Modeling Relationships between the Abundance of Fishery Species, Coastal Wetland Landscapes, and Salinity in the Barataria Basin, Louisiana

Denise J. Reed[i], Andrew Beall[i], Luis Martinez[i], Thomas J. Minello[ii], Ann M. Uzee O'Connell[i], Lawrence P. Rozas[ii], Shea Penland[i], Robert C. Cashner[i], Ann M. Commagere[i]

[i]*University of New Orleans*
[ii]*NOAA/National Marine Fisheries Service*

Report to
National Oceanic and Atmospheric Administration/
National Marine Fisheries Service and the
Louisiana Coastal Wetlands Conservation and Restoration Task Force

NOAA Project Officer – John Foret

Military Interdepartmental Purchase Request
W42HEM63554701

December 2007

THE UNIVERSITY *of* NEW ORLEANS

Acknowledgements

Many individuals contributed to the success of this project. Funding was provided by the Louisiana Coastal Wetlands Conservation and Restoration Task Force with NOAA Fisheries as the lead agency. Erik Zobrist, Gary Barone, and Cecelia Linder of NOAA assisted with the administration of the contract and John Foret of NOAA was the Project Manager providing support to all aspects of the study and the report. Charo Luke of LUMCON and Jenneke Visser of Louisiana State University also assisted with contracting.

The study team thanks Karen Foote and Jan Bowman of Louisiana Department of Wildlife and Fisheries for providing data and Sam Rogers (formally of UNO) for advice and assistance with statistical analyses. Shawn Hillen, Joy Merino, John Foret, Jennifer Doerr, Kirk Kilfoyle, John Anderson, Danny Bond, Juan Salas, Cherie O`Brien, Suraida Nanez James, Katie Turner, Elizabeth Wilson, Molly Dillender, Matt Prine, Harley Clinton, Lori Ortega, Jason Breeding, Brian Riley, Ebony Henderson, Mark London, Carolyn Martin, Bubba Taylor, Engi Guy, Joni Kernan, and Chris Fontenot are thanked for helping sort nekton samples and identifying species for Task 3. Sarah Fearnley, Laura Dancer, and Dana Bishara assisted with figures, tables and report editing.

TABLE OF CONTENTS

Glossary

Broken marsh	A station designation for LDWF data set indicating less than 86% water and greater than 130,000 m of edge in the circular 5 km^2 area analyzed around each station. Used in Task 1.
Dense marsh	A station designation for LDWF data set indicating less than 86% water and less than130,000 m of edge in the circular 5 km^2 area analyzed around each station. Used in Task 1.
Fragmented Marsh (FM)	Areas of marsh within 100 m from a Small Pond based on analysis of Myrtle Grove study area using 2 m pixels. Derived in Task 2 and used in Task 4.
Lakes	Areas of water that are ≥ 1 kilometer in diameter or 785,000 m^2. Derived in Task 2.
Large Open Water (LOW)	Areas of open water that are 400 – 1,000 m from side to side but which connect to larger bodies of water based on analysis of Myrtle Grove study area 2 m pixels. Derived in Task 2.
Large Water (LW)	The combined area of Large Ponds and Large Open Water categories. Used in Task 4.
Large Ponds (LP)	Areas of water that are 400 – 1,000 m in diameter or 125,600 – 785,000 m^2 based on analysis of Myrtle Grove study area using 2 m pixels. Derived in Task 2 used in Task 3.
Marsh type	The Marsh Classification by vegetative community: fresh/intermediate, brackish, saline.
Marsh-water classes	The Marsh Classification scheme developed in Task 2: Solid Marsh, Fragmented Marsh, Small Ponds, Medium Ponds, Medium Open Water, Large Ponds, Large Open Water, and Lakes.
Medium Open Water (MOW)	Areas of open water that are 30 – 400 m from side to side but which connect to larger bodies of water based on analysis of Myrtle Grove study area 2 m pixels. Derived in Task 2.
Medium Ponds (MP)	Areas of water that are 30 – 400 m in diameter or 706.5 – 125,600 m^2 based on analysis of Myrtle Grove study area using 2 m pixels. Derived in Task 2 used in Task 3.
Medium Water (MW)	The combined area of Medium Ponds and Medium Open Water categories. Used in Task 4.

