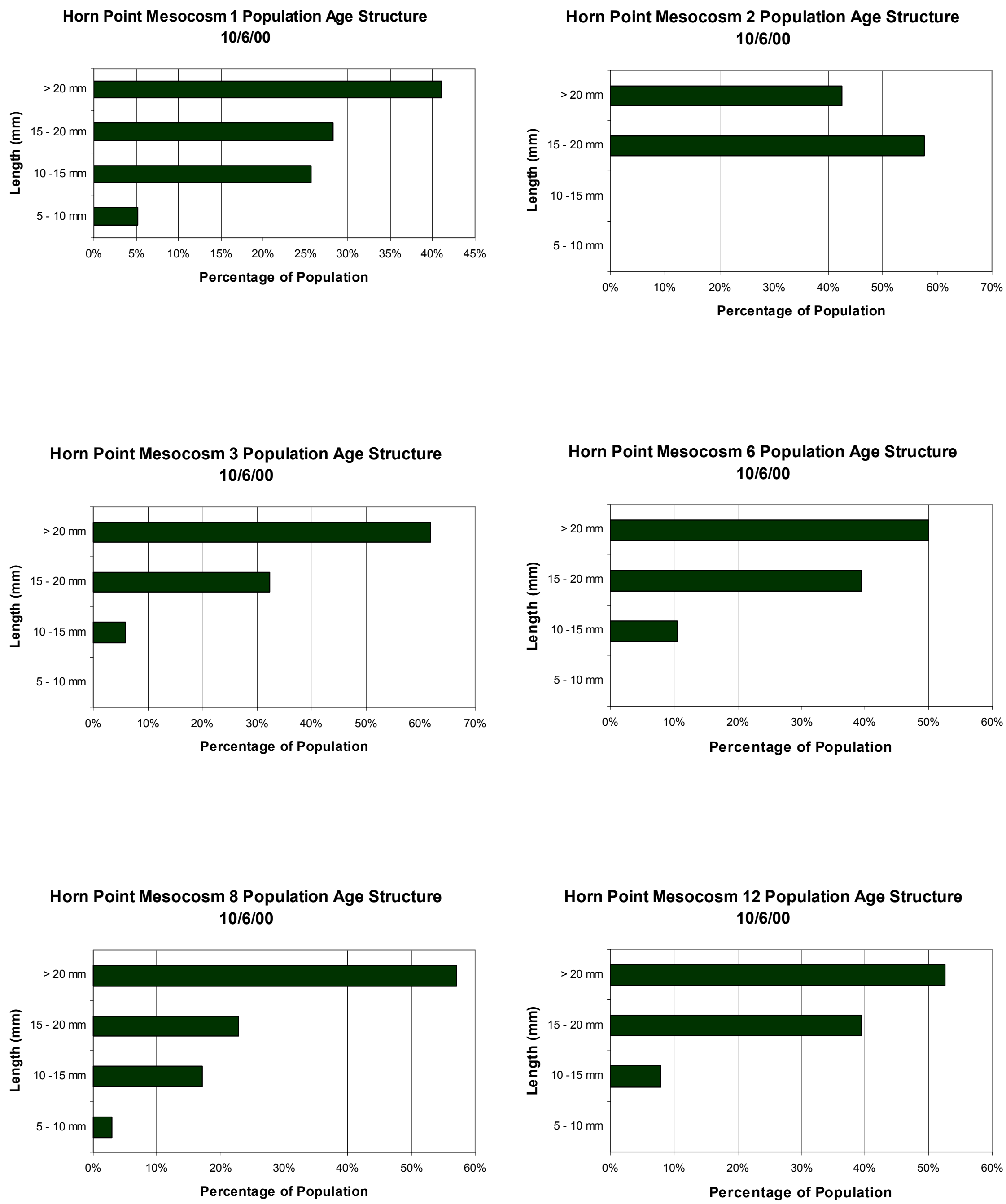


Figure 36. *L. irrorata* population age structure in individual Horn Point mesocosms, October 2000.

During the first season, the change in population density by age class in the mesocosms increased with age class. The greatest reductions in population density were in the 5-10 mm age class and 10-15 mm age class. The 15-20 mm age class and >20 mm age class both had increases in population density over 100%, indicating recruitment from smaller age classes. This pattern was not reflected in reference site plots, where the greatest increase in population density was in the 10-15 mm age class (Figure 37).

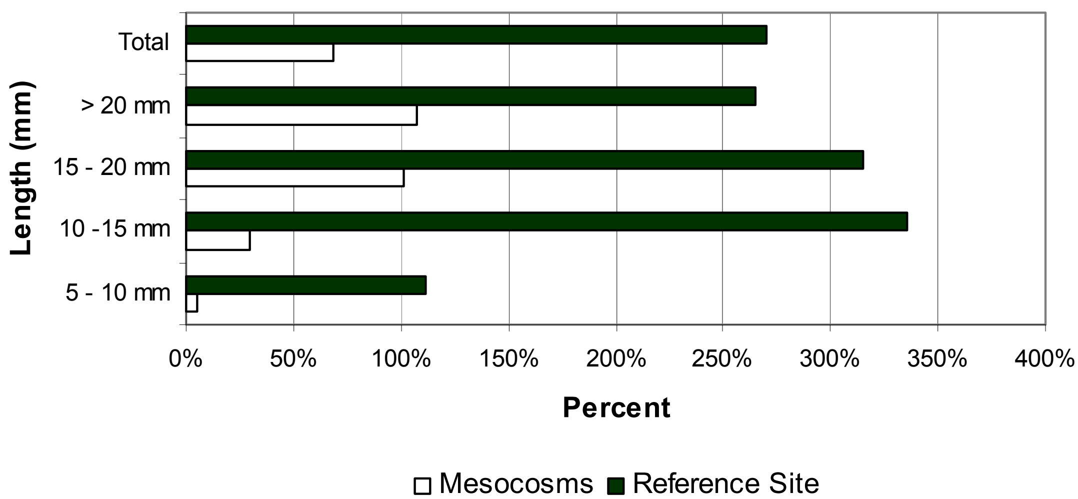


Figure 37. Change in *L. irrorata* population age structure in Slaughter Creek reference site and Horn Point mesocosms, June 2000 – October 2000.

During the second season, the change in population density by age class in the mesocosms also increased with class. The 5-10 mm age class and 10-15 mm age class represented 0% of the population. The 15-20 mm age class and >20 mm age class had more significant rates of increase than during the first season. This pattern was not reflected in reference site plots, where the greatest increase in population density was in the 15-20 mm age class (Figure 38).

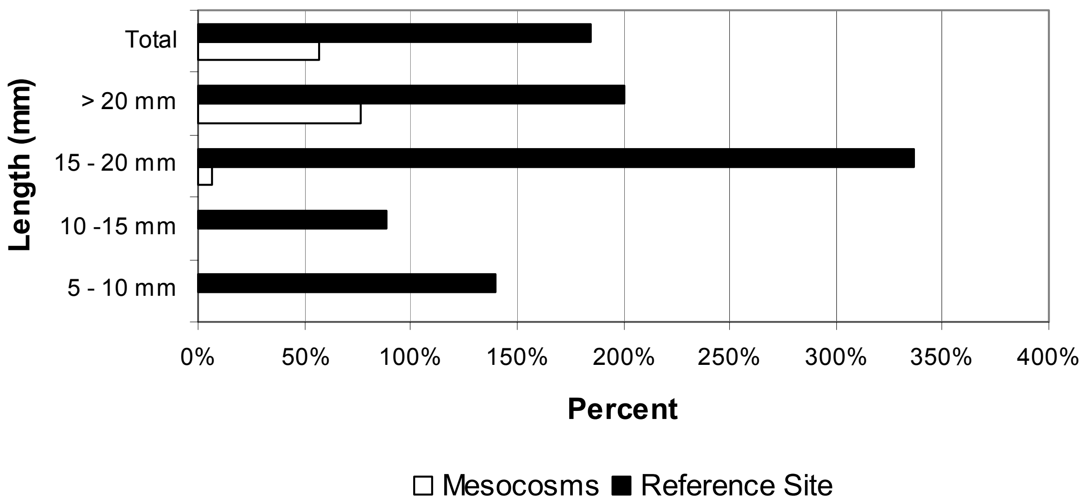


Figure 38. Change in *L. irrorata* population age structure in Slaughter Creek reference site and Horn Point mesocosms, June 2001 – November 2001.

At the end of the two-year study period, the two smallest age classes represented 0% of the mesocosm population. The greatest proportion of the population was in the largest age class for the mesocosms, and the greatest increase in population density was in the largest age class for the reference plots (Figure 39).

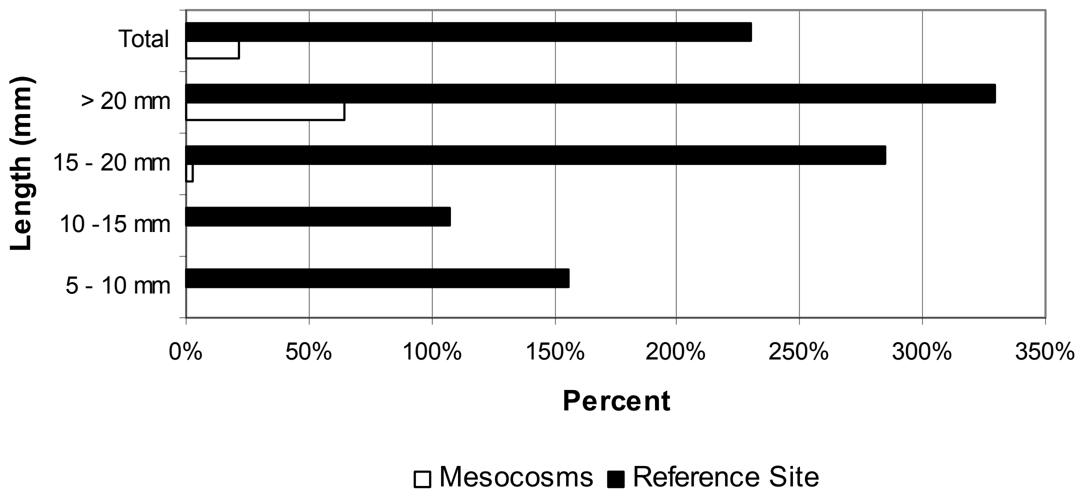


Figure 39. Change in *L. irrorata* population age structure in Slaughter Creek reference site and Horn Point mesocosms, June 2000 – November 2001.

During the two-year study period, the age structure in the mesocosms shifted steadily towards the larger age classes over time. The two smallest age classes were eliminated by the middle of the second season (8/17/01). At the end of the study period, the mesocosms were dominated by the largest age class, with minimal representation of the second largest age class (Figure 40 and Table 5).

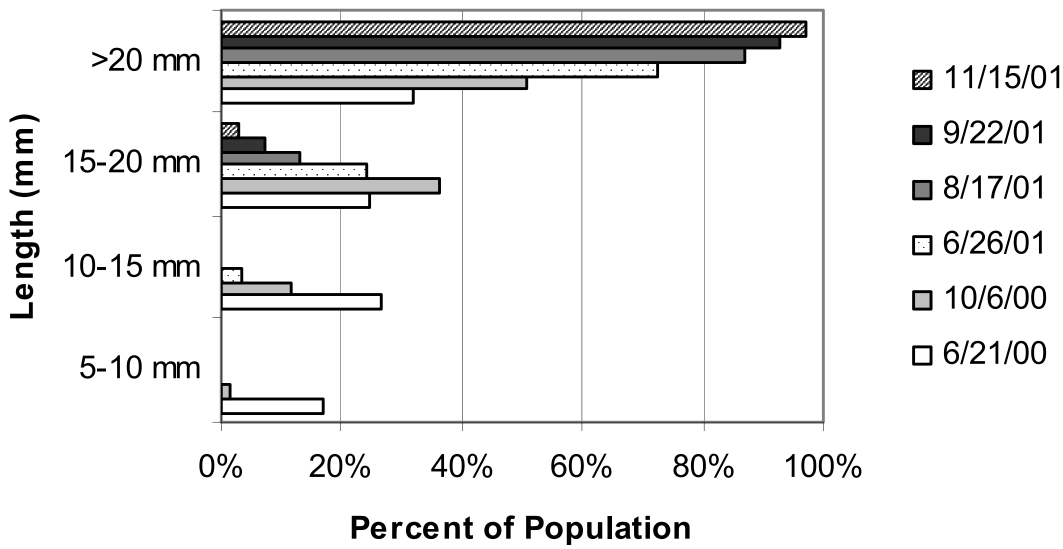


Figure 40. Change in *L. irrorata* population age structure in mesocosms, June 2000 - November 2001.

Table 5. Change in *L. irrorata* population age structure in mesocosms, percentage of population, June 2000 – November 2001.

Length (mm)	6/21/00	10/6/00	6/26/01	8/17/01	9/22/01	11/15/01
5-10 mm	17%	1%	0%	0%	0%	0%
10-15 mm	26%	12%	3%	0%	0%	0%
15-20 mm	25%	36%	24%	13%	7%	3%
>20 mm	32%	51%	72%	87%	93%	97%

The shift in age structure over time was similar in all mesocosms (Figure 41 and Table 6). The mean percent of population in the largest age class steadily increased between June 2000 and November 2001, while the mean percent of population in the three smaller age classes steadily declined (Figure 42 and Figure 44). The absolute number of individuals in each age class declined over time, with an overall loss of 79% of the population between June 2000 and November 2001 (Figure 43 and Figure 45).

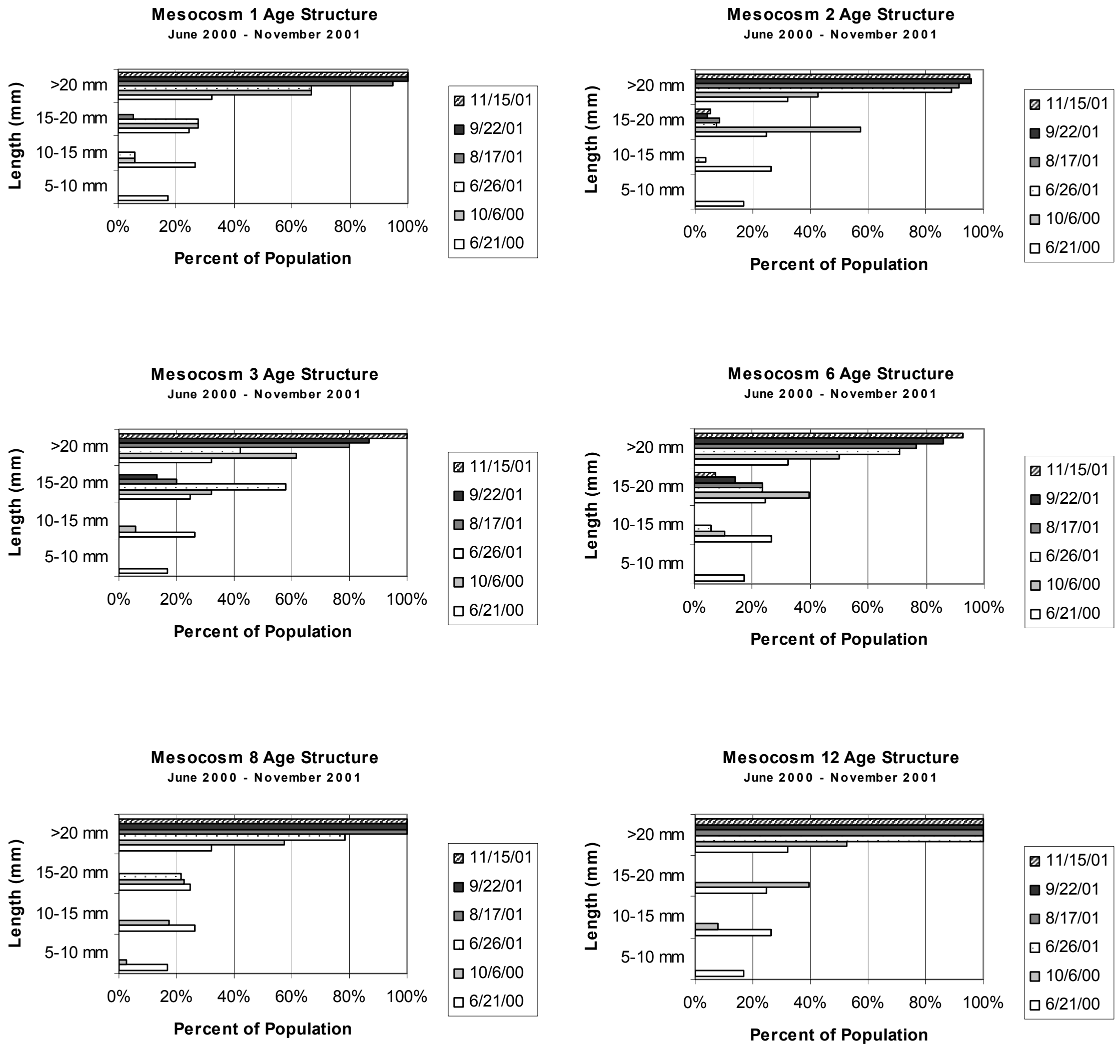


Figure 41. Change in *L. irrorata* population age structure in individual mesocosms, June 2000 - November 2001.

Table 6. Change in *L. irrorata* population age structure in individual mesocosms, percentage of population, June 2000 – November 2001.

			Mesocosm 1			
Length (mm)	6/21/00	10/6/00	6/26/01	8/17/01	9/22/01	11/15/01
5-10 mm	17%	0%	0%	0%	0%	0%
10-15 mm	26%	6%	6%	0%	0%	0%
15-20 mm	25%	28%	28%	5%	0%	0%
>20 mm	32%	67%	67%	95%	100%	100%
			Mesocosm 2			
Length (mm)	6/21/00	10/6/00	6/26/01	8/17/01	9/22/01	11/15/01
5-10 mm	17%	0%	0%	0%	0%	0%
10-15 mm	26%	0%	4%	0%	0%	0%
15-20 mm	25%	58%	7%	8%	4%	5%
>20 mm	32%	42%	89%	92%	96%	95%
			Mesocosm 3			
Length (mm)	6/21/00	10/6/00	6/26/01	8/17/01	9/22/01	11/15/01
5-10 mm	17%	0%	0%	0%	0%	0%
10-15 mm	26%	6%	0%	0%	0%	0%
15-20 mm	25%	32%	58%	20%	13%	0%
>20 mm	32%	62%	42%	80%	87%	100%
			Mesocosm 6			
Length (mm)	6/21/00	10/6/00	6/26/01	8/17/01	9/22/01	11/15/01
5-10 mm	17%	0%	0%	0%	0%	0%
10-15 mm	26%	11%	6%	0%	0%	0%
15-20 mm	25%	39%	24%	23%	14%	7%
>20 mm	32%	50%	71%	77%	86%	93%
			Mesocosm 8			
Length (mm)	6/21/00	10/6/00	6/26/01	8/17/01	9/22/01	11/15/01
5-10 mm	17%	3%	0%	0%	0%	0%
10-15 mm	26%	17%	0%	0%	0%	0%
15-20 mm	25%	23%	21%	0%	0%	0%
>20 mm	32%	57%	79%	100%	100%	100%
			Mesocosm 12			
Length (mm)	6/21/00	10/6/00	6/26/01	8/17/01	9/22/01	11/15/01
5-10 mm	17%	0%	0%	0%	0%	0%
10-15 mm	26%	8%	0%	0%	0%	0%
15-20 mm	25%	39%	0%	0%	0%	0%
>20 mm	32%	53%	100%	100%	100%	100%

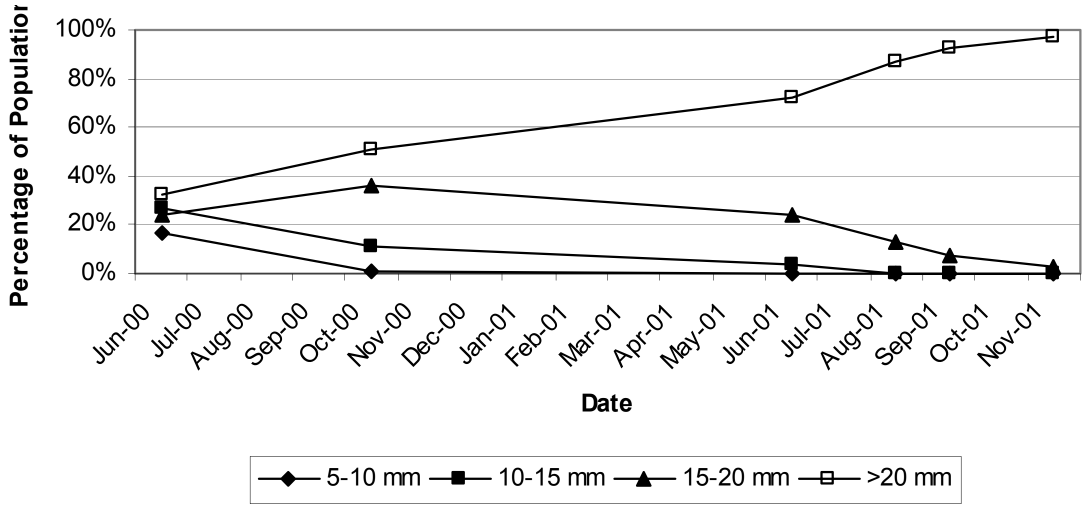


Figure 42. Change in percent of *L. irrorata* population in each age class in Horn Point mesocosms over time, June 2000 - November 2001.

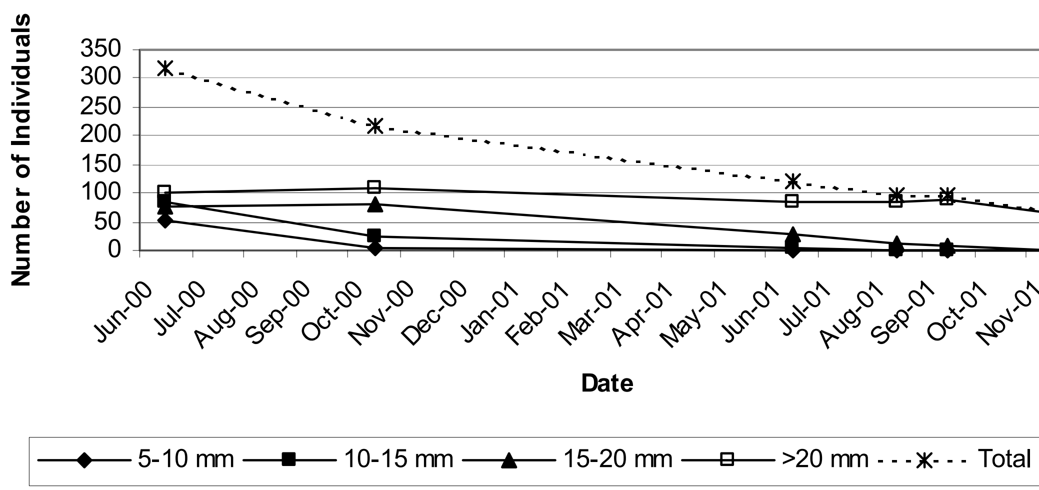


Figure 43. Change in number of *L. irrorata* individuals in each age class in Horn Point mesocosms over time, June 2000 - November 2001.

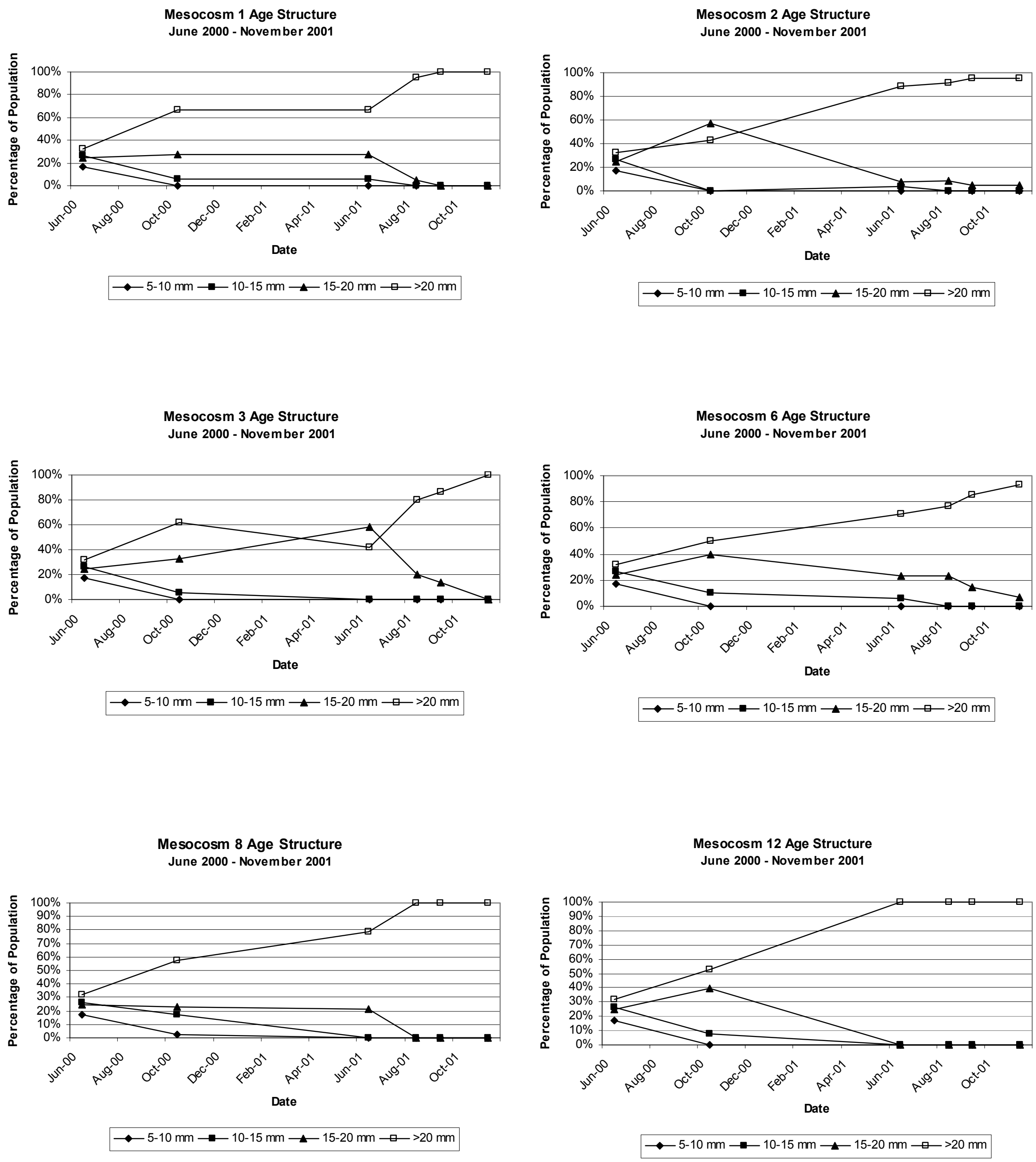


Figure 44. Change in percent of *L. irrorata* population in each age class in individual Horn Point mesocosms over time, June 2000 - November 2001.

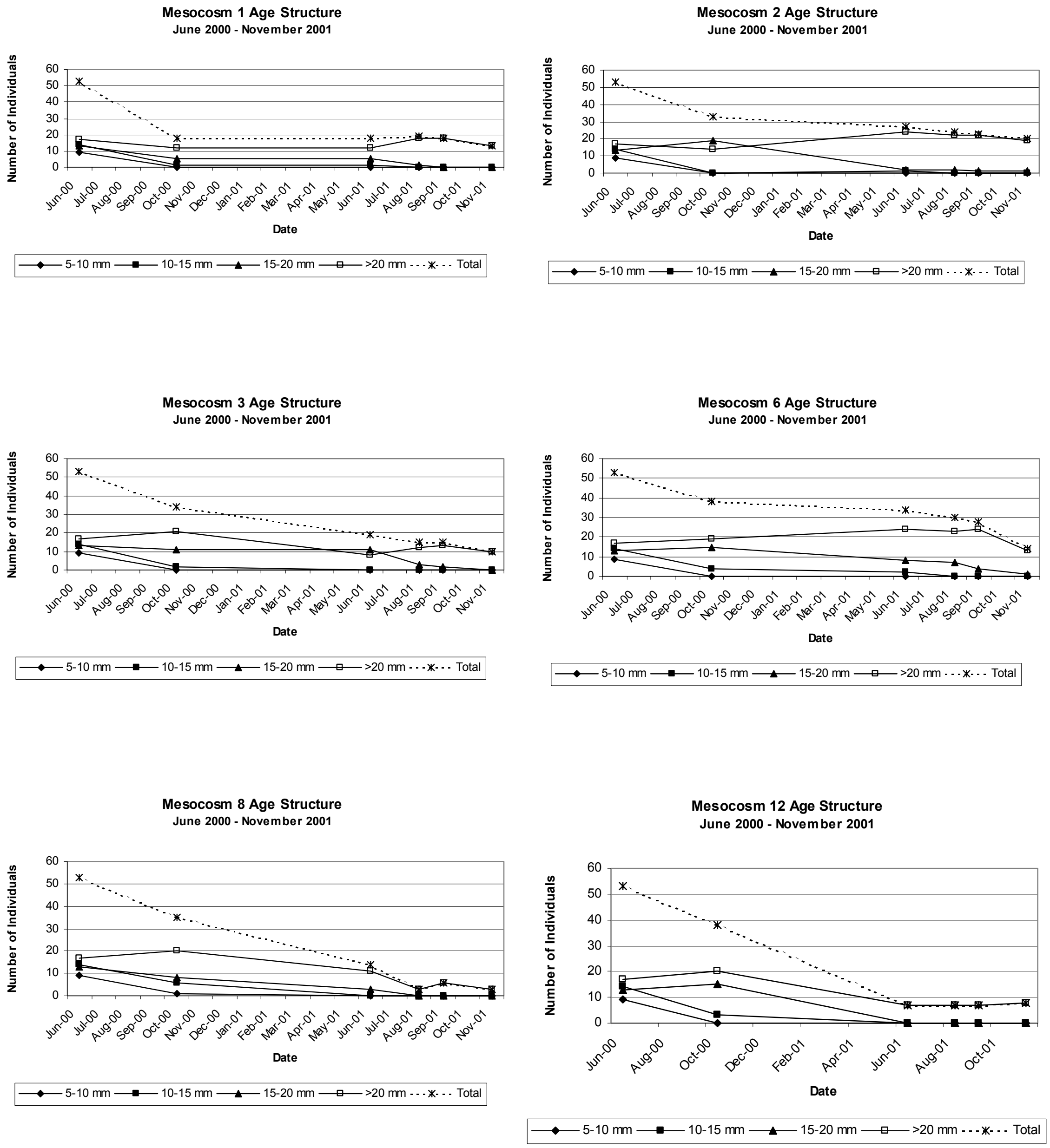


Figure 45. Change in number of *L. irrorata* individuals in each age class in individual Horn Point mesocosms over time, June 2000 - November 2001.

All mesocosms used in this research received groundwater with no nitrate. They were grouped by vegetation diversity (Low D and High D) and burn history for analysis. ANOVAs of the survey data indicate that survival by vegetation type (p=0.9705) and burn history (p=0.9381) were not significantly different over the course of the first season. The analysis conforms to a similarly consistent survival rate across all mesocosms for the same period (Figure 46).

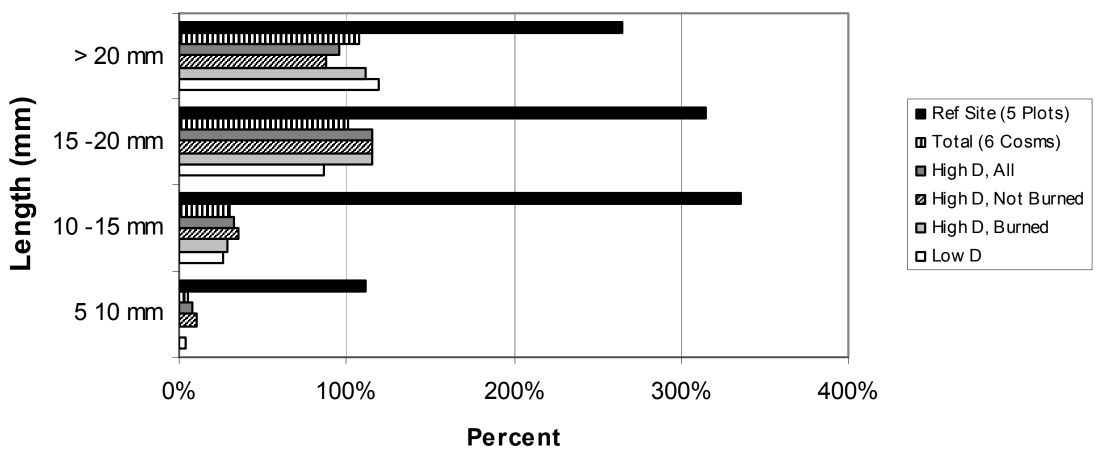


Figure 46. Change in *L. irrorata* population density by age class and vegetation diversity in Slaughter Creek reference site and Horn Point mesocosms, June 2000 – October 2000.

Table 7. Change in *L. irrorata* population density by age class and vegetation diversity in Horn Point mesocosms, percentage of population, June 2000 – October 2000.

Length (mm)	Low D	High D, Burned	High D, Not Burned	High D, All	Total (6 Cosms)	Ref Site (5 Plots)
5-10 mm	4%	0%	11%	7%	6%	111%
10-15 mm	26%	29%	36%	33%	30%	336%
15-20 mm	87%	115%	115%	115%	101%	315%
> 20 mm	120%	112%	88%	96%	108%	265%
Total	67%	72%	68%	69%	68%	270%

During the second season, there was a lower survival rate in the high diversity burned mesocosm than other mesocosms. The high diversity mesocosms that were not burned had a slightly higher survival rate than other mesocosms across all age classes (Figure 47 and Table 8). ANOVAs of the survey data indicate that survival by vegetation type was significantly different (p=0.0031), while survival by burn history was not significantly different (p=0.2181) over the course of the second season.

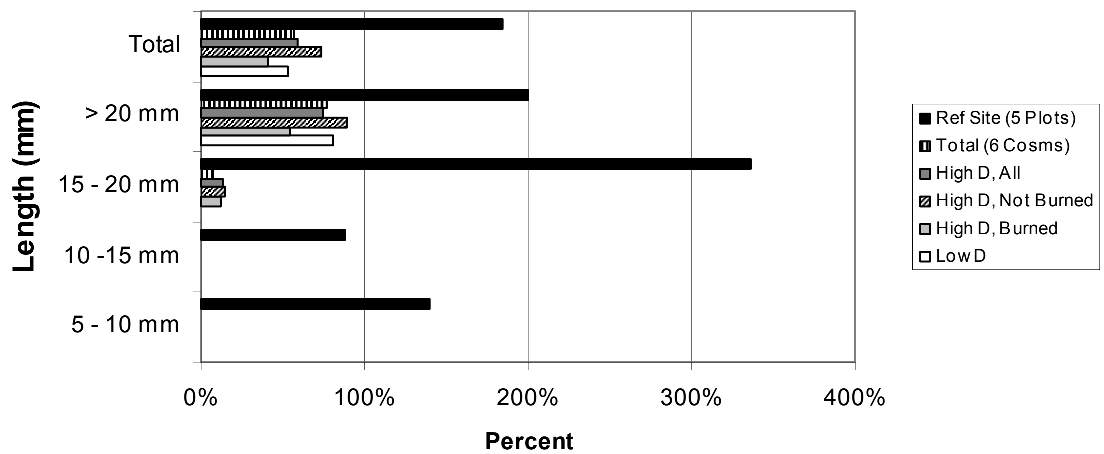


Figure 47. Change in *L. irrorata* population density by age class and vegetation diversity in Horn Point mesocosms, June 2001 – November 2001.

Table 8. Change in *L. irrorata* population density by age class and vegetation diversity in Horn Point mesocosms, percentage of population, June 2001 – November 2001.

Length (mm)	Low D	High D, Burned	High D, Not Burned	High D, All	Total (6 Cosms)	Ref Site (5 Plots)
5-10 mm	0%	0%	0%	0%	0%	140%
10-15 mm	0%	0%	0%	0%	0%	88%
15-20 mm	0%	13%	14%	13%	7%	336%
> 20 mm	81%	54%	89%	75%	77%	200%
Total	53%	41%	73%	60%	57%	184%

Survival by vegetation type and burn history in the mesocosms over the course of the two-year experiment was similar to survival for the 2001 field season (Figure 48 and Table 9). ANOVAs of the survey data indicate that survival by vegetation type (p=0.3774) and burn history (p=0.5719) were not significantly different over the course of the first season.

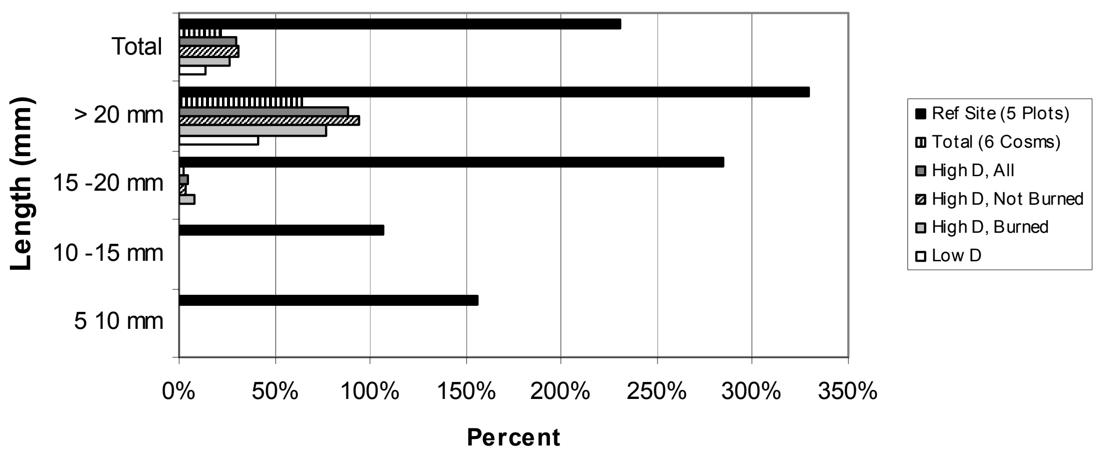


Figure 48. Change in *L. irrorata* population density by age class and vegetation diversity in Horn Point mesocosms, June 2000 – November 2001.

Table 9. Change in *L. irrorata* population density by age class and vegetation diversity in Horn Point mesocosms, percentage of population, June 2000 – November 2001.

Length (mm)	Low D	High D, Burned	High D, Not Burned	High D, All	Total (6 Cosms)	Ref Site (5 Plots)
5-10 mm	0%	0%	0%	0%	0%	156%
10-15 mm	0%	0%	0%	0%	0%	107%
15-20 mm	0%	8%	4%	5%	3%	285%
> 20 mm	41%	76%	94%	88%	65%	329%
Total	13%	26%	31%	30%	21%	230%

At the end of the first season, a strong preference for wall habitat in the mesocosms was observed. Occurrence of snails on walls in both the open water area and the vegetated area of the mesocosms ranged from 51% to 79% with a mean of 70%. Vegetation was removed from the open water area of Mesocosms 1 and 2 after the survey on August 17, 2001. The strongest wall-effect was observed in the 9/22/01 and 11/15/01 surveys following vegetation removal, indicating that wall habitat was preferred to the dense vegetation in the mesocosms, an artifact of mesocosm design (Figure 49).

Six 1 x 2 meter artificial walls were placed in the reference site marsh in July 2001 in order to test whether the high rate of occurrence of *L. irrorata* on walls in the Horn Point mesocosms was an artifact of system design or a demonstrated preference for wall habitat (Figure 12). Utilization of artificial wall habitat was based on *L. irrorata* that were actually attached to the walls at any height. The majority of individuals were observed at the base of the walls. The highest rate of utilization occurred in August, 2002. No individuals were observed on the walls in November 2001 or July 2002. Utilization increased significantly over September 2001 observations in August 2002 and decreased slightly in November 2002 (Figure 50). Standard error ranged from 0 to 1.41, and an ANOVA of the survey data indicated that there was no significant difference between the sampling dates ($p=0.0596$).

There was a marked difference between mean densities across all survey dates in the standard reference site plots, mesocosms, and artificial walls. The mean density in the reference site plots (June 2000 – November 2001) was 15.21 individuals per ¼ m^2, the mean density in the mesocosms (June 2000 – November 2001) was 4.21 individuals per ¼ m^2, and the mean density on the artificial walls in the reference site (September 2001 – November 2002) was 0.33 individuals per ¼ m^2.

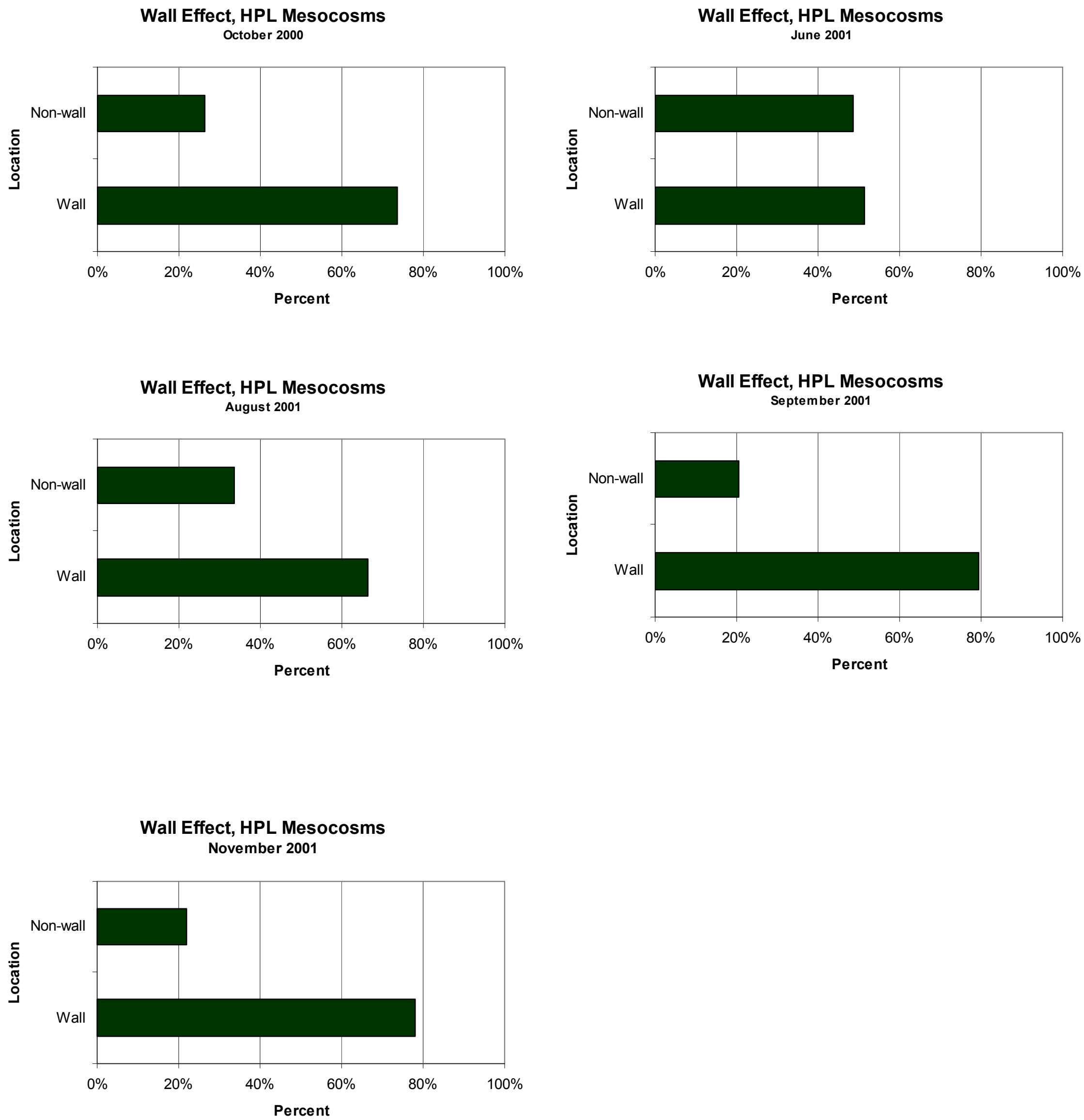


Figure 49. Occurrence of *L. irrorata* individuals on walls versus vegetated area in Horn Point mesocosms over time (survey dates: 10/00, 6/01, 8/01, 9/01, 11/01).

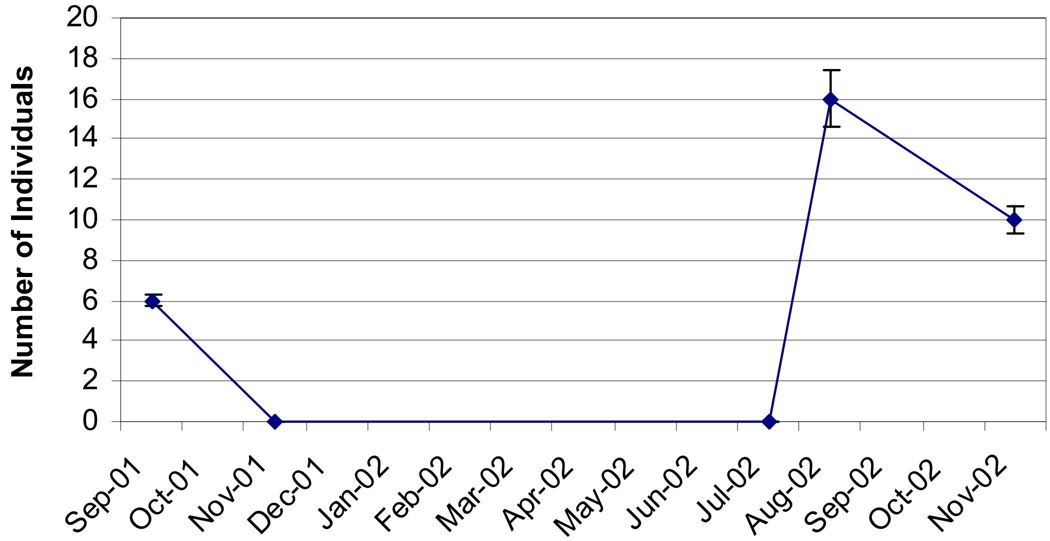


Figure 50. Utilization of artificial wall habitat in Slaughter Creek reference site by *L. irrorata*, September 2001 - November 2002.

Utilization of the base of artificial wall habitat was based on *L. irrorata* individuals that were adjacent to the walls but not attached. The majority of individuals were observed at the base of the walls. The highest rate of utilization occurred in August, 2002. No individuals were observed on the walls in November 2001 or July 2002. Utilization increased from July 2002 to August 2002 and decreased slightly in November 2002, with rates more than double those observed in September 2001 (Figure 51). The extreme drought and heat conditions in 2002 may have been a major factor in this increase, as individuals sought protection in artificial wall microclimates. Standard error ranged from 1.26 to 9.40, and an ANOVA of the survey data indicated that where significant differences between 9/22/01 and 7/6/02, 11/15/01 and 7/6/02, 7/6/02 and 8/15/02, and 7/6/02 and 11/11/02 ($p=0.0003$).

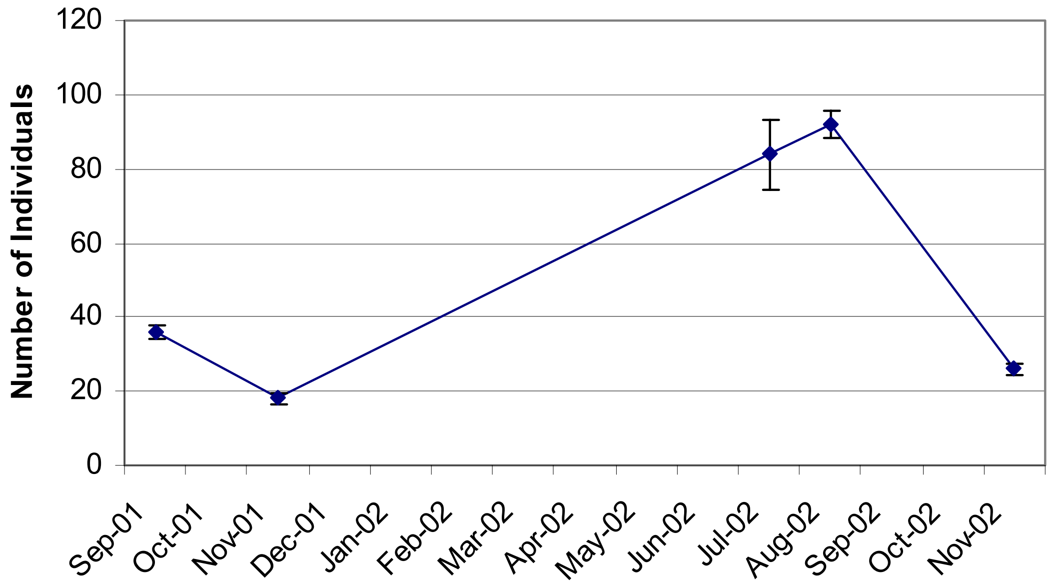


Figure 51. Utilization of base of artificial wall habitat in Slaughter Creek reference site by *L. irrorata*, September 2001 - November 2002.

CHAPTER VII: DISCUSSION AND CONCLUSIONS

GENERAL OBSERVATIONS

This work spanned six years, two coastal ecosystems, and their associated mesocosms. The data set produced is rich and documents multiple years of population surveys for both the Everglades mangrove forest and Chesapeake Bay salt marsh systems. Casual observations noted during population counts have provided additional insight to system function and the behavior of the periwinkle snails.