Nekton microhabitat	Zones of marsh and open water characterized by specific patterns of nekton use. In this study they are designated by distance from the marsh-water interface and extend both into the open water and into the vegetated marsh.
Nekton-use class	The Marsh Classification scheme created in Task 4 and derived from the marsh-water classes in Task 2.
Open water	A station designation for LDWF data set indicating more than 86% water (less than 14% marsh) in the circular 5 km^2 area analyzed around each station. Used in Task 1.
Small Ponds (SP)	Areas of water less than 30 m in diameter or 706.5 m^2 in area based on analysis of Myrtle Grove study area using 2 m pixels. Derived in Task 2 and used in Tasks 3 and 4.
Solid Marsh (SM)	Areas of marsh greater than 100 m from a Small Pond based on analysis of Myrtle Grove study area using 2 m pixels. Derived in Task 2 and used in Task 4.

List of Tables

List of Figures

Executive Summary

The goal of this project is to establish relationships between densities of selected fishery species and categorical patterns of marsh-water at a landscape scale in the Barataria Basin, Louisiana. These relationships are then used to develop a tool for assessing potential effects of landscape-scale restoration projects, such as a river diversion at Myrtle Grove, on fishery resources. The project examines such relationships using existing fishery-independent data and sampling conducted across designated land-water patterns. In elucidating the associations between landscape patterns and fishery use, the project aims to provide planners with information required to evaluate the effects of projected landscape changes on fishery populations. The outcome is a quantitative tool that can be used for both project development and regulatory assessments of restoration efforts. This tool should also be applicable to restoration activities in other areas of coastal Louisiana.

The project included five separate tasks which collectively allow the assessment of landscape change on fishery resources.

Task 1. Analysis of Existing Fisheries Monitoring Data

Data collected between 1990-2000 in and adjacent to the project area by the Louisiana Department of Wildlife and Fisheries (LDWF) were used to look for trends in catches of fishery species associated with current landscape patterns, with particular emphasis on marsh-water configuration and salinity. Three classes of marsh-water configuration were identified: dense marsh, broken marsh and open water.

Analysis showed similar catch occurred between dense and open water marsh-water categories, but overall both higher numbers of animals and higher biomass occurred in broken marsh. This may be explained by the greater amount of marsh edge in the broken marsh compared to the other marsh-water categories. In trawl data, brown shrimp biomass (but not number) was positively related to salinity for samples collected during spring. Salinity was higher in broken marsh than other marsh-water categories; however, there were no strong spatial differences in salinity. In seine data, the influence of salinity on juvenile fishes was difficult to verify due to the very low gradient in salinity among stations. The numbers of bay anchovy increased and striped mullet decreased during the 11-year study period, and these changes were unrelated to effects of salinity, temperature, or secchi disk depth. Neither brown shrimp nor white shrimp catch increased over time.

The study found no significant results to indicate reductions in populations of fishery species due to salinity changes or land loss in Barataria Bay over the 11-year study period. Bay anchovy is associated with open water, and the increase in catch over time could be a response to marshes reverting towards open water.

Task 2. Development and Application of a Morphological Classification for Marsh-Water Patterns

The goal was to develop and apply a finer scale classification to the marsh areas of the study area (i.e., to scale up patterns of nekton habitat identified at the <10 m scale to the study area as a whole) than that used in Task 1. Using aerial photography from the US Geological Survey National Wetlands Research Center (USGS-NWRC) captured between February and April 2001, the study area landscape was classified into eight classes: solid marsh, fragmented marsh, small ponds, medium ponds, medium open water, large ponds, large open water and lakes. Existing maps of vegetative community types were used to classify the landscape into three marsh types: fresh/intermediate, brackish and saline. Of the approximately 46,000 ha study area, over 61% was classified as water with less than 39% as land. Fragmented marsh (that within 100 m of a small pond) occupied over 35% of the study area.