MANGROVE

Some organisms, including *Melampus coffeus*, did extremely well in the Everglades mesocosm, while others, such as the *L. angulifera* and mud crabs, simply died out. This may be due in part to the fact that *M. coffeus* is a ground-dwelling snail and both humidity and temperature variation at the surface are lower than at the heights that *L. angulifera* occupies.

Perhaps of even greater interest is the fact that, given that there were adequate samples, the periwinkle snail population showed no signs of juvenile recruitment in the Everglades mesocosm. There are several factors that may have contributed to this lack of recruitment. Although the mesocosm was designed with pumps that would not damage swimming larvae, impellar pumps were pressed into service in Tanks 1 and 2. In addition, *L. angulifera* typically spawns when there is a minimum of 2.45 cm (one inch) of rainfall and full moon high tides. Although the mesocosm was equipped with a R/O fed rain system, it was generally not run for long enough to simulate 2.45 cm (one inch) of rainfall. Mesocosm design called for 0.245 cm (0.1 inch) per day in the dry season

(January through May) and 0.762 cm (0.3 inch) per day in the wet season (June through December) (Adey and Loveland 1991).

Tidal variation may have been insufficient to trigger spawning, as the average diurnal tide range in the Ten Thousand Islands area of the Everglades is 0.7 m and the Everglades mesocosm had a maximum range of 0.66 m. In addition, the photoperiod and light intensity requirements for reproduction in *L. angulifera* may not have been met at the more northern latitude of Washington, DC. However, the yearly difference in incoming light between Washington, DC and South Florida was minimal and natural, unshaded greenhouse light was deemed sufficient for design purposes (Adey and Loveland 1991).

The mean height of individuals in the reference plots was more than double that of the overall mesocosm survey mean of 74.50 cm across three different survey dates. This differential may have been due to lower humidity levels and rainfall in the mesocosm than in the natural system. It may also be an artifact analogous to the wall effect documented in the Horn Point Laboratory salt marsh mesocosms (discussed below).

SALT MARSH

All the salt marsh mesocosms experienced increased exposure in comparison to reference plots due to air circulation under the mesocosms as a result of design. In addition, the long and narrow design of the mesocosms, the lack of both fresh and brackish water flow over winter, and low salinity may have further contributed to mortality over the winter season. The Horn Point marsh, which was adjacent to the brackish water source for the mesocosms, did not appear to support a population of salt marsh periwinkle snails. Low salinity has been postulated as a potential cause for this absence (Stevenson, personal communication), although the salinity range in this area is 8 to 17 ppt, with the higher values registered during the summer. This salinity range should not have precluded colonization by *L. irrorata*, as Vaughn and Fisher (1992) found healthy populations of salt marsh periwinkle snails in a Galveston, Texas marsh with 5-15 ppt salinity. Furthermore, Robert Paul has postulated that mid-Atlantic *L. irrorata* populations can tolerate even lower salinities than more southern-dwelling populations. If salinity was, in fact, the critical factor leading to mortality, *L. irrorata* was probably the wrong indicator species to use as a measure of function in these mesocosms. There was not, however, any pronounced seasonal variation in mortality as one might expect due to extreme temperature and salinity conditions during the winter.

Another contributing factor to the low periwinkle snail survival rates in the salt marsh mesocosms may be the dense *S. patens* and *S. americanus* thatch accumulation. In the absence of regular tidal flushing and faunal grazing, a thick mat of senesced vegetation built up in the interior terrestrial portions of the mesocosms. *L. irrorata* prefers to feed on dead *S. alterniflora*, though its diet is also comprised of marsh sediment, live *S. alterniflora*, algal mats, and the fungus that colonizes *S. alterniflora*. The study populations of *L. irrorata* exhibited a preference for the walls near and adjacent to the open water portion of the mesocosms. This microclimate may have been the closest analog to the fringe vegetation and open mud flats that *L. irrorata* migrates onto at low tide in the Slaughter Creek reference site. Individuals may also have been grazing algae from the walls, as they do on natural mudflats at low tide. This behavior may have resulted in higher mortality rates in the mesocosms from extreme temperatures and dessication.

The “wall effect” was tested by placing 1 x 2 m panels in the Slaughter Creek reference site and monitoring them for two field seasons. The results of this experiment to test whether walls are a preferred habitat indicate that this behavior is an artifact of system design rather than a natural behavior. While a mean density of 15.21 individuals per ¼ m^2 was observed in the reference site plots surrounding the artificial walls, a mean density of only 0.33 individuals per ¼ m^2 was observed on the artificial walls. This data suggests that although the walls in the mesocosms may have been preferable to the vegetated area, *L. irrorata* did not exhibit a preference for walls when moderately dense fringe vegetation and open mud flats were available, as in the reference site.

Figure 52. *L. irrorata* on edge of Horn Point mesocosm (7/11/00).

L. irrorata was observed on the edges of the mesocosms (Figure 52) and empty shells were collected on a regular basis from the asphalt that the mesocosms were placed on. The extreme conditions in the mesoscosms appear to have triggered a behavioral response in *L. irrorata* that drove individuals to seek a more hospitable environment. This proved to be a deadly mistake, as the asphalt surrounding the mesocosms provided particularly poor habitat value. However, it is interesting to consider that a behavioral strategy of seeking habitat with a higher functional value when conditions fall below a certain threshold level may have been selected for in the constantly changing environment of the Chesapeake Bay since submersion of the main channel of the Susquehanna River commenced approximately 10,000 years ago. If rates of sea level rise continue to increase as predicted, large swathes of salt marsh are expected to be lost. *L. irrorata* may, however, be particularly well adapted to seeking out remaining patches of habitat or newly created habitat.

This potential ability to seek out new habitat was observed at the Head Range Farm on Church Creek at Route 16, a tributary of Fishing Creek, which flows to the Little Choptank River. This site was approximately 11 km (7 miles) south of Horn Point Laboratory, and 11 km (7 miles) northeast of the Slaughter Creek reference site. Dr. Ed Garbisch's organization, Environmental Concern, installed a narrow salt marsh buffer along the edge of Mr. Linthicum's property in 1996. There was a patch of natural salt marsh at one end of the property that was remarkably similar to the Slaughter Creek reference site, and appeared to serve as a refugium from which *L. irrorata* colonized the newly planted *S. alterniflora*. Population densities decreased with distance from the natural marsh.

The fact that *L. irrorata* juveniles under 5 mm in length were observed underwater in some of the salt marsh mesocosms, but do not appear to have recruited to the study populations, raises questions about the concept of "build it and they will come" that is generally relied upon in restoration and creation work. This method assumes that if the proper hydrology and vegetation are established, the appropriate fauna will soon colonize the new habitat. The habitat needs of associated fauna were considered in the design of both the Everglades mesocosm and the salt marsh mesocosms, but populations of periwinkle snails were unable to survive and reproduce in either system.

HYPERVOLUME NICHE THEORY

Given the complexity and engineering behind the Everglades and salt marsh mesocosms, it is surprising that they could not support these relatively simple organisms. This outcome can be related to hypervolume niche theory, which defines the intersection of ranges of tolerances for a set of resources utilized by an organism as a "multidimensional hypervolume" (Hutchinson 1959). One way to graphically represent Hutchinson's concept is to construct a two-dimensional area in which each axis represents the possible range for an environmental factor. The axes intersect at the point on each gradient that is optimal for the species in question, and a perimeter line defines its maximum and minimum limits of tolerance. The two-dimensional area delineated therein represents the species' niche (Richardson 1977). In the case of the Horn Point mesocosms, one or more of the critical gradients for *L. irrorata* (Figure 53) does not fit into the respective mesocosm hypervolume. Plants did very well in both the mangrove and salt marsh mesocosms, and one would expect that these relatively simple macro-organisms would have a sufficiently broad tolerance along each resource gradient to survive and reproduce successfully. The terrestrial nature of these two species of periwinkle snails may confer a lower tolerance along certain resource gradients. The fact that they do not reproduce and have low survival rates in the mesocosms may mean that they could serve as good indicators of ecosystem structure and function in constructed and restored ecosystems.

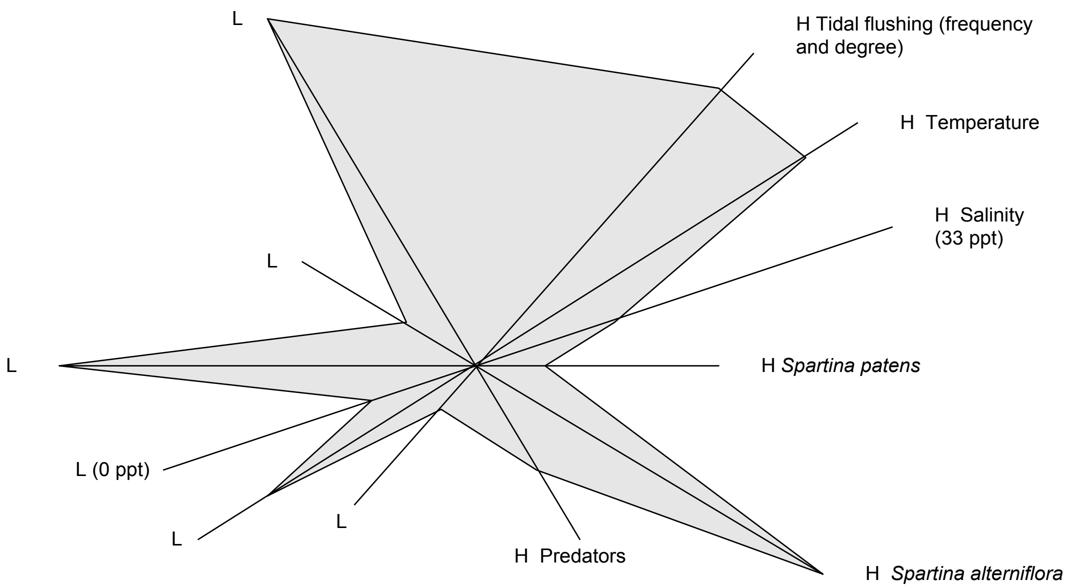


Figure 53. Two-dimensional niche diagram for *L. irrorata* (adapted from Richardson 1977).

RELATIONSHIP OF MESOCOSMS TO NATURAL SYSTEMS

One of the most interesting points to take away from these studies is their applicability to the real world. While there are many unique processes and novel behaviors at play in these systems, the zone of overlap in Figure 54 represents the lessons that we can take away. Fragmentation of habitat, edge effects, and island effects in isolated pockets of remaining habitat are critical points of concern, and the mesocosms studied in this work represent extreme examples of these phenomena. There is a very real possibility that the mesocosms were simply not large enough to support populations of periwinkle snails, despite evidence that *L. irrorata* individuals in particular do not generally utilize territories over 2 m^2. Extensive work has been undertaken to identify and preserve existing habitat corridors, and prioritize the acquisition and protection of areas that are adjacent to or link larger conservation areas in response to these issues.

The most important message in this case is to exercise caution in relying on restoration and creation to offset the effects of land conversion for residential and commercial development. Although success rates in both restoration and creation are improving, and restoration work is an excellent way to connect volunteers with the environment they live in, preservation is a vital tool in our attempts to maintain functioning natural ecosystems, particularly in coastal areas where population pressure is five times that in non-coastal areas.

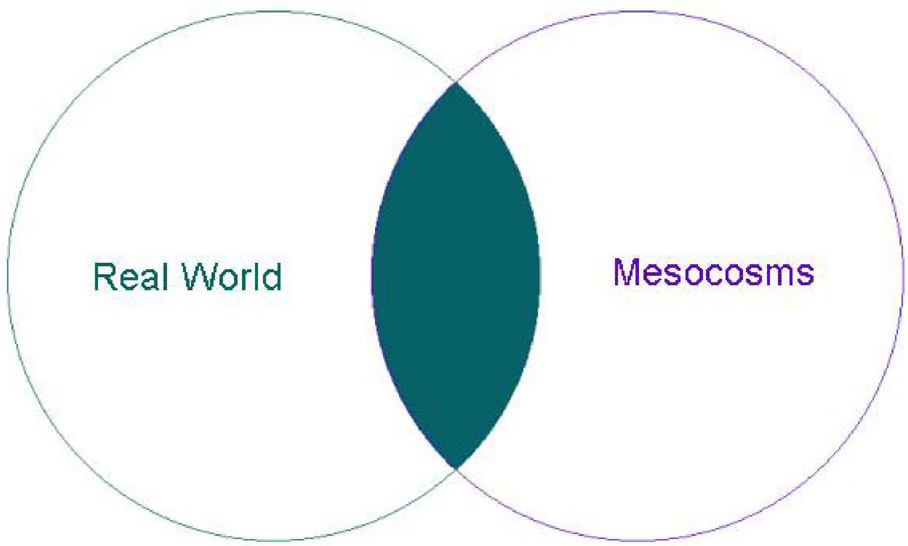


Figure 54. Venn diagram of the philosophical bases of mesocosms. (Adapted from Leffler 1980)

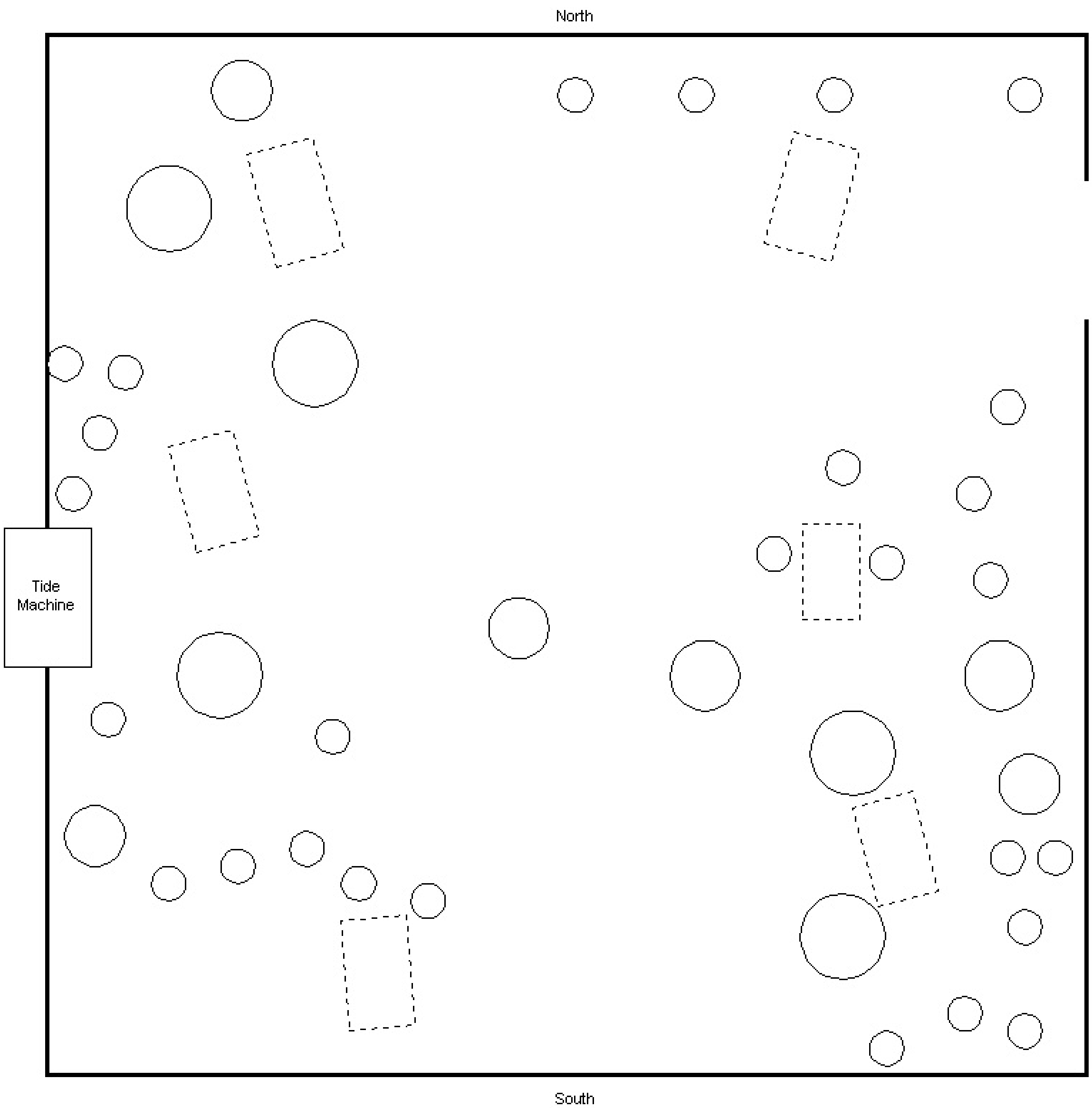
FUTURE DIRECTIONS

One of the questions that arose from this work is, "Periwinkles as indicators of what?" These organisms are clearly more sensitive than we expected, as healthy populations were unable to survive and reproduce in the mesocosms studied. Salinity, humidity, territory requirements, precipitation, photoperiod, and tidal variation are all excellent candidates for future study. There is not as extensive a body of natural history literature on these snails as is needed to be confident about certain aspects of their life history.

Additional work on the colonization of restored and created sites by periwinkle snails is needed in order to assess their utility as an indicator of functional processes. Another interesting study would involve stocking selected salt marsh mesocosms with large populations (>400 per m^2) of *L. irrorata* and monitoring their effect on vegetation density and nutrient uptake and pulsing. This could further inform our understanding of the role of salt marsh periwinkles in vegetation removal, the relationship between periwinkles and blue crabs, and the implications of sea level rise in the presence of depleted blue crab stocks as discussed by Bertness *et al.* (2004).

Appendix A. Everglades Mesocosm Data

Everglades Mesocosm - Tank 2



Date:

Time:

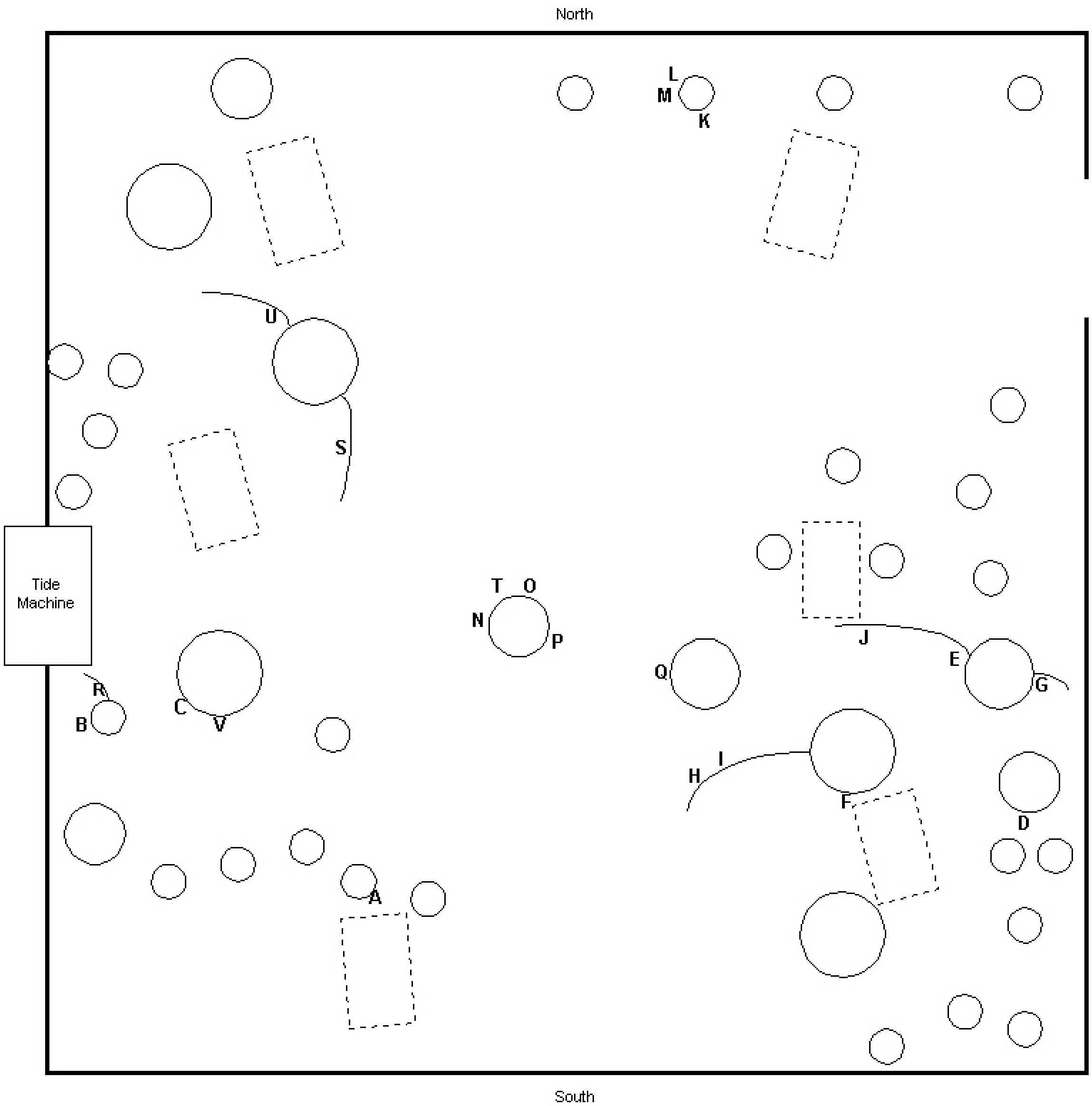
Weather:

Water level:

Total Count:

Notes:

Everglades Mesocosm - Tank 2



Date: 8/2/98

Time: 15:00

Weather: Sunny, 85 º

Water level: -6.5" to -7.5"

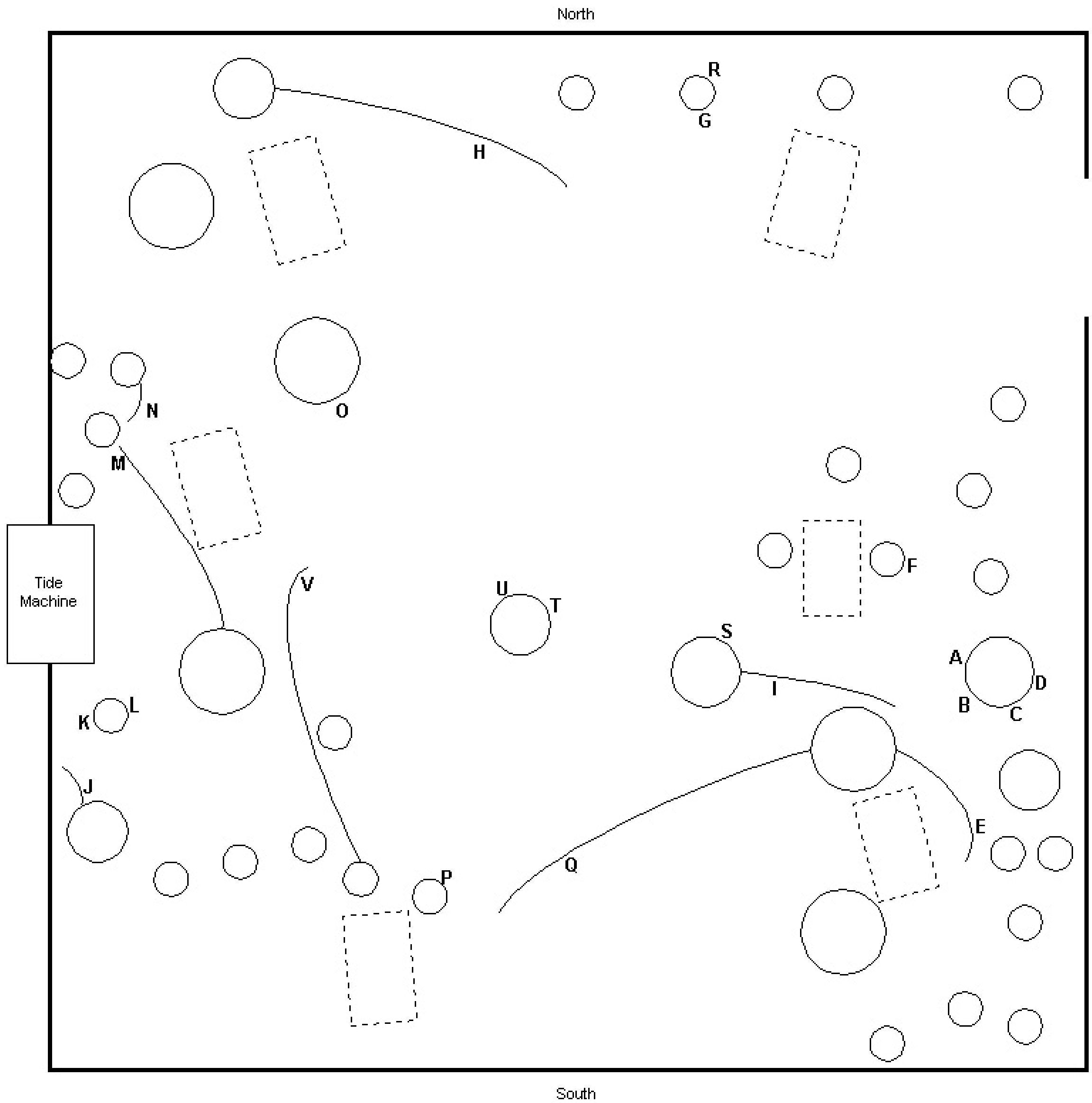
Total Count: 23

Notes: *Snail W was found in tank #4*

Date: 8/2/98
Time: 15:00
Weather: Sunny, 85°

Snail	Marked 8/2	Marked 8/17	Height above Sediment (cm)
A	✓		67.4
B	✓		50.8
C	✓		43.2
D	✓		69.9
E	✓		118.2
F	✓		95.3
G	✓		82.0
H	✓		50.2
I	✓		49.6
J	✓		57.2
K	✓		81.3
L	✓		119.4
M	✓		76.2
N	✓		66.1
O	✓		53.4
P	✓		52.1
Q	✓		61.0
R	✓		75.0
S	✓		67.4
T	✓		102.9
U	✓		42.6
V	✓		72.4
W	✓		86.4
		Mean:	**71.3**

Everglades Mesocosm - Tank 2



Date: 8/17/98

Time: 15:00

Weather: Overcast, 85 °

Water level: -4.5" to -6.0"

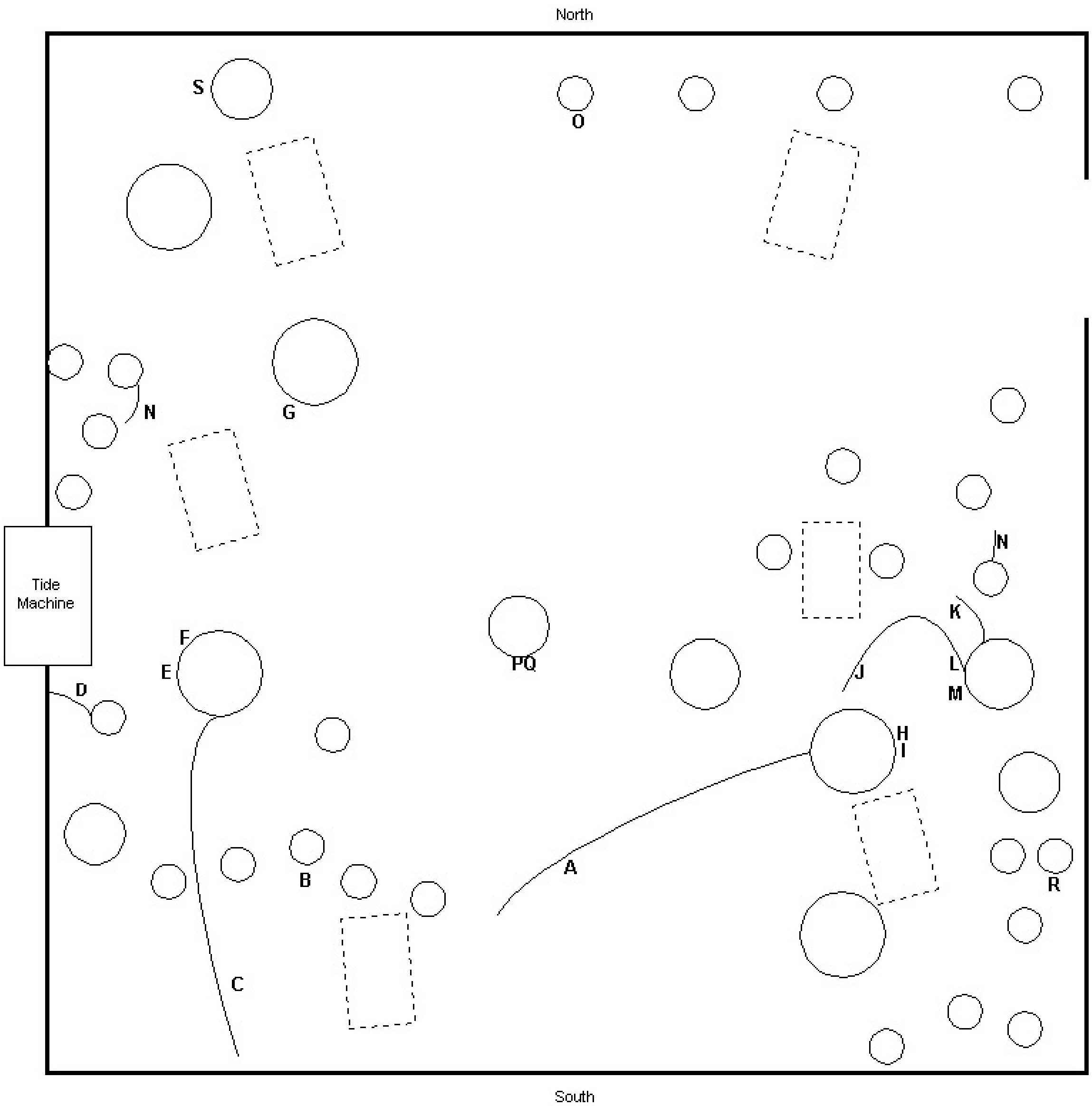
Total Count: 22

Notes:

Date: 8/17/98
Time: 15:00
Weather: Overcast, 85^{o}

Snail	Marked 8/2	Marked 8/17	Height above Sediment (cm)
A	✓	✓	88.9
B	✓	✓	64.8
C	✓	✓	141.0
D	✓	✓	151.2
E	✓	✓	57.8
F	✓	✓	83.2
G	✓	✓	38.8
H	✓	✓	48.9
I	✓	✓	68.6
J	✓	✓	48.3
K	✓	✓	114.3
L	✓	✓	78.8
M	✓	✓	85.1
N	✓	✓	43.2
O	✓	✓	45.8
P	✓	✓	87.0
Q	✓	✓	73.1
R		✓	124.5
S	✓	✓	148.6
T	✓	✓	55.3
U		✓	93.4
V	✓	✓	43.2
		Mean:	**81.1**

Everglades Mesocosm - Tank 2



Date: 9/7/98

Time: 10:00

Weather: Hot, sunny, 90 °

Water level: -9.5" to -8.0"

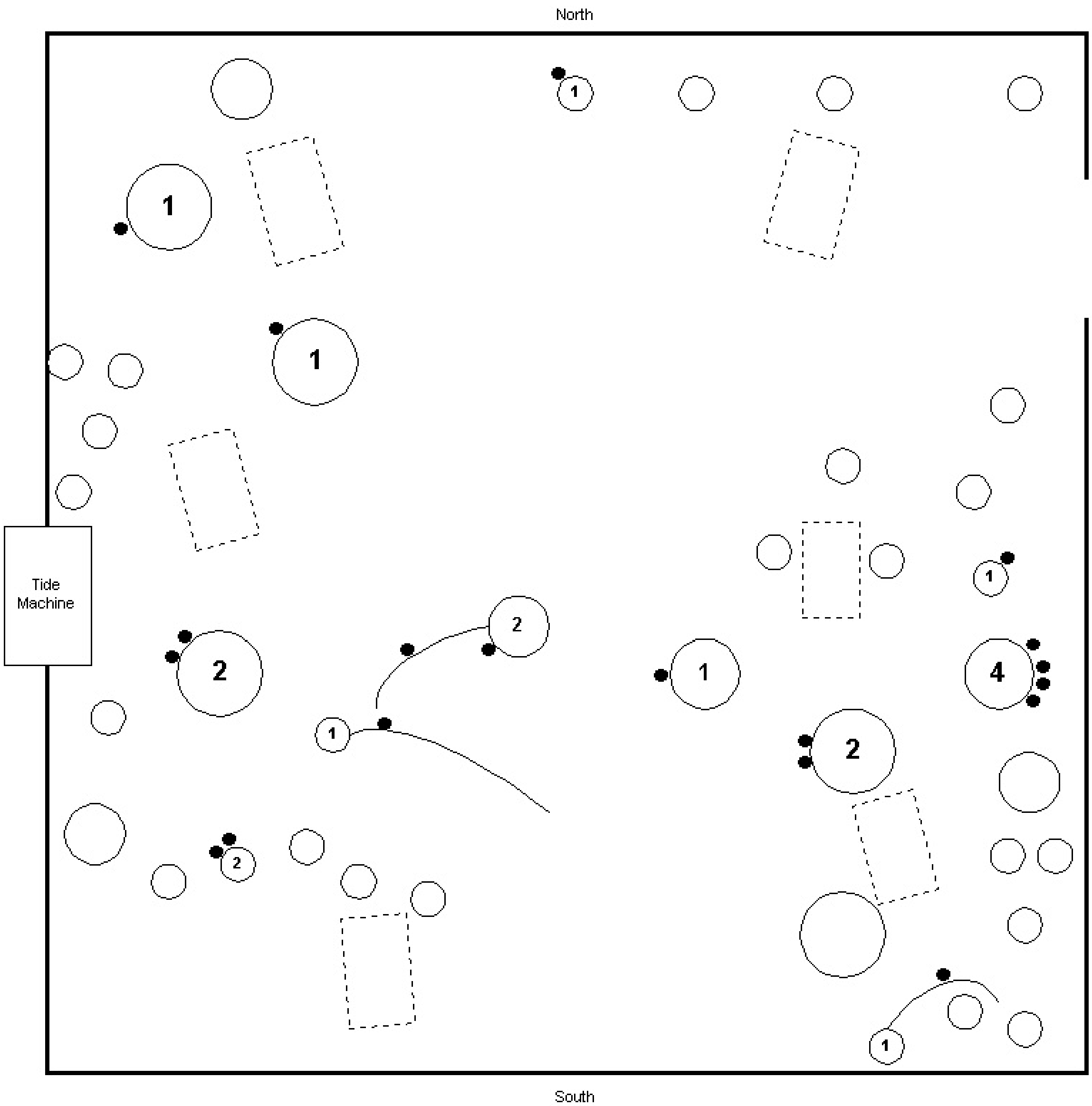
Total Count: 19

Notes:

Date: 9/7/98
Time: 10:00
Weather: Hot, sunny, 90^{o}

Snail	Marked 8/2	Marked 8/17	Height above Sediment (cm)
A	✓		49.6
B	✓	✓	39.4
C	✓	✓	63.5
D	✓	✓	59.7
E	✓	✓	88.9
F	✓		62.3
G	✓	✓	55.9
H	✓	✓	72.4
I		✓	72.4
J	✓	✓	82.6
K	✓	✓	87.7
L	✓		108.0
M	✓	✓	119.4
N	✓	✓	43.2
O	✓	✓	91.5
P	✓	✓	57.2
Q	✓	✓	57.2
R	✓	✓	72.4
S	✓	✓	61.0
		Mean:	**70.8**

Everglades Mesocosm - Tank 2



Date: 9/20/98

Time: 18:00

Weather: Hot, sunny, 90 °

Water level: N/A

Total Count: 19

Notes:

Date: 9/20/98
Time: 18:00
Weather: Hot, sunny, 90°

Snail	Length (mm)	Weight (g)
1	25.5	2.3
2	24.0	2.3
3	28.5	3.2
4	24.0	1.7
5	25.5	2.1
6	24.0	1.6
7	25.5	2.5
8	25.5	2.5
9	25.5	2.2
10	27.0	2.8
11	27.0	2.6
12	25.5	2.3
13	27.0	2.6
14	24.0	1.9
15	22.0	1.7
16	25.5	2.0
17	27.0	2.3
18	24.0	1.8
19	27.0	2.5
Mean:	**25.5**	**2.3**

Population Trend

Date	Population Count
5/15/95	200
7/15/97	42
7/17/97	39
7/22/97	31
7/24/97	32
7/29/97	35
7/31/97	31
8/5/97	31
8/7/97	30
8/14/97	35
8/19/97	37
8/26/97	35
9/2/97	34
9/11/97	29
9/19/97	25
9/25/97	34
9/30/97	33
10/10/97	35
10/28/97	32
11/4/97	35
11/11/97	24
8/2/98	23
8/17/98	22
9/7/98	19
9/20/98	19
3/21/99	13
4/2/99	14
5/2/99	11
7/10/99	8
5/13/00	1
11/16/00	0

Appendix B. Everglades Reference Site Data

10,000 Islands Plot #1 - Panther Key
Tidal Channel
11/19/99 - 11:00 AM

Sample Tree ~ 5m tall, 2x2 m plot
36 individuals collected, 2 shells destroyed before measuring/weighing,
3 individuals escaped before measuring/weighing

Height above sediment (m)		11/20/99 - 6:30 PM	
		Length (mm)	**Weight (g)**
0.93		24.0	1.50
1.60		22.0	1.20
1.80		21.0	1.00
0.55		24.0	1.30
0.48		21.5	0.90
1.52		20.5	0.60
0.80		17.0	0.60
1.50		20.5	1.00
1.38		15.0	0.30
1.55		19.5	0.90
1.80		20.0	0.80
1.23		21.5	1.10
1.40		22.5	1.00
2.00		20.0	0.80
2.25		19.5	0.80
2.51		22.0	1.10
2.80		20.0	0.80
2.10		25.0	1.40
2.08		22.5	1.40
1.60		19.0	0.90
1.60		19.5	0.80
1.18		23.5	1.50
3.50 (approximately)		23.0	1.20
1.19		23.0	1.20
1.19		21.0	1.00
2.44		24.5	1.40
2.09		22.0	1.30
2.55		21.5	1.00
2.70		22.0	1.20
2.70		19.5	0.90
3.00		23.0	0.90
2.80	**Mean:**	**21.3**	**1.03**
1.63			

	3.30
	2.30
	1.44
Mean:	**1.87**

10,000 Islands Plot #2 - White Horse Key
East Shoreline
11/20/99 - 9:00 AM

Sample Tree ~ 4.5m tall, 2x2 m plot
29 individuals total, none collected

	Height above sediment (m)
	1.72
	1.83
	1.84
	1.86
	1.70
	0.18
	0.50
	0.84
	0.55
	0.75
	0.90
	0.92
	0.93
	0.89
	0.65
	0.85
	0.55
	1.18
	1.18
	0.58
	0.69
	1.17
	1.57
	0.25
	2.12
	2.12
	2.55
	2.80
	2.90
Mean:	**1.26**

10,000 Islands Plot #3 - White Horse Key
East Shoreline
11/20/99 - 10:00 AM

Sample Tree ~ 4.5m tall, 2x2 m plot
41 individuals total, none collected

Height above sediment (m)
0.73
0.90
0.92
0.92
0.94
0.94
1.14
1.65
1.60
1.83
1.71
1.45
1.55
1.77
1.79
1.98
1.99
0.53
2.12
2.27
2.26
2.25
2.33
2.37
1.60
0.50
1.42
2.00
2.24
2.15
2.20
2.17
2.97
2.98
2.99
3.00
3.02

	3.05
	2.47
	2.82
	0.95
Mean:	**1.87**

10,000 Islands Plot #4 - White Horse Key
West Shoreline
11/20/99 - 1:00 PM

Sample Tree ~ 5m tall, 2x2 m plot
54 individuals collected, 2 individuals escaped before measuring/weighing

Height above sediment (m)	11/20/99 - 7:00 PM Length (mm)	Weight (g)
1.45	23.5	1.90
1.10	23.0	1.50
1.10	20.0	1.20
1.10	26.0	2.10
1.10	24.0	1.70
1.10	22.5	1.30
1.10	24.0	1.50
1.10	21.0	1.30
1.10	23.0	1.40
1.10	24.0	1.70
1.10	24.0	1.50
1.15	25.0	1.70
1.35	23.0	1.40
1.10	22.0	1.10
0.93	23.0	1.40
0.93	24.0	1.60
0.93	17.0	0.50
0.93	25.0	1.50
1.22	22.0	1.20
1.22	24.0	1.70
1.22	21.0	1.10
0.92	22.0	1.40
1.04	24.0	1.60
1.00	25.5	2.00
1.00	21.0	1.10
0.94	24.5	1.80
1.48	26.0	1.80
1.37	22.0	1.10
1.37	19.0	0.70
1.41	22.5	1.20
1.42	19.0	0.80
1.46	25.0	1.70
1.48	23.5	1.30
1.58	25.0	1.70

	1.73
	1.76
	1.76
	1.74
	1.95
	1.18
	1.18
	2.17
	2.27
	2.65
	2.30
	2.30
	2.20
	2.53
	2.72
	2.80
	3.40
	3.00
	2.68
	0.38
Mean:	**1.53**

	21.0	0.90
	17.0	0.70
	15.0	0.40
	23.0	1.50
	26.0	2.20
	25.0	1.70
	25.0	1.60
	20.0	1.00
	18.0	0.80
	23.5	1.60
	23.0	1.50
	24.5	1.90
	26.5	1.90
	23.5	1.50
	22.0	1.30
	25.5	1.80
	23.0	1.20
	24.0	1.30
Mean:	**22.8**	**1.41**

10,000 Islands Plot #5 - Oyster Reds
Edge
11/21/99 - 3:00 PM

Sample Tree ~ 4m tall, 2x2 m plot
10 individuals total, none collected

	Height above sediment (m)
	1.44
	1.10
	0.58
	2.12
	1.62
	1.20
	2.14
	2.35
	2.20
	2.35
Mean:	**1.71**

Appendix C. Horn Point Mesocosm Data

Horn Point Mesocosm Survey Summary

Date	Location	Mean Density*	Mean Length (mm)	Mean Weight (g)	Length - Weight R^2 Correlation
6/21/00	Horn Point Mesocosm 1	8.83	16.0	1.332	0.9126
6/21/00	Horn Point Mesocosm 2	8.83	16.1	1.268	0.9051
6/21/00	Horn Point Mesocosm 3	8.83	16.0	1.226	0.9023
6/21/00	Horn Point Mesocosm 6	8.83	15.3	1.180	0.8868
6/21/00	Horn Point Mesocosm 8	8.83	16.0	1.232	0.8989
6/21/00	Horn Point Mesocosm 12	8.83	15.9	1.316	0.9088
10/6/00	Horn Point Mesocosm 1	6.50	17.5		
10/6/00	Horn Point Mesocosm 2	5.50	18.7		
10/6/00	Horn Point Mesocosm 3	5.67	20.3		
10/6/00	Horn Point Mesocosm 6	6.33	19.9		
10/6/00	Horn Point Mesocosm 8	5.83	19.8		
10/6/00	Horn Point Mesocosm 12	6.33	18.7		
6/26/01	Horn Point Mesocosm 1	3.00	20.8		
6/26/01	Horn Point Mesocosm 2	4.50	21.5		
6/26/01	Horn Point Mesocosm 3	3.17	19.7		
6/26/01	Horn Point Mesocosm 6	5.67	20.7		
6/26/01	Horn Point Mesocosm 8	2.33	22.3		
6/26/01	Horn Point Mesocosm 12	1.17	22.7		
8/17/01	Horn Point Mesocosm 1	3.17	22.2		
8/17/01	Horn Point Mesocosm 2	4.00	21.8		
8/17/01	Horn Point Mesocosm 3	2.50	20.7		
8/17/01	Horn Point Mesocosm 6	5.00	21.2		
8/17/01	Horn Point Mesocosm 8	0.50	23.0		
8/17/01	Horn Point Mesocosm 12	1.17	23.9		
9/22/01	Horn Point Mesocosm 1	3.00	22.1		
9/22/01	Horn Point Mesocosm 2	3.83	22.1		
9/22/01	Horn Point Mesocosm 3	2.50	21.2		
9/22/01	Horn Point Mesocosm 6	4.67	21.6		
9/22/01	Horn Point Mesocosm 8	1.00	23.4		
9/22/01	Horn Point Mesocosm 12	1.17	23.9		
11/15/01	Horn Point Mesocosm 1	2.17	22.3		
11/15/01	Horn Point Mesocosm 2	3.33	22.2		
11/15/01	Horn Point Mesocosm 3	1.67	21.3		
11/15/01	Horn Point Mesocosm 6	2.33	21.7		
11/15/01	Horn Point Mesocosm 8	0.50	24.6		
11/15/01	Horn Point Mesocosm 12	1.33	24.4		
Mean - Mesocosms		**4.24**	**20.6**		

Notes:	Horn Point Mesocosms stocked with a density of ~8.85 snails per 1/4 m^2 per Taylor's Island 6/20/00 data.		
	Size structure of original mesocosm populations were as follows:	5 - 10 mm	9 individuals
		10 -15 mm	14 individuals
		15 - 20 mm	13 individuals
		> 20 mm	17 individuals

* All densities are calculated per ¼ m^2

Snails removed from mesocosms (from 1997 stocking)

Mesocosm	Date	Length (mm)	Weight (g)
2	5/17/00	24.0	2.93
2	5/17/00	25.0	2.80
2	5/17/00	26.0	3.49
2	5/17/00	24.0	2.40
5	5/17/00	23.0	2.55
6	5/17/00	25.0	2.92
6	5/19/00	24.0	2.74
6	5/19/00	25.0	3.05
6	6/22/00	27.5	3.99
7	5/17/00	22.0	2.41
7	5/17/00	23.0	2.48
7	5/17/00	23.0	2.71
7	5/17/00	23.0	2.91
7	5/17/00	22.0	2.62
7	5/17/00	23.0	3.17
7	5/17/00	22.0	2.52
7	5/17/00	22.0	2.50
7	5/17/00	21.0	2.37
7	5/17/00	24.0	2.56
10	5/17/00	24.0	3.19
10	5/17/00	22.0	2.30
10	5/17/00	22.0	2.60
10	5/17/00	21.0	1.96
10	5/17/00	23.0	2.69
10	5/17/00	23.0	2.99
10	5/17/00	20.0	1.97
10	5/19/00	22.0	2.67
10	5/19/00	21.0	1.84
10	5/19/00	22.0	2.27
10	5/19/00	20.5	1.93
10	5/19/00	22.0	2.65
10	5/19/00	22.5	2.60

Summary

Mesocom	Adults	Juveniles
1	0	Yes
2	4	No
3	0	Yes
4	0	Yes
5	1	Yes
6	4	No
7	10	Yes
8	0	No
9	0	Yes
10	13	Yes
11	0	No
12	0	Yes
Total	32	

Raw Mesocosm Survey Data

Mesocosm	Date	Zone*	Length (mm)	Weight (g)
1	6/21/00	E	7.0	0.079
1	6/21/00	E	7.0	0.078
1	6/21/00	E	7.0	0.079
1	6/21/00	E	7.5	0.090
1	6/21/00	E	8.0	0.104
1	6/21/00	E	8.0	0.104
1	6/21/00	E	8.0	0.116
1	6/21/00	E	8.5	0.121
1	6/21/00	E	9.0	0.114
1	6/21/00	E	10.0	0.196
1	6/21/00	E	10.0	0.230
1	6/21/00	E	10.0	0.225
1	6/21/00	E	10.5	0.250
1	6/21/00	E	12.0	0.396
1	6/21/00	E	12.0	0.466
1	6/21/00	E	12.5	0.476
1	6/21/00	E	12.5	0.515
1	6/21/00	E	13.0	0.496
1	6/21/00	E	14.0	0.625
1	6/21/00	E	14.5	0.743
1	6/21/00	E	14.5	0.681
1	6/21/00	E	14.5	0.692
1	6/21/00	E	14.5	0.718
1	6/21/00	E	15.5	0.909
1	6/21/00	E	16.0	0.996
1	6/21/00	E	16.0	0.950
1	6/21/00	E	16.0	1.051
1	6/21/00	E	16.0	1.036
1	6/21/00	E	17.0	1.321
1	6/21/00	E	17.0	1.254
1	6/21/00	E	18.0	1.332
1	6/21/00	E	18.0	1.254
1	6/21/00	E	18.0	1.152
1	6/21/00	E	18.0	1.284
1	6/21/00	E	18.5	1.919
1	6/21/00	E	19.5	1.849

1	6/21/00	E	20.0	1.792
1	6/21/00	E	20.0	2.290
1	6/21/00	E	20.0	2.206
1	6/21/00	E	20.0	2.196
1	6/21/00	E	20.5	2.557
1	6/21/00	E	22.0	2.449
1	6/21/00	E	22.0	2.617
1	6/21/00	E	22.0	2.639
1	6/21/00	E	22.5	3.367
1	6/21/00	E	22.5	3.424
1	6/21/00	E	22.5	2.666
1	6/21/00	E	23.0	3.134
1	6/21/00	E	23.5	3.027
1	6/21/00	E	23.5	2.824
1	6/21/00	E	23.5	2.887
1	6/21/00	E	24.5	3.172
1	6/21/00	E	25.5	3.440
1	10/6/00	A	23.0	
1	10/6/00	A	12.0	
1	10/6/00	A	19.5	
1	10/6/00	A	21.0	
1	10/6/00	A	22.0	
1	10/6/00	A	20.0	
1	10/6/00	A	23.0	
1	10/6/00	A	24.5	
1	10/6/00	A	11.0	
1	10/6/00	A	24.5	
1	10/6/00	A	19.0	
1	10/6/00	A	25.0	
1	10/6/00	A	23.5	
1	10/6/00	A	22.5	
1	10/6/00	A	15.5	
1	10/6/00	A	20.0	
1	10/6/00	B	21.0	
1	10/6/00	B	21.0	
1	10/6/00	B	23.5	
1	10/6/00	B	22.0	
1	10/6/00	C	22.0	
1	10/6/00	C	12.0	