Task 3. Assessments of Nekton Density Associated with Habitat Patterns

In order to specifically relate small-scale (<10 m) patterns of habitat use by nekton to the marsh-water classification, detailed monitoring of nekton abundance/densities was used to quantitatively establish use patterns for the study area. Nekton was sampled within and adjacent to ponds of three sizes (small, medium, and large) located in three different marsh types (intermediate, brackish, and saline).

Mean salinity generally decreased across marsh types with distance up estuary. Water depth was affected by marsh type, pond size, and distance to the marsh edge. Saline marsh flooded more deeply than brackish and intermediate marshes, and brackish more deeply than intermediate marsh. The depth of ponds also increased with pond size in all three marsh types.

The results show that brown shrimp, white shrimp, blue crab, heavy marsh crab, and square back crab were more abundant in saline than intermediate marsh types. In contrast, resident estuarine species (brackish grass shrimp, sheepshead minnow, rainwater killifish, and sailfin molly) were more abundant in intermediate than brackish and saline marsh types. Three patterns of distribution between marsh and ponds were observed: (1) consistently higher densities in marsh than ponds across all three marsh types (e.g., white shrimp, diamond killifish, gulf killifish); (2) higher densities in marsh than ponds in brackish and saline marsh types, but higher densities in ponds than marsh in intermediate areas (e.g., daggerblade grass shrimp, brackish grass shrimp, sheepshead minnow); and (3) consistently higher densities in ponds than marsh (e.g., gulf menhaden, gulf pipefish). Densities of most species were higher in large and medium ponds than small ponds.

Task 4. Refinement of Relationship between Nekton Density and Marsh-Water Patterns

Regression models were developed to predict densities of three fishery species (brown shrimp, white shrimp and blue crab) based on marsh/water patterns. For each species, the models predicted densities into the vegetation at 2 m intervals up to 10 m from the water edge. Into the water, densities were predicted up to 10 m and greater than 10 m from the marsh edge. The densities of all three species had significant declines within the marsh vegetation as distance from the edge increased. However, this trend was not always apparent within the ponds. Marsh type and pond size also had significant roles but varied with species.

These models were used with GIS analyses of the marsh landscape to make population estimations of these fishery species. In fresh/intermediate marsh, animals were more abundant in water areas with less than 1% of the modeled populations directly supported by vegetation. In contrast, 30% of the blue crab population, 9% of brown shrimp, and 78% of white shrimp occurred within the vegetation of brackish marsh. Saline marshes showed a similar pattern as brackish marsh in that 34% of the blue crab population, 32% of brown shrimp, and 81% of white shrimp occurred within the vegetation.

The density of nekton for the entire landscape, including areas of marsh more than 10 m from ponds, was calculated. The marsh classification scheme was simplified into four nekton-use classes: Solid Marsh, Fragmented Marsh (including Small Ponds), Medium Water (including Medium Open Water and Medium Ponds), and Large Water (including Large Open Water and Large Ponds).

Higher densities of blue crab were present in Medium and Large Water compared to Fragmented Marsh for all marsh types. The densities of blue crab in Fragmented Marsh were highest in saline marshes and nearly ten times higher in brackish marsh than in fresh/intermediate marsh. In general, fresh/intermediate marshes have the lowest densities and saline marshes the highest densities of blue crab.

Landscape densities of brown shrimp were relatively similar across marsh types in Medium and Large Water. In Fragmented Marsh, however, densities in fresh/intermediate marsh were approximately 44% and 26% of brackish and saline marsh, respectively. Furthermore, densities in Fragmented Marsh were less than 5% of either Medium or Large Water, regardless of marsh type. Overall, densities were low because few brown shrimp were in the study area when we collected nekton samples.