1	10/6/00	C	14.5
1	10/6/00	D	16.5
1	10/6/00	D	16.5
1	10/6/00	D	18.5
1	10/6/00	D	16.0
1	10/6/00	D	10.0
1	10/6/00	D	9.0
1	10/6/00	D	12.5
1	10/6/00	E	19.5
1	10/6/00	E	19.5
1	10/6/00	E	14.0
1	10/6/00	E	16.0
1	10/6/00	E	13.5
1	10/6/00	E	15.5
1	10/6/00	E	11.5
1	10/6/00	E	9.0
1	10/6/00	E	14.5
1	6/26/01	B	20.0
1	6/26/01	B	24.0
1	6/26/01	B	23.0
1	6/26/01	B	19.0
1	6/26/01	B	18.0
1	6/26/01	B	22.5
1	6/26/01	C	19.0
1	6/26/01	C	20.0
1	6/26/01	C	23.5
1	6/26/01	C	26.0
1	6/26/01	C	22.0
1	6/26/01	C	20.5
1	6/26/01	C	16.0
1	6/26/01	D	23.0
1	6/26/01	E	20.0
1	6/26/01	E	25.0
1	6/26/01	E	18.5
1	6/26/01	E	14.5
1	8/17/01	A	21.5
1	8/17/01	A	23.5
1	8/17/01	A	22.5
1	8/17/01	B	22.5

1	8/17/01	B	23.0
1	8/17/01	B	21.0
1	8/17/01	C	26.0
1	8/17/01	C	27.5
1	8/17/01	C	22.0
1	8/17/01	C	22.0
1	8/17/01	C	20.0
1	8/17/01	C	22.0
1	8/17/01	C	20.0
1	8/17/01	C	23.5
1	8/17/01	C	20.5
1	8/17/01	C	20.0
1	8/17/01	C	20.0
1	8/17/01	C	19.0
1	8/17/01	E	24.5
1	9/22/01	A	20.0
1	9/22/01	A	21.5
1	9/22/01	A	21.5
1	9/22/01	A	24.5
1	9/22/01	A	22.0
1	9/22/01	A	22.5
1	9/22/01	A	23.5
1	9/22/01	A	20.0
1	9/22/01	A	22.0
1	9/22/01	A	20.0
1	9/22/01	B	26.5
1	9/22/01	B	22.0
1	9/22/01	B	22.5
1	9/22/01	B	20.5
1	9/22/01	B	22.5
1	9/22/01	C	23.5
1	9/22/01	C	22.5
1	9/22/01	D	20.0
1	11/15/01	D	26.5
1	11/15/01	D	22.5
1	11/15/01	D	23.0
1	11/15/01	D	22.5
1	11/15/01	E	20.5
1	11/15/01	E	22.5

1	11/15/01	E	20.0
1	11/15/01	E	24.5
1	11/15/01	E	21.0
1	11/15/01	E	22.0
1	11/15/01	E	20.5
1	11/15/01	E	20.5
1	11/15/01	E	23.5
2	6/21/00	E	5.0
2	6/21/00	E	7.0
2	6/21/00	E	7.0
2	6/21/00	E	7.5
2	6/21/00	E	7.5
2	6/21/00	E	7.5
2	6/21/00	E	9.0
2	6/21/00	E	9.0
2	6/21/00	E	9.5
2	6/21/00	E	11.5
2	6/21/00	E	12.0
2	6/21/00	E	12.5
2	6/21/00	E	12.5
2	6/21/00	E	13.0
2	6/21/00	E	13.5
2	6/21/00	E	14.0
2	6/21/00	E	14.0
2	6/21/00	E	14.0
2	6/21/00	E	14.0
2	6/21/00	E	14.5
2	6/21/00	E	14.5
2	6/21/00	E	14.5
2	6/21/00	E	14.5
2	6/21/00	E	15.0
2	6/21/00	E	15.5
2	6/21/00	E	16.0
2	6/21/00	E	16.5
2	6/21/00	E	17.5
2	6/21/00	E	18.0
2	6/21/00	E	18.0
2	6/21/00	E	18.0
2	6/21/00	E	18.5

2	6/21/00	E	19.0
2	6/21/00	E	19.0
2	6/21/00	E	19.0
2	6/21/00	E	19.5
2	6/21/00	E	20.0
2	6/21/00	E	20.0
2	6/21/00	E	20.0
2	6/21/00	E	20.5
2	6/21/00	E	20.5
2	6/21/00	E	20.5
2	6/21/00	E	20.5
2	6/21/00	E	20.5
2	6/21/00	E	21.0
2	6/21/00	E	21.5
2	6/21/00	E	21.5
2	6/21/00	E	21.5
2	6/21/00	E	22.0
2	6/21/00	E	22.5
2	6/21/00	E	22.5
2	6/21/00	E	25.0
2	6/21/00	E	25.0
2	10/6/00	A	26.0
2	10/6/00	A	23.0
2	10/6/00	A	19.5
2	10/6/00	A	16.5
2	10/6/00	B	16.5
2	10/6/00	D	25.5
2	10/6/00	D	18.5
2	10/6/00	D	21.0
2	10/6/00	D	19.0
2	10/6/00	D	16.5
2	10/6/00	D	19.5
2	10/6/00	D	22.5
2	10/6/00	D	20.0
2	10/6/00	D	21.5
2	10/6/00	D	18.5
2	10/6/00	D	20.0
2	10/6/00	D	20.0
2	10/6/00	D	20.5

2	10/6/00	D	16.0
2	10/6/00	D	16.5
2	10/6/00	D	17.0
2	10/6/00	D	15.0
2	10/6/00	D	20.5
2	10/6/00	D	15.0
2	10/6/00	E	20.0
2	10/6/00	E	20.5
2	10/6/00	E	16.0
2	10/6/00	E	17.5
2	10/6/00	E	15.0
2	10/6/00	E	22.5
2	10/6/00	E	19.5
2	10/6/00	E	16.0
2	10/6/00	E	15.5
2	6/26/01	A	21.0
2	6/26/01	B	23.0
2	6/26/01	B	13.5
2	6/26/01	B	21.0
2	6/26/01	B	22.0
2	6/26/01	B	21.5
2	6/26/01	B	25.5
2	6/26/01	B	15.5
2	6/26/01	C	22.0
2	6/26/01	C	21.5
2	6/26/01	C	20.0
2	6/26/01	C	21.0
2	6/26/01	C	20.0
2	6/26/01	C	23.5
2	6/26/01	C	21.5
2	6/26/01	C	26.5
2	6/26/01	C	26.5
2	6/26/01	C	20.5
2	6/26/01	C	19.0
2	6/26/01	C	21.0
2	6/26/01	C	23.5
2	6/26/01	C	23.5
2	6/26/01	C	20.5
2	6/26/01	C	21.5

2	6/26/01	C	20.5
2	6/26/01	C	21.5
2	6/26/01	C	22.5
2	8/17/01	A	22.0
2	8/17/01	A	21.5
2	8/17/01	A	23.0
2	8/17/01	A	20.5
2	8/17/01	B	26.0
2	8/17/01	B	22.0
2	8/17/01	B	22.0
2	8/17/01	B	18.0
2	8/17/01	B	23.0
2	8/17/01	B	22.0
2	8/17/01	C	22.0
2	8/17/01	C	22.0
2	8/17/01	C	23.0
2	8/17/01	C	20.5
2	8/17/01	C	21.0
2	8/17/01	C	21.5
2	8/17/01	C	20.0
2	8/17/01	C	22.0
2	8/17/01	D	22.0
2	8/17/01	D	22.0
2	8/17/01	D	23.5
2	8/17/01	D	21.5
2	8/17/01	D	18.5
2	8/17/01	E	22.5
2	9/22/01	A	23.0
2	9/22/01	A	23.5
2	9/22/01	A	22.0
2	9/22/01	A	22.0
2	9/22/01	A	21.0
2	9/22/01	A	22.0
2	9/22/01	A	23.0
2	9/22/01	A	21.0
2	9/22/01	B	22.0
2	9/22/01	B	26.0
2	9/22/01	B	22.5
2	9/22/01	B	21.0

2	9/22/01	B	23.5	
2	9/22/01	B	22.0	
2	9/22/01	B	23.5	
2	9/22/01	B	22.0	
2	9/22/01	B	22.0	
2	9/22/01	B	21.5	
2	9/22/01	B	22.0	
2	9/22/01	B	20.5	
2	9/22/01	B	22.0	
2	9/22/01	C	22.5	
2	9/22/01	D	18.0	
2	11/15/01	B	26.0	
2	11/15/01	D	21.0	
2	11/15/01	D	21.0	
2	11/15/01	D	23.0	
2	11/15/01	D	22.0	
2	11/15/01	D	22.0	
2	11/15/01	D	21.5	
2	11/15/01	D	22.0	
2	11/15/01	D	22.5	
2	11/15/01	D	22.0	
2	11/15/01	D	21.0	
2	11/15/01	D	22.0	
2	11/15/01	D	19.5	
2	11/15/01	D	22.0	
2	11/15/01	D	22.5	
2	11/15/01	D	23.5	
2	11/15/01	D	23.0	
2	11/15/01	E	23.5	
2	11/15/01	E	21.5	
2	11/15/01	E	22.5	
3	6/21/00	E	6.0	0.040
3	6/21/00	E	7.0	0.072
3	6/21/00	E	8.0	0.086
3	6/21/00	E	8.0	0.102
3	6/21/00	E	8.0	0.125
3	6/21/00	E	9.0	0.147
3	6/21/00	E	9.0	0.171
3	6/21/00	E	9.5	0.189

3	6/21/00	E	9.5	0.207
3	6/21/00	E	11.0	0.279
3	6/21/00	E	11.0	0.331
3	6/21/00	E	12.0	0.430
3	6/21/00	E	12.5	0.552
3	6/21/00	E	13.0	0.519
3	6/21/00	E	13.0	0.578
3	6/21/00	E	13.5	0.514
3	6/21/00	E	13.5	0.561
3	6/21/00	E	13.5	0.569
3	6/21/00	E	14.0	0.619
3	6/21/00	E	14.0	0.670
3	6/21/00	E	14.5	0.638
3	6/21/00	E	14.5	0.691
3	6/21/00	E	14.5	0.697
3	6/21/00	E	15.0	0.755
3	6/21/00	E	15.5	0.927
3	6/21/00	E	16.0	0.913
3	6/21/00	E	16.0	1.052
3	6/21/00	E	17.0	1.082
3	6/21/00	E	17.0	1.108
3	6/21/00	E	17.0	1.182
3	6/21/00	E	17.0	1.242
3	6/21/00	E	18.0	1.400
3	6/21/00	E	18.0	1.400
3	6/21/00	E	18.5	1.290
3	6/21/00	E	19.5	1.753
3	6/21/00	E	19.5	1.785
3	6/21/00	E	20.0	1.736
3	6/21/00	E	20.0	1.780
3	6/21/00	E	20.0	1.898
3	6/21/00	E	20.5	1.965
3	6/21/00	E	20.5	2.271
3	6/21/00	E	21.0	2.010
3	6/21/00	E	21.0	2.528
3	6/21/00	E	21.5	2.404
3	6/21/00	E	21.5	2.568
3	6/21/00	E	21.5	2.593
3	6/21/00	E	22.0	2.165

3	6/21/00	E	22.0	2.206
3	6/21/00	E	22.0	2.404
3	6/21/00	E	22.0	2.481
3	6/21/00	E	22.0	2.538
3	6/21/00	E	23.0	3.308
3	6/21/00	E	24.0	3.458
3	10/6/00	A	23.5	
3	10/6/00	A	23.0	
3	10/6/00	A	20.0	
3	10/6/00	A	23.5	
3	10/6/00	A	22.0	
3	10/6/00	C	20.0	
3	10/6/00	C	20.0	
3	10/6/00	C	23.0	
3	10/6/00	C	18.0	
3	10/6/00	D	20.0	
3	10/6/00	D	18.5	
3	10/6/00	D	25.0	
3	10/6/00	D	23.0	
3	10/6/00	D	22.0	
3	10/6/00	D	19.5	
3	10/6/00	D	23.0	
3	10/6/00	D	24.0	
3	10/6/00	D	20.0	
3	10/6/00	D	18.0	
3	10/6/00	D	18.5	
3	10/6/00	D	13.0	
3	10/6/00	D	18.5	
3	10/6/00	D	20.0	
3	10/6/00	D	19.5	
3	10/6/00	D	22.0	
3	10/6/00	D	16.5	
3	10/6/00	D	17.5	
3	10/6/00	D	20.5	
3	10/6/00	D	18.5	
3	10/6/00	D	20.0	
3	10/6/00	E	20.5	
3	10/6/00	E	14.5	
3	10/6/00	E	23.5	

3	10/6/00	E	15.5
3	6/26/01	B	19.0
3	6/26/01	B	23.0
3	6/26/01	B	17.5
3	6/26/01	B	19.0
3	6/26/01	B	16.5
3	6/26/01	B	20.0
3	6/26/01	B	20.0
3	6/26/01	B	23.0
3	6/26/01	B	19.5
3	6/26/01	B	20.5
3	6/26/01	B	17.5
3	6/26/01	C	19.0
3	6/26/01	C	21.5
3	6/26/01	C	21.5
3	6/26/01	C	18.0
3	6/26/01	C	19.5
3	6/26/01	C	19.5
3	6/26/01	C	22.0
3	6/26/01	E	18.0
3	8/17/01	A	20.0
3	8/17/01	A	20.0
3	8/17/01	B	20.0
3	8/17/01	B	19.0
3	8/17/01	B	23.0
3	8/17/01	B	22.0
3	8/17/01	B	20.0
3	8/17/01	C	19.0
3	8/17/01	C	22.0
3	8/17/01	C	23.0
3	8/17/01	C	21.5
3	8/17/01	C	20.0
3	8/17/01	C	23.5
3	8/17/01	C	21.0
3	8/17/01	D	17.0
3	9/22/01	A	20.5
3	9/22/01	A	20.5
3	9/22/01	A	23.0
3	9/22/01	A	20.5

3	9/22/01	B	18.0	
3	9/22/01	B	18.0	
3	9/22/01	C	21.0	
3	9/22/01	C	24.0	
3	9/22/01	E	23.0	
3	9/22/01	E	20.0	
3	9/22/01	E	23.5	
3	9/22/01	E	20.0	
3	9/22/01	E	22.0	
3	9/22/01	E	24.0	
3	9/22/01	E	20.0	
3	11/15/01	D	20.5	
3	11/15/01	D	23.0	
3	11/15/01	D	24.0	
3	11/15/01	D	20.0	
3	11/15/01	D	20.5	
3	11/15/01	D	20.0	
3	11/15/01	D	20.0	
3	11/15/01	D	21.5	
3	11/15/01	D	22.5	
3	11/15/01	D	20.5	
6	6/21/00	E	5.0	0.030
6	6/21/00	E	6.0	0.051
6	6/21/00	E	6.0	0.052
6	6/21/00	E	6.5	0.056
6	6/21/00	E	7.0	0.078
6	6/21/00	E	7.0	0.079
6	6/21/00	E	7.5	0.079
6	6/21/00	E	7.5	0.085
6	6/21/00	E	8.5	0.127
6	6/21/00	E	10.0	0.197
6	6/21/00	E	11.5	0.367
6	6/21/00	E	11.5	0.368
6	6/21/00	E	11.5	0.404
6	6/21/00	E	12.0	0.367
6	6/21/00	E	12.5	0.446
6	6/21/00	E	12.5	0.467
6	6/21/00	E	13.0	0.512
6	6/21/00	E	13.0	0.526

6	6/21/00	E	13.5	0.628
6	6/21/00	E	14.0	0.648
6	6/21/00	E	14.0	0.668
6	6/21/00	E	14.5	0.638
6	6/21/00	E	14.5	0.702
6	6/21/00	E	15.0	0.809
6	6/21/00	E	15.0	0.815
6	6/21/00	E	15.0	0.830
6	6/21/00	E	15.0	0.859
6	6/21/00	E	15.0	0.871
6	6/21/00	E	15.5	0.822
6	6/21/00	E	15.5	0.946
6	6/21/00	E	15.5	0.965
6	6/21/00	E	16.0	1.035
6	6/21/00	E	16.0	1.058
6	6/21/00	E	16.5	1.052
6	6/21/00	E	17.0	1.264
6	6/21/00	E	19.5	1.840
6	6/21/00	E	20.0	1.867
6	6/21/00	E	20.0	2.170
6	6/21/00	E	20.5	2.154
6	6/21/00	E	20.5	2.223
6	6/21/00	E	20.5	2.230
6	6/21/00	E	21.0	2.078
6	6/21/00	E	21.0	2.156
6	6/21/00	E	21.0	2.163
6	6/21/00	E	21.0	2.210
6	6/21/00	E	21.0	2.441
6	6/21/00	E	21.0	2.871
6	6/21/00	E	21.5	2.122
6	6/21/00	E	21.5	2.323
6	6/21/00	E	22.0	2.718
6	6/21/00	E	22.5	2.889
6	6/21/00	E	24.5	3.924
6	6/21/00	E	25.0	3.255
6	10/6/00	A	23.0	
6	10/6/00	A	23.0	
6	10/6/00	D	20.0	
6	10/6/00	D	20.0	

6	10/6/00	D	23.0
6	10/6/00	D	25.5
6	10/6/00	D	26.0
6	10/6/00	D	18.5
6	10/6/00	D	15.0
6	10/6/00	D	16.5
6	10/6/00	D	16.0
6	10/6/00	D	24.5
6	10/6/00	D	22.0
6	10/6/00	D	19.5
6	10/6/00	D	18.5
6	10/6/00	D	19.5
6	10/6/00	D	18.0
6	10/6/00	D	20.0
6	10/6/00	D	22.5
6	10/6/00	D	20.0
6	10/6/00	D	16.0
6	10/6/00	D	22.0
6	10/6/00	D	14.0
6	10/6/00	D	23.5
6	10/6/00	D	21.5
6	10/6/00	D	23.5
6	10/6/00	D	18.0
6	10/6/00	D	22.5
6	10/6/00	D	14.0
6	10/6/00	D	16.5
6	10/6/00	D	17.5
6	10/6/00	E	21.5
6	10/6/00	E	18.5
6	10/6/00	E	22.0
6	10/6/00	E	10.0
6	10/6/00	E	19.0
6	10/6/00	E	10.0
6	10/6/00	E	17.0
6	6/26/01	B	23.5
6	6/26/01	B	21.5
6	6/26/01	B	22.5
6	6/26/01	B	19.0
6	6/26/01	B	22.0

6	6/26/01	B	22.0
6	6/26/01	B	20.0
6	6/26/01	B	18.5
6	6/26/01	B	25.5
6	6/26/01	B	23.0
6	6/26/01	B	20.0
6	6/26/01	B	18.0
6	6/26/01	B	22.0
6	6/26/01	B	22.5
6	6/26/01	B	22.0
6	6/26/01	B	18.0
6	6/26/01	B	20.5
6	6/26/01	B	21.0
6	6/26/01	B	20.0
6	6/26/01	B	18.0
6	6/26/01	B	18.0
6	6/26/01	B	20.0
6	6/26/01	B	24.5
6	6/26/01	B	21.0
6	6/26/01	C	20.0
6	6/26/01	C	21.0
6	6/26/01	E	23.0
6	6/26/01	E	22.0
6	6/26/01	E	24.5
6	6/26/01	E	14.5
6	6/26/01	E	19.5
6	6/26/01	E	25.5
6	6/26/01	E	17.0
6	6/26/01	E	14.5
6	8/17/01	A	22.0
6	8/17/01	A	19.5
6	8/17/01	A	25.5
6	8/17/01	A	23.5
6	8/17/01	A	22.0
6	8/17/01	A	24.5
6	8/17/01	A	23.0
6	8/17/01	A	19.0
6	8/17/01	A	21.0
6	8/17/01	A	24.5

6	8/17/01	B	19.0
6	8/17/01	B	20.5
6	8/17/01	B	21.5
6	8/17/01	B	22.0
6	8/17/01	B	24.0
6	8/17/01	B	22.5
6	8/17/01	B	19.0
6	8/17/01	B	19.0
6	8/17/01	B	18.0
6	8/17/01	B	20.0
6	8/17/01	B	20.0
6	8/17/01	B	22.5
6	8/17/01	B	20.0
6	8/17/01	D	21.0
6	8/17/01	D	22.0
6	8/17/01	D	20.5
6	8/17/01	D	22.0
6	8/17/01	D	20.0
6	8/17/01	E	21.5
6	8/17/01	E	17.5
6	9/22/01	A	21.0
6	9/22/01	A	21.0
6	9/22/01	A	21.5
6	9/22/01	A	18.5
6	9/22/01	A	20.5
6	9/22/01	A	21.5
6	9/22/01	A	23.0
6	9/22/01	B	23.5
6	9/22/01	B	25.0
6	9/22/01	B	22.5
6	9/22/01	B	20.5
6	9/22/01	B	23.5
6	9/22/01	B	22.0
6	9/22/01	B	20.0
6	9/22/01	B	20.0
6	9/22/01	B	24.5
6	9/22/01	B	22.5
6	9/22/01	B	19.5
6	9/22/01	B	22.0

6	9/22/01	B	22.5	
6	9/22/01	B	22.5	
6	9/22/01	C	20.0	
6	9/22/01	C	20.0	
6	9/22/01	D	23.0	
6	9/22/01	D	19.0	
6	9/22/01	E	25.5	
6	9/22/01	E	19.5	
6	9/22/01	E	20.0	
6	11/15/01	D	22.5	
6	11/15/01	D	23.0	
6	11/15/01	D	23.0	
6	11/15/01	D	20.0	
6	11/15/01	D	19.5	
6	11/15/01	D	20.5	
6	11/15/01	D	18.5	
6	11/15/01	D	21.0	
6	11/15/01	D	21.5	
6	11/15/01	D	21.0	
6	11/15/01	D	24.5	
6	11/15/01	E	20.5	
6	11/15/01	E	25.5	
6	11/15/01	E	23.0	
8	6/21/00	E	6.5	0.041
8	6/21/00	E	6.5	0.061
8	6/21/00	E	7.0	0.082
8	6/21/00	E	7.5	0.094
8	6/21/00	E	8.0	0.108
8	6/21/00	E	8.0	0.112
8	6/21/00	E	8.0	0.122
8	6/21/00	E	9.5	0.166
8	6/21/00	E	9.5	0.203
8	6/21/00	E	10.0	0.202
8	6/21/00	E	11.5	0.383
8	6/21/00	E	12.5	0.430
8	6/21/00	E	13.0	0.501
8	6/21/00	E	13.0	0.595
8	6/21/00	E	13.5	0.543
8	6/21/00	E	13.5	0.589

8	6/21/00	E	14.0	0.565
8	6/21/00	E	14.0	0.568
8	6/21/00	E	14.0	0.580
8	6/21/00	E	14.0	0.607
8	6/21/00	E	14.5	0.604
8	6/21/00	E	14.5	0.639
8	6/21/00	E	14.5	0.690
8	6/21/00	E	15.0	0.633
8	6/21/00	E	15.0	0.768
8	6/21/00	E	15.0	0.820
8	6/21/00	E	15.5	0.786
8	6/21/00	E	15.5	0.865
8	6/21/00	E	15.5	1.081
8	6/21/00	E	16.0	1.006
8	6/21/00	E	17.0	1.143
8	6/21/00	E	18.0	1.759
8	6/21/00	E	18.5	1.934
8	6/21/00	E	19.5	1.499
8	6/21/00	E	19.5	1.698
8	6/21/00	E	19.5	1.740
8	6/21/00	E	20.0	1.662
8	6/21/00	E	20.0	2.225
8	6/21/00	E	20.5	2.011
8	6/21/00	E	20.5	2.239
8	6/21/00	E	20.5	2.618
8	6/21/00	E	21.0	2.004
8	6/21/00	E	21.0	2.122
8	6/21/00	E	21.0	2.305
8	6/21/00	E	21.5	2.575
8	6/21/00	E	22.0	1.989
8	6/21/00	E	22.0	2.457
8	6/21/00	E	22.0	2.583
8	6/21/00	E	23.0	2.369
8	6/21/00	E	23.0	2.701
8	6/21/00	E	24.0	2.583
8	6/21/00	E	24.0	3.222
8	6/21/00	E	24.0	3.435
8	10/6/00	A	21.5	
8	10/6/00	A	23.0	

8	10/6/00	A	24.0
8	10/6/00	A	21.5
8	10/6/00	A	24.0
8	10/6/00	A	19.0
8	10/6/00	B	20.5
8	10/6/00	C	20.5
8	10/6/00	D	26.5
8	10/6/00	D	25.0
8	10/6/00	D	19.5
8	10/6/00	D	23.0
8	10/6/00	D	24.0
8	10/6/00	D	18.5
8	10/6/00	D	21.5
8	10/6/00	D	20.5
8	10/6/00	D	19.5
8	10/6/00	D	23.0
8	10/6/00	D	20.0
8	10/6/00	D	22.5
8	10/6/00	D	22.0
8	10/6/00	D	18.0
8	10/6/00	D	19.0
8	10/6/00	D	22.5
8	10/6/00	D	24.0
8	10/6/00	D	18.5
8	10/6/00	E	24.0
8	10/6/00	E	13.0
8	10/6/00	E	15.0
8	10/6/00	E	13.5
8	10/6/00	E	14.0
8	10/6/00	E	13.5
8	10/6/00	E	9.0
8	10/6/00	E	11.5
8	10/6/00	E	10.0
8	6/26/01	A	24.0
8	6/26/01	A	25.0
8	6/26/01	B	24.5
8	6/26/01	B	20.5
8	6/26/01	B	25
8	6/26/01	B	24.5

8	6/26/01	B	23	
8	6/26/01	B	19	
8	6/26/01	B	23	
8	6/26/01	B	19	
8	6/26/01	C	20.0	
8	6/26/01	C	23.5	
8	6/26/01	C	19.5	
8	6/26/01	C	22.0	
8	8/17/01	A	21.0	
8	8/17/01	B	24.5	
8	8/17/01	C	23.5	
8	9/22/01	A	22.0	
8	9/22/01	A	25.0	
8	9/22/01	C	25.0	
8	9/22/01	C	24.0	
8	9/22/01	D	23.5	
8	9/22/01	D	21.0	
8	11/15/01	A	25.0	
8	11/15/01	D	25.5	
8	11/15/01	D	23.5	
12	6/21/00	E	6.0	0.058
12	6/21/00	E	7.0	0.074
12	6/21/00	E	7.5	0.104
12	6/21/00	E	8.0	0.131
12	6/21/00	E	8.5	0.127
12	6/21/00	E	8.5	0.127
12	6/21/00	E	9.0	0.162
12	6/21/00	E	9.0	0.180
12	6/21/00	E	9.5	0.176
12	6/21/00	E	10.0	0.217
12	6/21/00	E	10.5	0.248
12	6/21/00	E	10.5	0.250
12	6/21/00	E	10.5	0.258
12	6/21/00	E	11.0	0.290
12	6/21/00	E	11.5	0.437
12	6/21/00	E	12.5	0.557
12	6/21/00	E	12.5	0.591
12	6/21/00	E	13.0	0.528
12	6/21/00	E	13.5	0.543

12	6/21/00	E	13.5	0.648
12	6/21/00	E	14.0	0.608
12	6/21/00	E	14.0	0.612
12	6/21/00	E	14.0	0.724
12	6/21/00	E	15.0	0.852
12	6/21/00	E	15.0	0.852
12	6/21/00	E	15.5	0.865
12	6/21/00	E	16.0	0.975
12	6/21/00	E	16.0	1.015
12	6/21/00	E	16.5	1.256
12	6/21/00	E	18.0	1.331
12	6/21/00	E	18.5	1.285
12	6/21/00	E	18.5	1.346
12	6/21/00	E	18.5	1.588
12	6/21/00	E	19.0	1.776
12	6/21/00	E	19.5	1.835
12	6/21/00	E	19.5	1.985
12	6/21/00	E	20.0	1.953
12	6/21/00	E	20.0	2.114
12	6/21/00	E	20.5	1.882
12	6/21/00	E	20.5	1.929
12	6/21/00	E	20.5	2.150
12	6/21/00	E	20.5	2.159
12	6/21/00	E	21.0	2.233
12	6/21/00	E	21.5	1.916
12	6/21/00	E	21.5	2.339
12	6/21/00	E	22.0	2.654
12	6/21/00	E	22.5	3.242
12	6/21/00	E	23.5	3.561
12	6/21/00	E	24.0	3.284
12	6/21/00	E	24.0	3.308
12	6/21/00	E	24.0	3.635
12	6/21/00	E	24.5	3.563
12	6/21/00	E	25.0	3.207
12	10/6/00	A	23.0	
12	10/6/00	A	25.5	
12	10/6/00	A	25.5	
12	10/6/00	A	20.5	
12	10/6/00	A	17.5	

12	10/6/00	A	22.5
12	10/6/00	A	25.5
12	10/6/00	A	19.0
12	10/6/00	A	21.0
12	10/6/00	A	23.5
12	10/6/00	A	22.5
12	10/6/00	A	22.5
12	10/6/00	A	21.5
12	10/6/00	A	24.5
12	10/6/00	A	18.0
12	10/6/00	A	18.5
12	10/6/00	B	16.0
12	10/6/00	B	18.0
12	10/6/00	B	18.0
12	10/6/00	B	18.0
12	10/6/00	B	18.5
12	10/6/00	B	20.5
12	10/6/00	B	19.5
12	10/6/00	B	19.5
12	10/6/00	B	18.0
12	10/6/00	B	16.5
12	10/6/00	C	22.5
12	10/6/00	C	22.0
12	10/6/00	C	20.0
12	10/6/00	C	18.5
12	10/6/00	C	20.0
12	10/6/00	C	20.5
12	10/6/00	C	17.0
12	10/6/00	C	14.5
12	10/6/00	C	20.0
12	10/6/00	D	22.0
12	10/6/00	E	13.5
12	10/6/00	E	10.5
12	6/26/01	A	22.5
12	6/26/01	C	22.5
12	6/26/01	C	23.0
12	6/26/01	C	23.0
12	6/26/01	C	21.0
12	6/26/01	C	25.0

12	6/26/01	C	22.0
12	8/17/01	A	25.0
12	8/17/01	A	23.5
12	8/17/01	A	23.0
12	8/17/01	B	26.0
12	8/17/01	B	24.0
12	8/17/01	B	23.5
12	8/17/01	C	22.0
12	9/22/01	A	25.0
12	9/22/01	A	23.5
12	9/22/01	A	23.0
12	9/22/01	B	26.0
12	9/22/01	B	24.0
12	9/22/01	B	23.5
12	9/22/01	C	22.0
12	11/15/01	B	22.5
12	11/15/01	B	25.0
12	11/15/01	B	25.0
12	11/15/01	B	24.5
12	11/15/01	D	23.5
12	11/15/01	D	24.5
12	11/15/01	D	24.5
12	11/15/01	D	26.0

* Zone A: Open water wall, above water line
Zone B: Open water wall, below water line
Zone C: Vegetation in open water
Zone D: Wall in vegetated zone
Zone E: Vegetated zone (not on walls)

Appendix D. Slaughter Creek Reference Site Data

Slaughter Creek Reference Site Survey Summary

Date	Location	Mean Density	Mean Length (mm)	Mean Weight (g)	Length - Weight R^2 Correlation
6/20/00	Slaughter Creek Reference Site	8.85	15.9	1.309	0.9551
8/10/00	Slaughter Creek Reference Site	11.65	16.4		
9/30/00	Slaughter Creek Reference Site	18.25	16.2		
6/26/01	Slaughter Creek Reference Site	12.85	16.6		
8/17/01	Slaughter Creek Reference Site	15.15	16.1		
9/22/01	Slaughter Creek Reference Site	18.75	17.5		
11/15/01	Slaughter Creek Reference Site	21.00	18.0		
Mean - Reference Site		**15.21**	**16.7**		

All densities are calculated per ¼ m^2

Slaughter Creek Reference Site Density Data

Reference Site - Route 16, Slaughter Creek
June 20, 2000 - 1:30 PM to 3:30 PM
Sunny, 85 degrees, Low Humidity, Low Tide

Plot	Density	Description
1	0	dense *S. patens* thatch
2	6	dense *S. patens* thatch, moist soil, dry vegetation
3	7	slightly less dense vegetation, high ground, moist soil, dry vegetation – *J. romereanus* and *S. patens*
4	1	dense *J. romereanus* - mostly dead thatch, moist soil
5	29	*S. alterniflora* and algae-like growth, relatively less dense
6	10	combination of dense *S. patens* thatch, *S. alterniflora*, and exposed mud
7	0	dense matted *S. patens* thatch
8	1	dense matted *S. patens* thatch with minimal sun penetration to soil, some live *S. alterniflora*
9	0	dense *S. patens* thatch
10	2	dense *S. patens* thatch
11	0	extremely dense *S. patens* thatch matted to ground, no exposed soil or sun penetration
12	3	dense *S. patens* thatch, live *S. patens* and *S. alterniflora* near *J. romereanus*
13	1	similar to site 12, surrounded by *J. romereanus* but some depressed areas
14	15	dense *S. patens* thatch, *S. alterniflora*, closer to inlet with dead tree laying across, lower elevation
15	27	similar to site 14
16	2	dense *S. patens* thatch overhanging water in depressed areas
17	19	dense *S. patens* thatch and live *S. patens* and *S. alterniflora* near water
18	20	dense *S. patens* thatch, more *S. alterniflora*
19	2	dense *S. patens* thatch - matted, more *S. alterniflora*, farther from water and drier, near *J. romereanus*
20	32	dense *S. patens* thatch, matted across plot, farther from water, dense vegetation
Mean	8.85	

Reference Site - Route 16, Slaughter Creek
August 10, 2000 - 10:45 AM
Sunny, Breezy, 80 degrees

Plot	Density	Description
1	0	dense *S. patens* and *S. alterniflora* at edge of tidal creek
2	28	*J. romereanus* and *S. alterniflora* at edge of tidal creek inlet
3	11	dense *S. patens* with some *J. romereanus* and *S. alterniflora*, high ground ~1 m from edge of tidal creek
4	5	dense *S. patens* with some *S. alterniflora*, ~1.5 m from edge of tidal creek
5	23	dense *S. patens* and *S. alterniflora* at edge of tidal creek
6	33	dense *S. patens* and *S. alterniflora* far from inundated areas
7	0	extremely dense *S. patens* thatch matted to ground, some *S. alterniflora*, far from inundated areas, bordered by *J. romereanus*
8	3	less dense (~1/2) *S. patens* and *S. alterniflora* ~1 m from site 7, similar conditions, bordered by *J. romereanus*
9	0	primarily *S. alterniflora*, 3/4 coverage, far from inundation, bordered by *J. romereanus*
10	0	*S. alterniflora* with *S. patens* thatch, far from inundation
11	21	*S. alterniflora* with *S. patens* thatch, ~3/4 coverage, ~1.5 m from high tide inundation
12	9	dense *S. patens* and *S. alterniflora* ~2 m from high tide inundation
13	11	dense *S. patens* thatch with *S. alterniflora*, ~1/2 m from inundated area
14	19	dense *S. patens* and *S. alterniflora* ~1/2 m from high tide inundation
15	14	*S. patens* with some *S. alterniflora* at edge of high tide inundation
16	37	*S. alterniflora* with some *S. patens* at edge of high tide inundation
17	0	dense matted *S. patens* thatch and live *S. patens* surrounded by high tide inundation
18	5	dense *S. patens* and *S. alterniflora*
19	0	extremely dense *S. patens* and *S. alterniflora*
20	14	extremely dense *S. patens* and *S. alterniflora*
Mean	11.65	

Reference Site - Route 16, Slaughter Creek

September 30, 2000 - 9:45 AM

High Tide, Sunny, Breezy, 60 degrees

Plot	Density	Description
1	17	50-50 *S. alterniflora* and *S. patens,* some *S. patens* thatch, 100% cover, 25% inundated
2	26	Dominated by *S. patens,* some *S. alterniflora*, 100% cover, 100% inundated, 1.5 m from creek, lots of melampus
3	65	Dominated by *S. alterniflora*, 50% cover, 100% inundated, 5 m from creek
4	3	Dominated by *S. patens,* some *S. alterniflora*, 90% cover, hummock surrounded by inundation, 10 m from creek
5	32	75% matted down *S. patens,* 25% *S. alterniflora*, 25% inundated, 7 m from tidal inlet
6	24	50-50 *S. alterniflora* and *S. patens,* edge of inundation, 6 m from tidal inlet
7	10	75% matted down *S. patens,* 25% *S. alterniflora*, edge of inundation, 7 m from tidal inlet, 90% cover
8	16	50-50 *S. alterniflora* and *S. patens,* edge of inundation, 10 m from tidal inlet
9	26	Dominated by *J. romereanus*, some *S. alterniflora* and S. patens
10	7	Dominated by *S. patens,* some *S. alterniflora*, borderd by *J. romereanus*, 15 m from tidal inlet
11	11	75% *S. alterniflora*, 25% *S. patens,* bordered by *J. romereanus*, edge of inundation
12	41	50-50 *S. alterniflora* and *S. patens,* edge of inundation
13	1	50-50 *S. alterniflora* and *S. patens,* partially inundated
14	1	100% *S. alterniflora* bordered by *J. romereanus*
15	12	50-50 *S. alterniflora* and *S. patens,* 100% inundated
16	8	75% *S. alterniflora*, 25% *S. patens,* 100% inundated
17	8	50% *S. alterniflora*, 25% *S. patens,* 25% *J. romereanus*, 100% inundated
18	27	50-50 *S. alterniflora* and *S. patens,* bordered by *J. romereanus*, 100% inundated
19	20	50-50 *S. alterniflora* and *S. patens* on hummocks surrounded by inundation
20	10	75% matted down *S. patens, S. alterniflora*, edge of inundation
Mean	18.25	

Reference Site - Route 16, Slaughter Creek
June 26, 2001 - 10:30 AM
Sunny, light breeze, high tide receding, ~90 degrees

Plot	Density
1	14
2	11
3	0
4	15
5	26
6	1
7	9
8	44
9	13
10	20
11	6
12	24
13	0
14	7
15	10
16	1
17	22
18	19
19	3
20	12
Mean	12.85

August 17, 2001 - 9:00 AM
Sunny, dry, 75 degrees

Plot	Density
1	5
2	8
3	21
4	12
5	39
6	18
7	27
8	0
9	16
10	8
11	29
12	28
13	13
14	6
15	33
16	7
17	5
18	17
19	11
20	0
Mean	15.15

Reference Site - Route 16, Slaughter Creek
September 22, 2001 - 11:30 AM
Partly cloudy, humid, 75 degrees

Plot	Density
1	31
2	2
3	40
4	8
5	33
6	21
7	4
8	15
9	27
10	47
11	18
12	1
13	26
14	3
15	2
16	29
17	16
18	20
19	9
20	23
Mean	18.75

Reference Site - Route 16, Slaughter Creek
November 15, 2001 - 11:30 AM
Sunny, 65 degrees

Plot	Density
1	14
2	51
3	27
4	23
5	7
6	12
7	19
8	21
9	34
10	10
11	17
12	32
13	25
14	1
15	22
16	30
17	4
18	15
19	20
20	36
Mean	21

Slaughter Creek Reference Site Data – 5 of 20 Plots per Survey

Date	Plot	Length	Weight
6/20/00	1	16.0	1.065
6/20/00	1	10.0	0.228
6/20/00	1	12.0	0.376
6/20/00	1	9.0	0.169
6/20/00	1	10.0	0.221
6/20/00	1	7.5	0.102
6/20/00	2	16.5	1.227
6/20/00	2	12.5	0.538
6/20/00	2	11.5	0.329
6/20/00	2	10.5	0.291
6/20/00	2	7.5	0.114
6/20/00	2	8.5	0.149
6/20/00	2	7.0	0.096
6/20/00	3	10.0	0.196
6/20/00	4	23.0	2.950
6/20/00	4	10.0	0.233
6/20/00	4	19.0	1.641
6/20/00	4	20.0	1.859
6/20/00	4	20.0	1.962
6/20/00	4	21.0	2.163
6/20/00	4	16.5	1.113
6/20/00	4	21.5	2.767
6/20/00	4	18.5	1.395
6/20/00	4	25.5	3.174
6/20/00	4	23.5	2.995
6/20/00	4	23.5	2.706
6/20/00	4	22.0	2.603
6/20/00	4	18.0	1.867
6/20/00	4	23.0	2.679
6/20/00	4	19.5	1.866
6/20/00	4	21.0	2.247
6/20/00	4	19.0	1.831
6/20/00	4	20.0	1.868
6/20/00	4	19.0	1.765
6/20/00	4	12.0	0.403
6/20/00	4	11.5	0.347

6/20/00	4	10.5	0.306
6/20/00	4	10.0	0.289
6/20/00	4	9.5	0.203
6/20/00	4	9.5	0.201
6/20/00	4	6.0	0.063
6/20/00	4	10.0	0.235
6/20/00	4	9.5	0.174
6/20/00	5	20.5	1.972
6/20/00	5	22.5	2.751
6/20/00	5	17.5	1.267
6/20/00	5	25.0	3.424
6/20/00	5	19.5	1.925
6/20/00	5	23.5	2.893
6/20/00	5	18.0	1.470
6/20/00	5	18.5	1.422
6/20/00	5	22.5	2.658
6/20/00	5	13.0	0.569
8/10/00	2	25.0	
8/10/00	2	21.0	
8/10/00	2	22.5	
8/10/00	2	23.0	
8/10/00	2	23.0	
8/10/00	2	24.6	
8/10/00	2	18.0	
8/10/00	2	19.5	
8/10/00	2	20.0	
8/10/00	2	19.5	
8/10/00	2	25.0	
8/10/00	2	21.0	
8/10/00	2	20.0	
8/10/00	2	17.5	
8/10/00	2	19.0	
8/10/00	2	18.5	
8/10/00	2	18.5	
8/10/00	2	18.5	
8/10/00	2	18.0	
8/10/00	2	16.0	
8/10/00	2	16.0	

8/10/00	2	11.5
8/10/00	2	11.0
8/10/00	2	10.5
8/10/00	2	9.0
8/10/00	2	9.0
8/10/00	2	7.5
8/10/00	2	8.5
8/10/00	3	23.0
8/10/00	3	22.5
8/10/00	3	24.5
8/10/00	3	21.0
8/10/00	3	24.0
8/10/00	3	22.5
8/10/00	3	19.0
8/10/00	3	18.0
8/10/00	3	13.0
8/10/00	3	10.0
8/10/00	3	8.5
8/10/00	4	12.0
8/10/00	4	11.0
8/10/00	4	10.5
8/10/00	4	9.0
8/10/00	4	10.0
8/10/00	5	19.0
8/10/00	5	25.0
8/10/00	5	22.5
8/10/00	5	24.0
8/10/00	5	23.0
8/10/00	5	20.5
8/10/00	5	22.0
8/10/00	5	24.0
8/10/00	5	22.5
8/10/00	5	17.0
8/10/00	5	16.5
8/10/00	5	17.0
8/10/00	5	15.0
8/10/00	5	12.0
8/10/00	5	10.0

8/10/00	5	8.0
8/10/00	5	9.0
8/10/00	5	7.5
8/10/00	5	8.0
8/10/00	5	8.5
8/10/00	5	7.0
8/10/00	5	6.5
8/10/00	5	6.0
9/30/00	1	5.5
9/30/00	1	12.5
9/30/00	1	6.0
9/30/00	1	7.0
9/30/00	1	4.5
9/30/00	1	6.0
9/30/00	1	11.0
9/30/00	1	12.5
9/30/00	1	11.0
9/30/00	1	20.0
9/30/00	1	19.5
9/30/00	1	10.0
9/30/00	1	20.0
9/30/00	1	15.5
9/30/00	1	11.0
9/30/00	1	23.5
9/30/00	1	12.5
9/30/00	2	18.5
9/30/00	2	10.5
9/30/00	2	12.0
9/30/00	2	18.5
9/30/00	2	11.0
9/30/00	2	10.5
9/30/00	2	10.5
9/30/00	2	15.0
9/30/00	2	9.0
9/30/00	2	11.0
9/30/00	2	9.0
9/30/00	2	10.0
9/30/00	2	12.0

9/30/00	2	13.5
9/30/00	2	14.0
9/30/00	2	11.5
9/30/00	2	12.0
9/30/00	2	9.5
9/30/00	2	10.5
9/30/00	2	12.5
9/30/00	2	12.0
9/30/00	2	12.0
9/30/00	2	9.0
9/30/00	2	10.5
9/30/00	2	11.0
9/30/00	2	19.0
9/30/00	3	12.0
9/30/00	3	11.5
9/30/00	3	17.0
9/30/00	3	19.0
9/30/00	3	19.0
9/30/00	3	20.0
9/30/00	3	19.5
9/30/00	3	17.0
9/30/00	3	19.0
9/30/00	3	23.0
9/30/00	3	22.5
9/30/00	3	21.5
9/30/00	3	23.0
9/30/00	3	20.0
9/30/00	3	20.0
9/30/00	3	23.0
9/30/00	3	22.0
9/30/00	3	17.0
9/30/00	3	10.0
9/30/00	3	16.5
9/30/00	3	12.5
9/30/00	3	18.0
9/30/00	3	14.5
9/30/00	3	19.5
9/30/00	3	18.5

9/30/00	3	18.5
9/30/00	3	16.0
9/30/00	3	16.0
9/30/00	3	16.0
9/30/00	3	12.0
9/30/00	3	19.0
9/30/00	3	19.5
9/30/00	3	11.0
9/30/00	3	10.0
9/30/00	3	19.0
9/30/00	3	13.5
9/30/00	3	18.5
9/30/00	3	15.0
9/30/00	3	17.5
9/30/00	3	18.5
9/30/00	3	19.5
9/30/00	3	17.5
9/30/00	3	20.0
9/30/00	3	22.0
9/30/00	3	21.0
9/30/00	3	20.0
9/30/00	3	15.5
9/30/00	3	20.0
9/30/00	3	12.0
9/30/00	3	19.0
9/30/00	3	20.0
9/30/00	3	21.0
9/30/00	3	11.5
9/30/00	3	16.0
9/30/00	3	23.5
9/30/00	3	10.0
9/30/00	3	16.5
9/30/00	3	20.0
9/30/00	3	18.0
9/30/00	3	20.0
9/30/00	3	24.0
9/30/00	3	16.5
9/30/00	3	21.0

9/30/00	3	18.0
9/30/00	3	20.5
9/30/00	4	11.0
9/30/00	4	13.0
9/30/00	4	23.0
9/30/00	5	20.0
9/30/00	5	21.5
9/30/00	5	25.0
9/30/00	5	13.5
9/30/00	5	20.0
9/30/00	5	16.0
9/30/00	5	17.0
9/30/00	5	23.0
9/30/00	5	13.0
9/30/00	5	15.5
9/30/00	5	10.0
9/30/00	5	22.5
9/30/00	5	21.5
9/30/00	5	24.0
9/30/00	5	23.0
9/30/00	5	22.0
9/30/00	5	11.0
9/30/00	5	22.0
9/30/00	5	13.0
9/30/00	5	20.0
9/30/00	5	19.5
9/30/00	5	20.0
9/30/00	5	10.0
9/30/00	5	20.5
9/30/00	5	25.0
9/30/00	5	25.0
9/30/00	5	21.5
9/30/00	5	10.5
9/30/00	5	22.5
9/30/00	5	21.0
9/30/00	5	11.0
9/30/00	5	7.5
6/26/01	1	22.5

6/26/01	1	24.0
6/26/01	1	20.0
6/26/01	1	22.0
6/26/01	1	21.0
6/26/01	1	19.5
6/26/01	1	18.5
6/26/01	1	27.5
6/26/01	1	19.0
6/26/01	1	19.5
6/26/01	1	17.5
6/26/01	1	14.0
6/26/01	1	12.0
6/26/01	1	11.5
6/26/01	2	24.0
6/26/01	2	23.0
6/26/01	2	4.0
6/26/01	2	21.5
6/26/01	2	19.5
6/26/01	2	15.0
6/26/01	2	12.0
6/26/01	2	13.5
6/26/01	2	11.0
6/26/01	2	10.0
6/26/01	2	10.0
6/26/01	4	26.0
6/26/01	4	25.0
6/26/01	4	21.0
6/26/01	4	22.5
6/26/01	4	21.5
6/26/01	4	20.5
6/26/01	4	22.5
6/26/01	4	22.0
6/26/01	4	18.0
6/26/01	4	20.5
6/26/01	4	12.0
6/26/01	4	13.5
6/26/01	4	9.5
6/26/01	4	8.5

6/26/01	4	5.5
6/26/01	5	23.0
6/26/01	5	24.0
6/26/01	5	23.5
6/26/01	5	24.0
6/26/01	5	25.5
6/26/01	5	21.0
6/26/01	5	20.5
6/26/01	5	20.5
6/26/01	5	22.5
6/26/01	5	21.5
6/26/01	5	15.5
6/26/01	5	15.0
6/26/01	5	15.0
6/26/01	5	13.0
6/26/01	5	14.0
6/26/01	5	10.5
6/26/01	5	10.5
6/26/01	5	10.0
6/26/01	5	10.5
6/26/01	5	10.5
6/26/01	5	9.5
6/26/01	5	9.5
6/26/01	5	7.5
6/26/01	5	6.0
6/26/01	5	6.0
6/26/01	5	6.5
8/17/01	1	23.0
8/17/01	1	13.5
8/17/01	1	7.5
8/17/01	1	21.5
8/17/01	1	16.0
8/17/01	2	21.0
8/17/01	2	21.5
8/17/01	2	20.5
8/17/01	2	22.0
8/17/01	2	23.5
8/17/01	2	21.0