Landscape densities of white shrimp were highest in saline marsh and lowest in fresh/intermediate marsh. The pattern across nekton-use classes and marsh types was markedly different from blue crab and brown shrimp. At the landscape scale, white shrimp densities in brackish marsh were highest in Medium Water. In brackish and saline marshes, Fragmented Marsh had higher densities than Large Water. In fresh/intermediate marshes, this pattern was reversed but densities were lower across all classes of this marsh type.

Implications for Restoration

The goal of many restoration projects in coastal Louisiana is to increase marsh-water ratios at the landscape scale. This would mean a shift away from broken or fragmented marsh to marsh with fewer ponds and a decrease in marsh edge. The results of our study show that for all marsh types, Fragmented Marsh and the Small Ponds embedded within this nekton-use class have lower densities of blue crab, brown shrimp, and white shrimp than Medium and Large Water areas. Medium-sized (30-400 m in diameter) open water areas and their immediately adjacent marsh support relatively high densities of fishery species. Therefore, a shift to a more intact marsh landscape would have less impact on populations of fishery species if the reduction in open water occurred at the expense of Fragmented Marsh (and Small Ponds) rather than Medium Open Water.

The findings of this study point to the need for restoration methods that are matched to specific needs of locations within the estuary if impacts to fisheries are to be avoided. For example, sediment introductions and high freshwater flows could be used directly in the fresh/intermediate zone with little potential impacts to fisheries. Freshwater diversions could be operated to vary flows annually and seasonally to both benefit the marsh and reduce the impact to fisheries. Fisheries may suffer during high flow years, but benefits (e.g., increased fishery production) would accrue during the other years, and over the long term, marsh loss could be reversed. Whether such a strategy would provide beneficial far field effects to the brackish/saline zones by stopping or reversing marsh loss, but not changing the landscape patterns (i.e., converting high edge areas to Solid Marsh), requires a more detailed examination of sediment distribution from diversions of different magnitudes and improved predictions of potential marsh response. As restoration proceeds in an adaptive management context, it must include monitoring the effects of river diversions and adjusting operations to learn more about effects on landscape, salinity, and fishery populations.

1.0 Introduction

Current projections of Louisiana coastal land loss estimate that an additional 1,329 square kilometers of marsh and swamps will convert to open water by 2050 unless the scale of restoration efforts escalates (Barras et al. 2003). In response, the State of Louisiana (the State), in partnership with the US Army Corps of Engineers (USACE), has identified critical restoration actions that must be undertaken in the near-term to protect the coast in the Louisiana Coastal Area (LCA) plan (US Army Corps of Engineers 2004). This project builds on the strategic plan laid out in 1998 by Coast 2050 (LCWCRTF & WCRA 1998). One of the lynchpin elements of current plans is the diversion of river water from the Mississippi into adjacent swamps, marshes, and coastal bays. Such projects are expensive - a structure to divert 300 m^3/s operating at Davis Pond, Louisiana and undergoing continuous modifications, cost over $100 million. One of the critical near-term features of the LCA plan is a diversion of 425 m^3/s to be constructed near Myrtle Grove, Louisiana. This project, "Delta building diversion at Myrtle Grove" (herein BA-33), builds on existing work under the Coastal Wetlands Planning Protection and Restoration Act (CWPPRA) by USACE and NOAA Fisheries to rejuvenate and sustain the deteriorating marshes of the Barataria Basin and restore some of the lost land. Although knowledge of coastal processes supports such strategies as the best approach for combating land loss, the specific impacts and benefits of the project need to be evaluated during the planning phase to meet National Environmental Policy Act (NEPA) requirements and to justify funding the project.

Such large-scale coastal restoration in Louisiana is expected to affect fishery resources, but effects are difficult to predict given the current state of our knowledge. Fishery benefits of existing smaller-scale restoration efforts are based largely on generalized relationships and inferred from changes in total wetland area (Turner 1977). CWPPRA projects are rarely monitored for fishery impacts, and even if they were, such monitoring would not be at the appropriate scale for predicting large-scale restoration effects. However, the move to implement larger and more complex restoration projects, such as the diversion at Myrtle Grove, requires knowledge of the effects of landscape-scale change in marsh patterns on fishery species in order to plan and implement these projects in an ecosystem context. Further, this information is required to provide realistic expectations about project outcomes to the public and resource agencies.