8/17/01	2	9.0
8/17/01	2	8.5
8/17/01	3	19.5
8/17/01	3	22.0
8/17/01	3	22.0
8/17/01	3	21.0
8/17/01	3	4.0
8/17/01	3	22.5
8/17/01	3	23.0
8/17/01	3	18.0
8/17/01	3	16.0
8/17/01	3	15.0
8/17/01	3	12.5
8/17/01	3	15.5
8/17/01	3	15.0
8/17/01	3	13.0
8/17/01	3	11.0
8/17/01	3	10.5
8/17/01	3	9.5
8/17/01	3	8.0
8/17/01	3	5.0
8/17/01	3	7.0
8/17/01	3	5.0
8/17/01	4	22.5
8/17/01	4	20.0
8/17/01	4	20.5
8/17/01	4	16.5
8/17/01	4	16.0
8/17/01	4	15.0
8/17/01	4	11.0
8/17/01	4	11.0
8/17/01	4	11.0
8/17/01	4	9.5
8/17/01	4	8.5
8/17/01	4	6.0
8/17/01	5	23.5
8/17/01	5	20.0
8/17/01	5	21.0

8/17/01	5	19.0
8/17/01	5	18.0
8/17/01	5	20.0
8/17/01	5	20.0
8/17/01	5	19.5
8/17/01	5	18.5
8/17/01	5	19.0
8/17/01	5	18.0
8/17/01	5	19.5
8/17/01	5	23.0
8/17/01	5	21.0
8/17/01	5	21.5
8/17/01	5	21.0
8/17/01	5	17.5
8/17/01	5	18.5
8/17/01	5	16.5
8/17/01	5	19.0
8/17/01	5	18.0
8/17/01	5	17.0
8/17/01	5	20.0
8/17/01	5	18.0
8/17/01	5	19.0
8/17/01	5	17.0
8/17/01	5	16.0
8/17/01	5	16.0
8/17/01	5	18.5
8/17/01	5	16.0
8/17/01	5	13.0
8/17/01	5	12.5
8/17/01	5	13.0
8/17/01	5	13.0
8/17/01	5	12.5
8/17/01	5	11.0
8/17/01	5	11.5
8/17/01	5	9.0
8/17/01	5	10.0
9/22/01	1	20.5
9/22/01	1	23.5

9/22/01	1	22.0
9/22/01	1	22.5
9/22/01	1	22.0
9/22/01	1	20.0
9/22/01	1	25.0
9/22/01	1	22.5
9/22/01	1	23.0
9/22/01	1	23.5
9/22/01	1	21.5
9/22/01	1	22.5
9/22/01	1	23.0
9/22/01	1	22.0
9/22/01	1	19.0
9/22/01	1	17.5
9/22/01	1	17.0
9/22/01	1	22.0
9/22/01	1	16.0
9/22/01	1	12.0
9/22/01	1	18.0
9/22/01	1	19.5
9/22/01	1	17.5
9/22/01	1	12.0
9/22/01	1	14.0
9/22/01	1	13.5
9/22/01	1	10.5
9/22/01	1	11.0
9/22/01	1	6.5
9/22/01	1	8.0
9/22/01	1	9.0
9/22/01	2	24.0
9/22/01	2	18.5
9/22/01	3	23.0
9/22/01	3	22.0
9/22/01	3	25.0
9/22/01	3	21.0
9/22/01	3	22.0
9/22/01	3	23.5
9/22/01	3	22.0

9/22/01	3	21.0
9/22/01	3	22.0
9/22/01	3	21.0
9/22/01	3	22.0
9/22/01	3	21.5
9/22/01	3	16.5
9/22/01	3	19.0
9/22/01	3	16.5
9/22/01	3	19.5
9/22/01	3	17.5
9/22/01	3	17.5
9/22/01	3	16.0
9/22/01	3	17.0
9/22/01	3	18.5
9/22/01	3	16.5
9/22/01	3	15.5
9/22/01	3	14.5
9/22/01	3	16.0
9/22/01	3	15.5
9/22/01	3	15.0
9/22/01	3	14.5
9/22/01	3	13.5
9/22/01	3	12.0
9/22/01	3	9.0
9/22/01	3	12.5
9/22/01	3	18.0
9/22/01	3	16.5
9/22/01	3	11.0
9/22/01	3	10.5
9/22/01	3	10.0
9/22/01	3	8.0
9/22/01	3	7.5
9/22/01	3	6.0
9/22/01	4	22.0
9/22/01	4	21.5
9/22/01	4	23.0
9/22/01	4	21.0
9/22/01	4	16.5

9/22/01	4	14.0
9/22/01	4	10.0
9/22/01	4	9.5
9/22/01	5	21.0
9/22/01	5	21.5
9/22/01	5	22.0
9/22/01	5	22.0
9/22/01	5	21.0
9/22/01	5	21.5
9/22/01	5	22.5
9/22/01	5	19.0
9/22/01	5	21.0
9/22/01	5	23.0
9/22/01	5	22.5
9/22/01	5	22.0
9/22/01	5	23.5
9/22/01	5	21.0
9/22/01	5	18.0
9/22/01	5	19.5
9/22/01	5	23.0
9/22/01	5	22.5
9/22/01	5	17.5
9/22/01	5	19.5
9/22/01	5	16.0
9/22/01	5	17.0
9/22/01	5	15.5
9/22/01	5	19.0
9/22/01	5	15.0
9/22/01	5	14.5
9/22/01	5	13.0
9/22/01	5	13.0
9/22/01	5	13.5
9/22/01	5	11.0
9/22/01	5	7.0
9/22/01	5	8.5
9/22/01	5	5.0
11/15/01	1	3.0
11/15/01	1	4.0

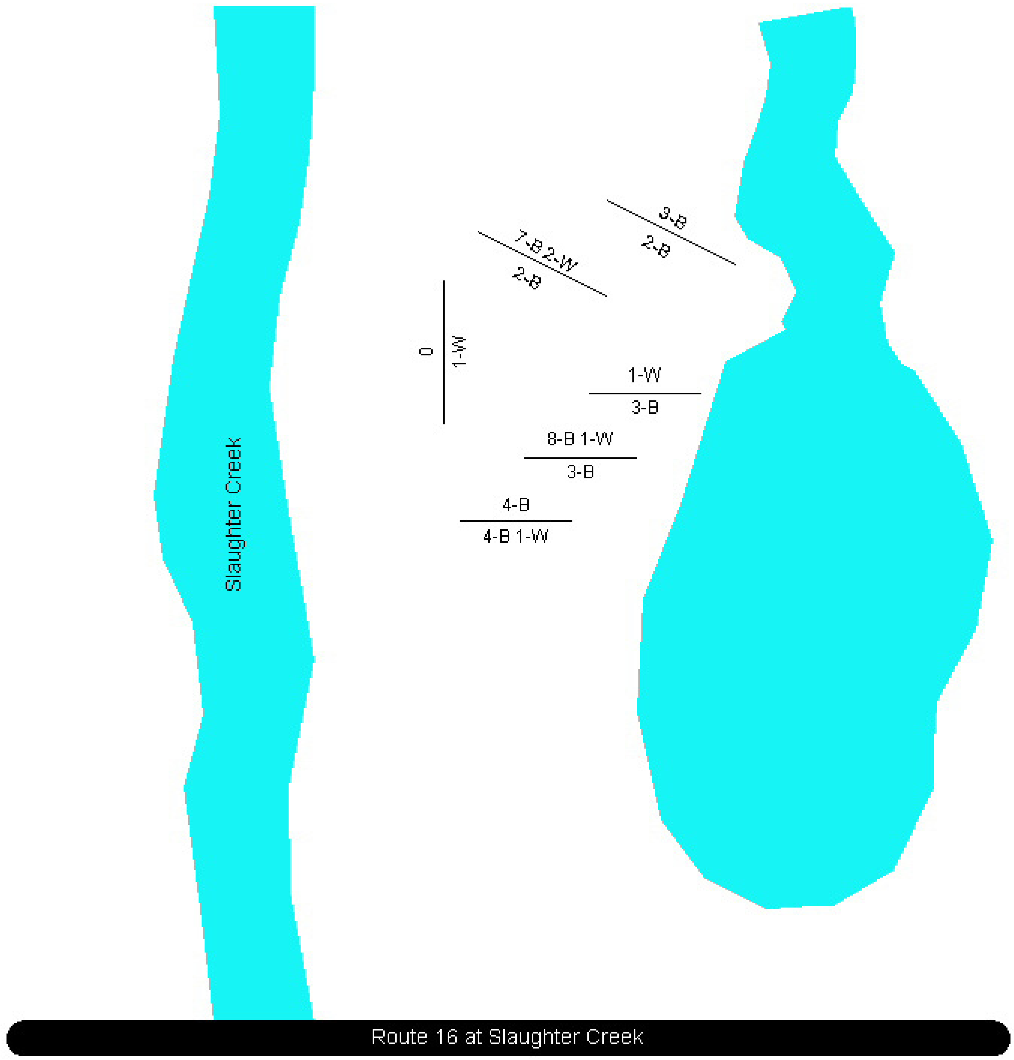
11/15/01	1	26.0
11/15/01	1	23.5
11/15/01	1	23.0
11/15/01	1	22.5
11/15/01	1	21.5
11/15/01	1	24.5
11/15/01	1	23.0
11/15/01	1	19.5
11/15/01	1	18.5
11/15/01	1	17.0
11/15/01	1	10.5
11/15/01	1	9.5
11/15/01	2	20.5
11/15/01	2	20.5
11/15/01	2	23.0
11/15/01	2	24.0
11/15/01	2	22.0
11/15/01	2	18.5
11/15/01	2	20.5
11/15/01	2	20.0
11/15/01	2	22.0
11/15/01	2	19.5
11/15/01	2	21.0
11/15/01	2	22.5
11/15/01	2	20.5
11/15/01	2	23.0
11/15/01	2	22.0
11/15/01	2	21.5
11/15/01	2	22.0
11/15/01	2	21.5
11/15/01	2	18.5
11/15/01	2	19.5
11/15/01	2	19.0
11/15/01	2	16.5
11/15/01	2	15.0
11/15/01	2	19.0
11/15/01	2	18.5
11/15/01	2	16.0

11/15/01	2	17.0
11/15/01	2	19.5
11/15/01	2	18.0
11/15/01	2	15.0
11/15/01	2	19.5
11/15/01	2	17.5
11/15/01	2	18.0
11/15/01	2	19.0
11/15/01	2	17.0
11/15/01	2	15.0
11/15/01	2	14.0
11/15/01	2	13.0
11/15/01	2	14.5
11/15/01	2	12.0
11/15/01	2	17.5
11/15/01	2	19.0
11/15/01	2	12.5
11/15/01	2	10.0
11/15/01	2	9.5
11/15/01	2	8.5
11/15/01	2	7.0
11/15/01	2	10.5
11/15/01	2	6.0
11/15/01	2	5.5
11/15/01	2	9.5
11/15/01	3	23.0
11/15/01	3	25.0
11/15/01	3	23.5
11/15/01	3	21.5
11/15/01	3	23.0
11/15/01	3	22.0
11/15/01	3	22.0
11/15/01	3	25.0
11/15/01	3	21.5
11/15/01	3	22.0
11/15/01	3	24.0
11/15/01	3	22.5
11/15/01	3	22.5

11/15/01	3	19.0
11/15/01	3	21.5
11/15/01	3	19.5
11/15/01	3	22.0
11/15/01	3	18.5
11/15/01	3	17.0
11/15/01	3	14.0
11/15/01	3	15.5
11/15/01	3	13.0
11/15/01	3	11.0
11/15/01	3	12.5
11/15/01	3	9.5
11/15/01	3	9.0
11/15/01	3	8.0
11/15/01	4	19.0
11/15/01	4	23.0
11/15/01	4	20.5
11/15/01	4	21.5
11/15/01	4	22.0
11/15/01	4	22.5
11/15/01	4	20.0
11/15/01	4	21.5
11/15/01	4	20.0
11/15/01	4	20.5
11/15/01	4	23.0
11/15/01	4	22.0
11/15/01	4	22.0
11/15/01	4	19.5
11/15/01	4	21.5
11/15/01	4	21.5
11/15/01	4	19.0
11/15/01	4	15.0
11/15/01	4	19.0
11/15/01	4	20.0
11/15/01	4	14.0
11/15/01	4	10.5
11/15/01	4	6.5
11/15/01	5	23.0

11/15/01	5	25.5
11/15/01	5	24.0
11/15/01	5	19.0
11/15/01	5	17.0
11/15/01	5	12.5
11/15/01	5	8.5

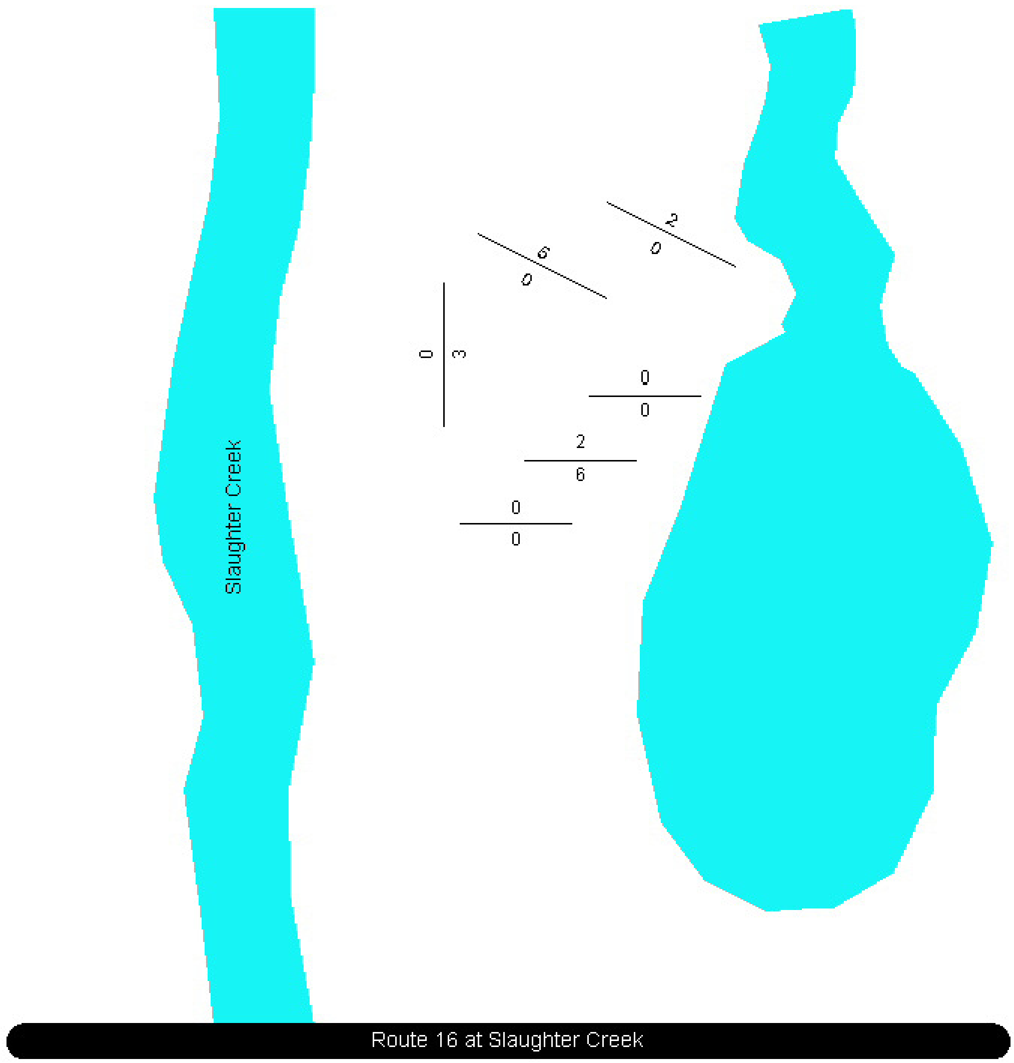
Appendix E: Artificial Wall Data



September 22, 2001 - 11:30 AM
Snails found on panels (W) and at base of panels (B)

	9/22/2001								
	Front			Back			Total		
Panel	Base	Wall	Total	Base	Wall	Total	Base	Wall	Panel
1	4.00	1.00	5.00	4.00	0.00	4.00	8.00	1.00	9.00
2	3.00	0.00	3.00	8.00	1.00	9.00	11.00	1.00	12.00
3	3.00	0.00	3.00	0.00	1.00	1.00	3.00	1.00	4.00
4*	0.00	0.00	0.00	0.00	1.00	1.00	0.00	1.00	1.00
5	2.00	0.00	2.00	7.00	2.00	9.00	9.00	2.00	11.00
6	2.00	0.00	2.00	3.00	0.00	3.00	5.00	0.00	5.00
Total	14.00	1.00	15.00	22.00	5.00	27.00	36.00	6.00	42.00
Mean	2.33	0.17	2.50	3.67	0.83	4.50	6.00	1.00	7.00
S.E.	0.3651	0.4082	0.4243	0.7220	0.3367	0.7071	0.6831	0.2582	0.6690

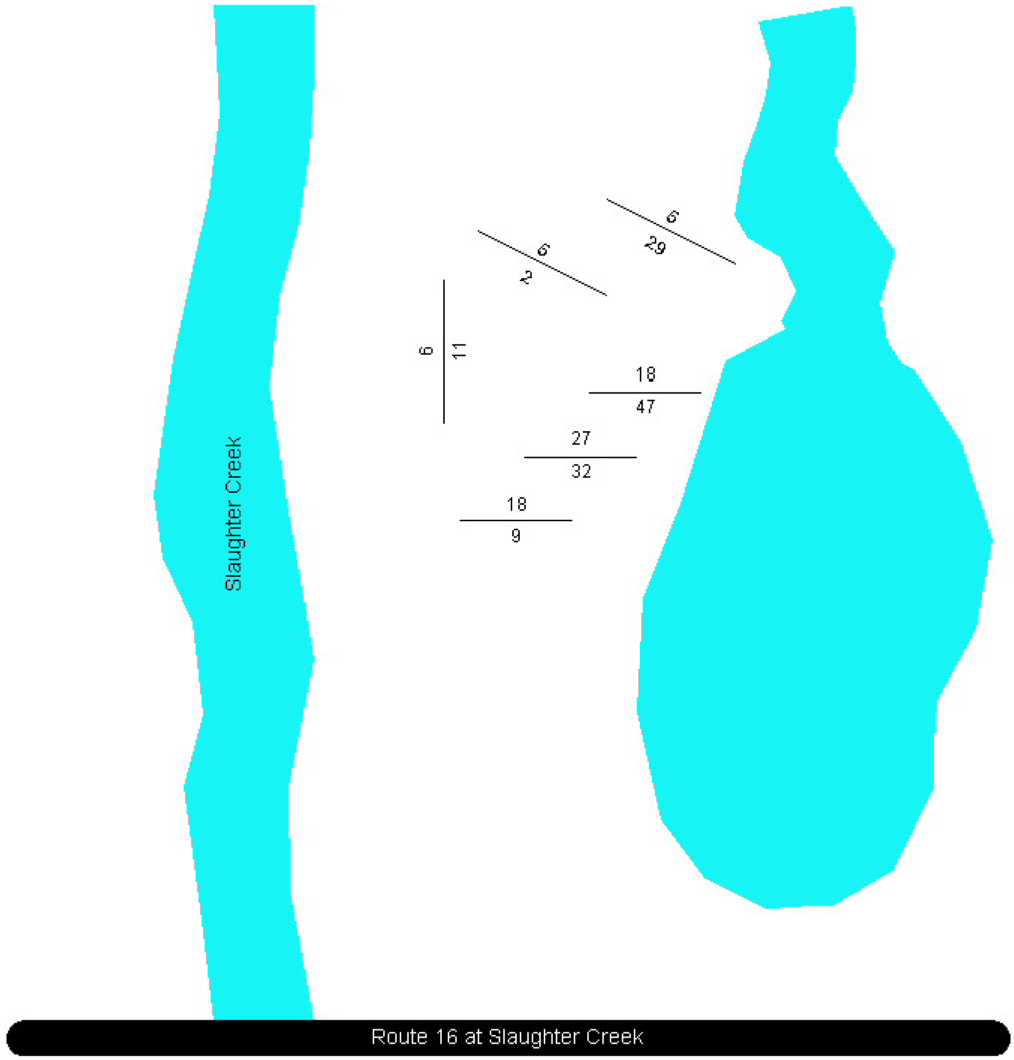
* Front = Slaughter Creek/sun, Back = Inlet/shade



November 15, 2001 - 11:30 AM
All snails found at base of panels.

	11/15/2001								
	Front			Back			Total		
Panel	Base	Wall	Total	Base	Wall	Total	Base	Wall	Panel
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	6.00	0.00	6.00	2.00	0.00	2.00	8.00	0.00	8.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4*	0.00	0.00	0.00	3.00	0.00	3.00	3.00	0.00	3.00
5	0.00	0.00	0.00	5.00	0.00	5.00	5.00	0.00	5.00
6	0.00	0.00	0.00	2.00	0.00	2.00	2.00	0.00	2.00
Total	6.00	0.00	6.00	12.00	0.00	12.00	18.00	0.00	18.00
Mean	1.00	0.00	1.00	2.00	0.00	2.00	3.00	0.00	3.00
S.E.	1.0000	0.0000	1.0000	0.5477	0.0000	0.5477	0.7303	0.0000	0.7303

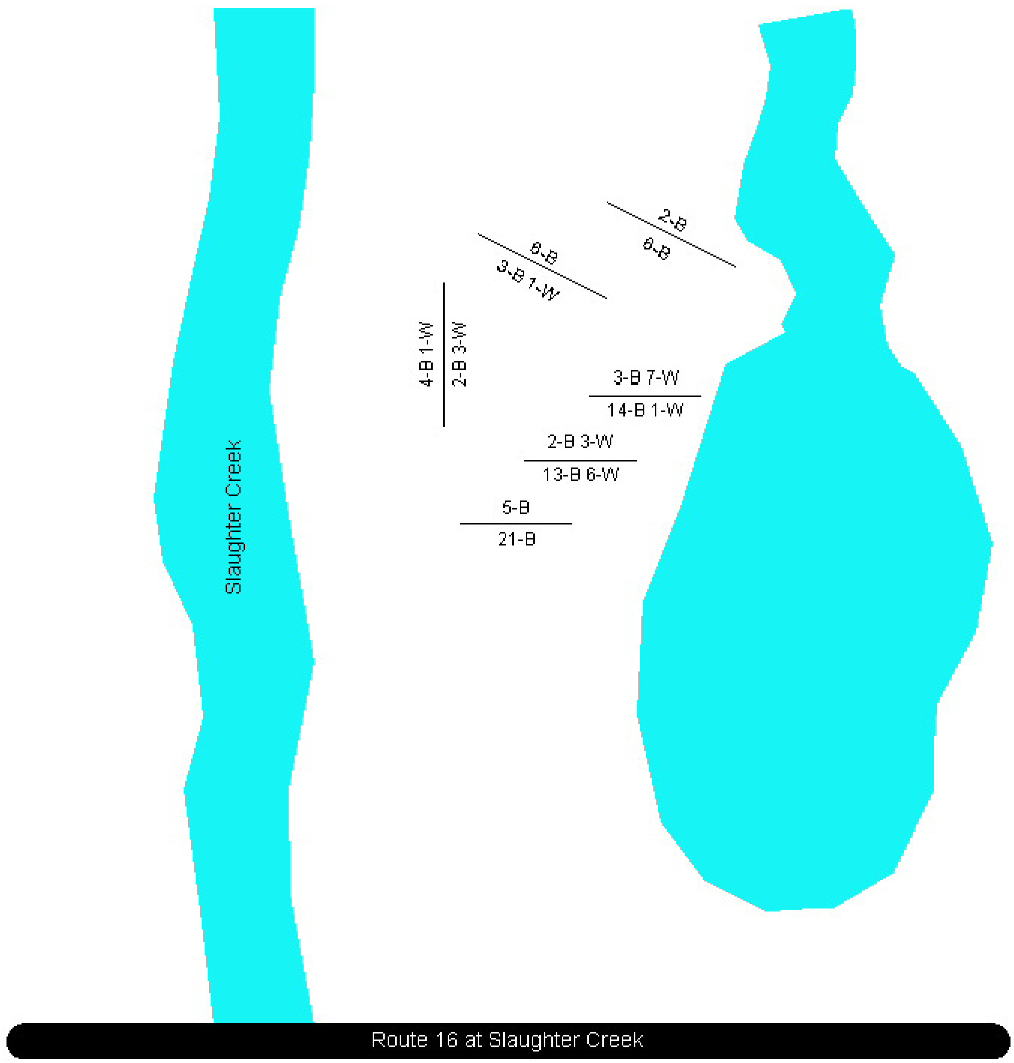
* Front = Slaughter Creek/sun, Back = Inlet/shade



July 6, 2002 - 4:30 PM
All snails found at base of panels.

	7/6/2002								
	Front			Back			Total		
Panel	Base	Wall	Total	Base	Wall	Total	Base	Wall	Panel
1	9.00	0.00	9.00	18.00	0.00	18.00	27.00	0.00	27.00
2	32.00	0.00	32.00	27.00	0.00	27.00	59.00	0.00	59.00
3	47.00	0.00	47.00	18.00	0.00	18.00	65.00	0.00	65.00
4*	6.00	0.00	6.00	11.00	0.00	11.00	17.00	0.00	17.00
5	2.00	0.00	2.00	5.00	0.00	5.00	7.00	0.00	7.00
6	29.00	0.00	29.00	5.00	0.00	5.00	34.00	0.00	34.00
Total	125.00	0.00	125.00	84.00	0.00	84.00	209.00	0.00	209.00
Mean	20.83	0.00	20.83	14.00	0.00	14.00	34.83	0.00	34.83
S.E.	1.5954	0.0000	1.5954	0.9411	0.0000	0.9411	1.5921	0.0000	1.5921

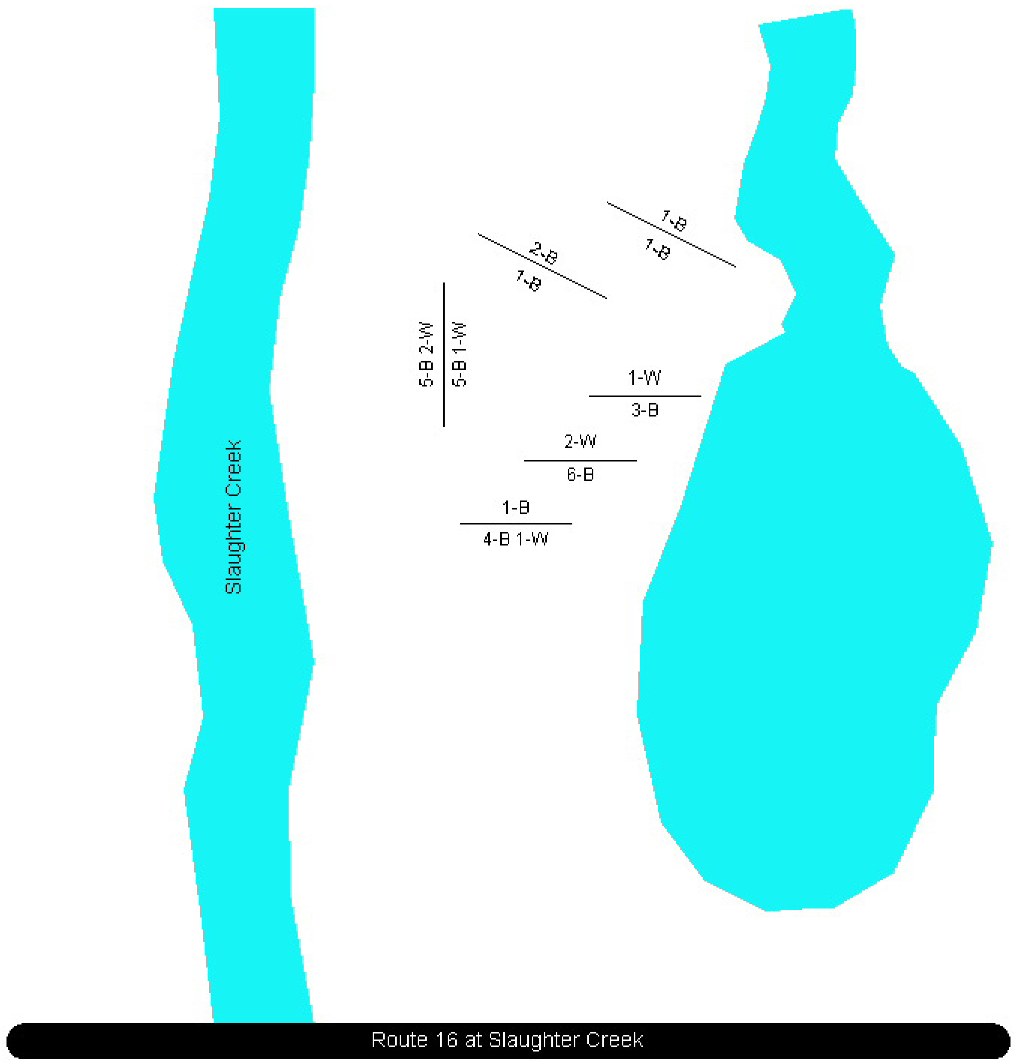
* Front = Slaughter Creek/sun, Back = Inlet/shade



August 15, 2002 - 5:00 PM
Snails found on panels (W) and at base of panels (B).

	8/15/2002								
	Front			Back			Total		
Panel	Base	Wall	Total	Base	Wall	Total	Base	Wall	Panel
1	21.00	0.00	21.00	5.00	0.00	5.00	26.00	0.00	26.00
2	13.00	6.00	19.00	2.00	3.00	5.00	15.00	9.00	24.00
3	14.00	1.00	15.00	14.00	1.00	15.00	28.00	2.00	30.00
4*	4.00	1.00	5.00	2.00	3.00	5.00	6.00	4.00	10.00
5	3.00	1.00	4.00	6.00	0.00	6.00	9.00	1.00	10.00
6	6.00	0.00	6.00	2.00	0.00	2.00	8.00	0.00	8.00
Total	61.00	9.00	70.00	31.00	7.00	38.00	92.00	16.00	108.00
Mean	10.17	1.50	11.67	5.17	1.17	6.33	15.33	2.67	18.00
S.E.	0.8996	0.7528	0.9061	0.8379	0.5563	0.7231	0.9949	0.8612	0.9349

* Front = Slaughter Creek/sun, Back = Inlet/shade



November 11, 2002 - 1:00 PM
Snails found on panels (W) and at base of panels (B).
Melampus found on panels for first time.

	11/11/2002								
	Front			Back			Total		
Panel	Base	Wall	Total	Base	Wall	Total	Base	Wall	Panel
1	4.00	1.00	5.00	1.00	0.00	1.00	5.00	1.00	6.00
2	6.00	0.00	6.00	0.00	2.00	2.00	6.00	2.00	8.00
3	0.00	3.00	3.00	0.00	1.00	1.00	0.00	4.00	4.00
4*	5.00	2.00	7.00	5.00	1.00	6.00	10.00	3.00	13.00
5	1.00	0.00	1.00	2.00	0.00	2.00	3.00	0.00	3.00
6	1.00	0.00	1.00	1.00	0.00	1.00	2.00	0.00	2.00
Total	17.00	6.00	23.00	9.00	4.00	13.00	26.00	10.00	36.00
Mean	2.83	1.00	3.83	1.50	0.67	2.17	4.33	1.67	6.00
S.E.	0.6023	0.5164	0.5343	0.6236	0.4082	0.5383	0.6869	0.5164	0.6749

* Front = Slaughter Creek/sun, Back = Inlet/shade

REFERENCES

Adam, P. 1990. Saltmarsh Ecology. Cambridge University Press: Cambridge, Great Britain.

Adey, WH and K Loveland. 1991. Dynamic Aquaria: Building Living Ecosystems. Academic Press: San Diego, California.

Adey, WH; M Finn; P Kangas; L Lange; C Luckett; DM Spoon. 1996. A Florida Everglades Mesocosm – model veracity after four years of self organization. Ecological Engineering, vol. 6, pp. 171-224.

Alexander, SK. 1979. Diet of the periwinkle *Littorina irrorata* in a Louisiana salt marsh. Gulf Research Reports, vol. 6, no. 3, pp. 293-295.

Anderson, MJ and AJ Underwood. 1997. Effects of gastropod grazers on recruitment and succession of an estuarine assemblage: a multivariate and univariate approach. Oecologia, Vol. 109, pp. 442-453.

Baerlocher, F and SY Newell. 1994. Growth of the salt marsh periwinkle *Littoraria irrorata* on fungal and cordgrass diets. Marine Biology, vol. 118, no. 1, pp. 109-114.

Baerlocher, F and SY Newell. 1994. Phenolics and proteins affecting palatability of *Spartina* leaves to the gastropod *Littoraria irrorata*. Marine Ecology, vol. 15, no. 1, pp. 65-75.

Baker, JM and WJ Wolff, eds. 1987. Biological Surveys of Estuaries and Coasts. Cambridge University Press: Cambridge, Great Britain.

Bandel, K and D Kadolsky. 1982. Western Atlantic Species of *Nodilittorina* (Gastropoda: Prosobranchia): Comparative morphology and its functional, ecological, phylogenetic and taxonomic implications. Veliger, vol. 25, pp. 1-42.

Begon, M; JL Harper; CR Townsend. 1986. Ecology: Individuals, Populations and Communities. Sinauer Associates Inc. Publishers: Sunderland, Massachusetts.

Bertness, MD. 1994. Habitat and community modification by an introduced herbivorous snail. Ecology, vol. 65, no. 2, pp. 370-381.

Bertness, MD; BR Silliman; R Jefferies. 2004. Salt Marshes Under Siege: Agricultural practices, land development and overhavesting of the seas explain complex ecological cascades that threaten our shorelines. American Scientist, vol. 92, pp. 54-61.

Bingham, FO. 1969. The influence of environmental stimuli on the direction of movement of the supralittoral gastropod *Littorina irrorata*, with notes on additional biological aspects of the species. M.S. Thesis, Florida State University, Tallahassee.

Bingham, FO. 1972. The influence on environmental stimuli on the direction of movement of the supralittoral gastropod *Littorina irrorata*. Bulletin of Marine Science, vol. 22, pp. 309-335.

Blanco, JF and JR Cantera. 1999. The vertical distribution of mangrove gastropods and environmental factors relative to tide level at Buenaventura Bay, Pacific coast of Colombia. Bulletin of Marine Science, vol. 65, no. 3, pp. 617-630.

Bleil, DF and ME Gunn. 1978. Submergence avoidance behavior in the periwinkle *Littorina irrorata* is not due to threat of drowning. Estuaries, vol. 1, no. 4, p. 267.

Cammen, LM. 1976. Abundance and production of macroinvertebrates from natural and artificially established salt marshes in North Carolina. American Midland Naturalist, col. 96, pp. 487-493.

Cammen, LM. 1979. The macro-infauna of a North Carolina salt marsh. American Midland Naturalist, vol. 102, pp. 244-253.

Carter, MR; LA Burns; TR Cavinder; KR Dugger; PL Fore; DB Hicks; HL Revells; TW Schmidt. 1973. Ecosystems Analysis of the Big Cypress Swamp and Estuaries. USEPA Region 4, No. 904/9-74-002.

Chapman, VJ, ed. 1977. Wet Coastal Ecosystems. Elsevier Scientific Publishing Company: Amsterdam, The Netherlands.

Currin, CA; SY Newell; HW Paerl. 1995. The role of standing dead *Spartina alterniflora* and benthic microalgae in salt marsh food webs: Considerations based on multiple stable isotope analysis. Marine Ecology Progress Series, vol. 121, no. 1-3, pp. 99-116.

Dahl, TE. 1990. Wetlands losses in the United States 1780's to 1980's. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC. Northern Prairie Wildlife Research Center Home Page: Jamestown, ND. http://www.npwrc.usgs.gov/resource/othrdata/wetloss/wetloss.htm (Version 16JUL97).

Dame, RF, ed. 1979. Marsh-Estuarine Systems Simulation. University of South Carolina Press: Columbia, South Carolina.

Dayan, NS and RT Dillon, Jr. 1995. Florida as a biogeographic boundary: Evidence from the population genetics of *Littorina irrorata*. Nautilus, vol. 108, no. 3, pp. 49-54.

Dix, TL and PV Hamilton. 1993. Chemically mediated escape behavior in the marsh periwinkle *Littoraria irrorata* Say. Journal of Experimental Marine Biology and Ecology, vol. 166, no. 1, pp. 135-149.

Duncan, RS and WA Szelistowski. 1998. Influence of puffer predation on vertical distribution of mangrove littorinids in the Gulf of Nicoya, Costa Rica. Oecologia, vol. 117, pp. 433-442.

Eliott, R. 1997. Faking Nature: The Ethics of Environmental Restoration. Routledge: London.

Feierabend, SJ and JM Zelanzy. 1987. Status Report on our Nation's Wetlands. National Wildlife Federation: Washington, District of Columbia.

Frank, PW. 1964. The biodemography of an intertidal snail population. Ecology, vol. 46, pp. 831-844.

Gardner, RH; WM Kemp; VS Kennedy; JE Petersen (eds.). 2001. Scaling Relations in Experimental Ecology. Columbia University Press: New York, New York.

Giesy, J (ed.). 1980. Microcosms in Ecological Research. US Technical Information Center, US Department of Energy, Symposium Series 52 (Conf. 781101).

Gomez-Cornejo, E and DS Wethey. 1991. Microclimate and behavior: Periwinkles (*Littorina irrorata*) in southeastern salt marshes. American Zoologist, vol. 31, no. 5, p. 126A.

Grahame, J. 1973. Assimilation efficiency of *Littorina littorea* (L.) (Gastropoda:Prosobranchiata). The Journal of Animal Ecology, vol. 42, no. 2, pp. 383-389.

Graney, RL; JH Kennedy; JH Rodgers, Jr. (eds.). 1994. Aquatic Mesocosm Studies in Ecological Risk Assessment. Lewis Publishers: Boca Raton, Florida.

Gutierrez, PC. 1988. The Ecology and Behavior of the Mangrove Periwinkle, *Littorina angulifera*. Biotropica, vol. 20, no. 4, pp. 352-356.

Hamilton, PV. 1976. Predation on *Littorina irrorata* (Mollusca:Gastropoda) by *Callinectes sapidus* (Crustacea:Portunidae). Bulletin of Marine Science, vol. 26, pp. 403-409.

Hamilton, PV. 1977. Daily movements and visual location of plant stems by *Littorina irrorata* (Mollusca:Gastropoda). Marine Behaviour and Physiology, vol. 4, pp. 293-304.

Hamilton, PV. 1978a. Adaptive visually-mediated movements of *Littorina irrorata* (Mollusca:Gastropoda) when displaced from their natural habitat. Marine Behaviour and Physiology, vol. 5, pp. 255-271.

Hamilton, PV. 1978b. Intertidal distribution and long-term movements of *Littorina irrorata* (Mollusca:Gastropoda). Marine Biology, vol. 46, pp. 49-58.

Havens, KJ; LM Varnell; JG Bradshaw. 1995. An assessment of ecological conditions in a constructed tidal marsh and two natural reference tidal marshes in coastal Virginia. Ecological Engineering, vol. 4, pp. 117-141.

Henry, RP; CJ McBride; AH Williams. 1993. Responses of the marsh periwinkle, *Littoraria (littorina) irrorata* to temperature, salinity and desiccation, and the potential physiological relationship to climbing behavior. Marine Behaviour and Physiology, vol. 24, no. 1, pp. 45-54.

Hook, DD; WH McKee, Jr.; HK Smith; J Gregory; VG Burrell, Jr.; MR DeVoe; RE Sojka; S Gilbert; R Banks; LH Stolzy; C Brooks; TD Matthews; TH Shear. 1988. The Ecology and Management of Wetlands. Croom Helm: New South Wales, Australia.

Hughes, RM. 1994 Defining acceptable biological status by comparing with reference conditions. pp. 31-47. In: Biological Assessment and Criteria. WS Davis and TP Simon (eds.). Lewis Publishers: Boca Raton, Florida.

Hunter, RD and WD Russell-Hunter. 1983. Bioenergetic and community changes in intertidal aufwuchs grazed by *Littorina littorea*. Ecology, vol. 64, no. 4, pp. 761-769.

Hutchinson, GE. 1959. Homage to Santa Rosalia or Why are there so many kinds of animals? The American Naturalist, vol. XCII, no. 870, pp. 146-159.

Jordan, WR III; ME Gilpin; JD Aber, eds. 1987. Restoration Ecology: A synthetic approach to ecological research. The Cambridge University Press: Cambridge, United Kingdom.

Kangas, PC and WH Adey. 1996. Mesocosms and ecological engineering. Ecological Engineering, vol. 6, pp. 1-5.

Kangas, PC. 2004. Ecological Engineering, Principles and Practices. Lewis Publishers: Boca Raton, Florida.

Karr, JR and EW Chu. 1999. Restoring Life in Running Waters: Better Biological Monitoring. Island Press: Washington, District of Columbia.

Karr, JR and DR Dudley. 1981. Ecological perspective on water quality goals. Environmental Management, vol. 5, pp. 55-68.

Kemp, PF; SY Newell; CS Hopkinson. 1990. Importance of grazing on the salt-marsh grass *Spartina alterniflora* to nitrogen turnover in a macrofaunal consumer, *Littorina irrorata*, and to decomposition of standing-dead *Spartina*. Marine Biology, vol. 104, no. 2, pp. 311-319.

Kovacs, M, ed. 1992. Biological Indicators in Environmental Protection. Ellis Horwood Limited: England.

Kruczynski, WL; CB Subrahmanyam; SH Drake. 1978. Studies on the plant community of a north Florida salt marsh. Part II. Nutritive value and decomposition. Bulletin of Marine Science, vol. 28, pp. 707-715.

Lange, L; P Kangas; G Robbins; W Adey. 1994. A Mesocosm Model of the Everglades: An Extreme Example of Wetland Creation. pp. 95-105. In: FJ Webb, Jr., ed. Proceedings of the Twenty First Annual Conference on Wetlands Restoration and Creation. Hillsborough Community College, Tampa, Florida.

Lasserre, P. 1990. Marine microcosms: small-scale controlled ecosystems. pp. 20-60. In: enclosed Experimental Marine Ecosystems: A Review and Recommendations. CM Lalli (ed.). Springer-Verlag: New York, New York.

Leffler, JW. 1980. Microcosms in Ecological Research. JP Giesy, Jr. (ed.). US Department of Energy, Washington, DC.

Lenderking, RE. 1954. Some recent observations on the biology of *Littorina angulifera* Lam. of Biscayne and Virginia Keys, Florida. Bulletin of Marine Science of the Gulf and Caribbean, vol. 3, no. 4, pp. 273-295.

Lewis, DB and LA Eby. 2002. Spatially heterogeneous refugia and predation risk in intertidal salt marshes. Oikos, vol. 96, no. 1, pp. 119-129.

Lippson, A (ed.). 1973. The Chesapeake Bay in Maryland: An Atlas of Natural Resources. Johns Hopkins University Press: Baltimore, Maryland.

Lippson, A; M Haire; AF Holland; F Jacobs; J Jenson; RL Moran-Johnson; T Polgar; W Richkus. 1979. Environmental Atlas of the Potomac Estuary. Martin Marietta Corp., Environmental Center, Baltimore, Maryland.

Long, SP and CF Mason. 1983. Saltmarsh Ecology. Blackie: Glasgow and London.

Lubchenco, J. 1983. *Littorina* and *Fucus*: effects of herbivores, substratum heterogeneity, and plant escapes during succession. Ecology, vol. 64, no. 5, pp. 1116-1123.

Merkt, RE and AM Ellison. 1998. Geographic and habitat-specific morphological variation of *Littoraria (Littorinopsis) angulifera* (Lamarck, 1822). Malacologia, vol. 40, pp. 279-295.

Mitsch, WJ and JG Gosselink. 2000. Wetlands. John Wiley and Sons, Inc.: New York, New York.

Mitsch, WJ and SE Jorgensen. 2004. Ecological Engineering and Ecosystem Restoration. John Wiley & Sons, Inc.: Hoboken, New Jersey.

Newell, SY and F Baerlocher. 1993. Removal of fungal and total organic matter from decaying cordgrass leaves by shredder snails. Journal of Experimental Marine Biology and Ecology, vol. 171, no. 1, pp. 39-49.

Nixon, SW. 1980. Between coastal marshes and coastal waters – A review of twenty years of speculation and research on the role of salt marshes in estuarine productivity. In: Estuarine and Wetland Processes. P Hamilton and KB MacDonald (eds.). Plenum Press: New York, New York, pp. 437-525.

Odum, EP. 1984. The mesocosm. Bioscience, vol. 34, pp. 558-562.

Paul, RW. 1988. Life history and ecology of the salt marsh periwinkle, *Littorina irrorata* Say (Gastropoda, Prosobranchia). The Maryland Naturalist, vol 32, no. 3-4, pp. 63-75.

Paul, RW. 1994. The salt marsh periwinkle *Littorina irrorata*. Wetland Journal, vol. 6, no. 1, pp. 13-14.

Peck, MA; PE Fell; EA Allen; JA Gieg; CR Guthke; MD Newkirk. 1994. Evaluation of tidal marsh restoration: comparison of selected macroinvertebrate populations on a restored impounded valley marsh and an unimpounded valley marsh within the same salt marsh system in Connecticut, USA. Environmental Management, vol. 18, pp. 283-293.

Pritchard, DW. 1952. Salinity distribution and circulation in the Chesapeake Bay estuarine system. Journal of Marine Research, vol. 11, no. 2, pp. 106-123.

Ranwell, DS. 1972. Ecology of Salt Marshes and Sand Dunes. Chapman and Hall: London, Great Britain.

Reid, DG. 1986. The Littorinid Molluscs of Mangrove Forests in the Indo-Pacific Region: the Genus Littoraria. British Museum (Natural History), London, Great Britain.

Reid, DG. 1989. The comparative morphology, phylogeny and evolution of the gastropod family Littorinidae. Philosophical Transactions of the Royal Society of London. Series B, vol. 324, pp. 1-110.

Reid, DG. 1996. Systematics and Evolution of *Littorina*. The Ray Society (Series) No. 164. London, United Kingdom.

Richardson, JL. 1977. Dimensions of Ecology. The Williams and Wilkins Company: Baltimore, Maryland.

Sacco, JN; ED Seneca; TR Wentworth. 1994. Infaunal community development of artificially established salt marshes in North Carolina. Estuaries, vol. 17, pp. 489-500.

Schindler, DE; BM Johnson; NA MacKay; N Bouwes; JF Kitchell. 1994. Crab:snail size-structured interactions and salt marsh predation gradients. Oecologia, vol. 97, no. 1, pp. 49-61.

Schmitz, JP. 2000. Meso-scale community organization and response to burning in mesocosms and a field salt marsh. M.S. Thesis, University of Maryland, College Park.

Schomer, NS and RD Drew. 1982. An ecological characterization of the Lower Everglades, Florida Bay and the Florida Keys. U.S. Fish and Wildlife Service, Office of Biological Services: Washington, District of Columbia. FWS/OBS-82/58.1.

Schulze, PC, ed. 1999. Measures of Environmental Performance and Ecosystem Condition. National Academy Press: Washington, District of Columbia.

Scodari, PF. 1997. Measuring the benefits of federal wetland programs. Environmental Law Institute: Washington, District of Columbia.

Sheridan, PF. 1992. Comparative habitat utilization by estuarine macrofauna within the mangrove ecosystem of Rookery Bay, Florida. Bulletin of Marine Science, vol. 50, no. 1, pp. 21-37.

Silliman, BR and JC Zieman. 2001. Top-down control of *Spartina alterniflora* production by periwinkle grazing in a Virginia salt marsh. Ecology, vol. 82, no. 10, pp. 2830-2845.

Siry, JV. 1984. Marshes of the Ocean Shore. Texas A&M University Press: College Station, Texas.

Sommer, U. 1999. The susceptibility of benthic microalgae to periwinkle (*Littorina littorea*, Gastropoda) grazing in laboratory experiments. Aquatic Botany, vol. 63, pp. 11-21.

Stevenson, JC; KL Sundberg; JC Cornwell. 1999. Community structure and species diversity in salt marsh mesocosms. 15th International Conference - Estuarine Research Federation, New Orleans, September 25-30. (Abstract)

Stiven, AE and EJ Kuenzler. 1979. The response of two salt marsh molluscs, *Littorina irrorata* and *Geukensia demissa*, to field manipulations of density and Spartina litter. Ecological Monographs, vol. 49, no. 2, pp. 151-171.

Stroup, ED and RJ Lynn. 1963. Atlas of salinity and temperature distributions in Chesapeake Bay 1952-1961 and seasonal averages 1949-1961. Chesapeake Bay Institute, Graphical Summary Report 2, Reference Number 63-1.

Subrahmanyam, CB; WL Kruczynski; SH Drake. 1976. Studies on the animal communities in two north Florida salt marshes. Part II. Macroinvertebrate communities. Bulletin of Marine Science, vol. 26, pp. 172-195.

Tabb, DC. 1963. A summary of existing information on the fresh-water, brackish-water, and marine ecology of the Florida Everglades region in relation to fresh-water needs of Everglades National Park an Fort Jefferson National Monument.

Urbanska, KM; NR Webb; PJ Edwards, eds. 2000. Restoration Ecology and Sustainable Development. Cambridge University Press: Cambridge, England.

Vaughn, CC and FM Fisher. 1992. Dispersion of the salt-marsh periwinkle *Littoraria irrorata*: Effects of water level, size, and season. Estuaries, vol. 15, no. 2, pp. 246-250.

Wanless, HR; RW Parkinson; LP Tedesco. 1994. Sea level control on stability of Everglades wetlands. pp. 199-224. In: SM Davis and JC Ogden (eds.). Everglades: the ecosystem and its restoration. St. Lucie Press: Delray Beach, Florida.

Whittaker, RH and SA Levin, eds. 1975. Niche Theory and Application. Dowden, Hutchinson & Ross, Inc.: Stroudsburg, Pennsylvania.