The density of juvenile fishery species appears to be a good indicator of habitat value in estuarine systems (Minello 1999, Beck et al. 2001). While relationships between nekton density, habitat value, and secondary productivity are complex, density patterns also appear to be reasonable indicators of fishery productivity (Deegan et al. 2000, Zimmerman et al. 2000). Fine-scale (1-10 m) studies of nekton density patterns have shown that juveniles of many species (including brown shrimp, white shrimp, spotted seatrout, red drum, blue crab, and striped mullet) are closely associated with shoreline areas and the marsh surface in coastal wetlands (Turner 1977, Zimmerman et al. 1984, Rozas and Reed 1993, Minello et al. 1994, Peterson and Turner 1994, Rozas and Minello 1998, Minello 1999, Rozas and Zimmerman 2000, Zimmerman et al. 2000, Castellanos ad Rozas 2001, Minello and Rozas 2002, Stunz et al. 2002, Webb and Kneib 2002, Fry et al. 2003, Minello et al. 2003). Other species such as gulf menhaden and bay anchovy are associated with nonvegetated bottom or open waters (Minello et al. 1994, Minello and Webb 1997, Minello 1999, Rozas and Zimmerman 2000, Castellanos and Rozas 2001, Minello et al. 2003), while spot and Atlantic croaker use both environments (Zimmerman and

Minello 1984, Miltner et al. 1995, Minello 1999, Minello et al. 2003). Although the factors that affect the use of these marsh related environments have not been completely defined, distance to the vegetation/water interface, salinity, marsh surface elevation, and tidal connectivity have all been identified as important regulators of habitat use and value. Thus, the spatial configurations of marshes and open water areas, their location in the landscape, the salinity regime, and a small number of other important environmental variables determine the value of nursery habitats for these species. Our understanding of landscape-scale fishery impacts, however, is hampered by the disconnect between observed fine-scale nekton-use patterns within individual marshes and the basin-scale changes in marsh characteristics associated with large restoration projects.

New modeling and GIS approaches have made progress linking fishery species and habitats at these different scales. Two empirical spatially-explicit density models have been developed for fishery species in the Galveston Bay system of Texas. The first modeling approach describes the density patterns of brown shrimp, white shrimp, and blue crab in relation to salt marsh edge and has been used to estimate population sizes in natural marsh systems as well as to simulate changes in fishery populations associated with different marsh-water patterns (Minello and Rozas, 2002; Minello et al., in press). The second approach uses regression models to describe the relationships between salinity, habitat type (marsh edge, inner marsh, shallow nonvegetated bottom (SNB), and submerged aquatic vegetation (SAV)), and density of brown shrimp, white shrimp, and pinfish (Clark et al. 1999, Clark et al. 2004).

Our project attempts to develop, apply, and validate such density models for marsh-water patterns in the Barataria estuarine system and relate catches of selected fishery species with landscape patterns. In elucidating the associations between landscape patterns and fishery use presented here, we aim to provide planners with information required to evaluate the effects of projected landscape changes on fishery populations and an essential quantitative tool for both project development and assessments of restoration efforts under the National Environmental Policy Act. This tool should also be applicable to restoration activities in other areas of coastal Louisiana that alter landscape pattern.

The project goals are:

1. to establish the relationships between densities of selected fishery species and categorical patterns of marsh-water and salinity in coastal wetland environments of the Barataria Basin, Louisiana.
2. to develop a tool for assessing potential effects of landscape scale restoration projects, such as the diversion at Myrtle Grove, on fishery resources.

These goals will be achieved by conducting four separate tasks aimed at understanding the spatial and temporal relationships among the abundance and density of fisheries species and marsh landscape characteristics.

- Task 1. Analysis of existing fishery monitoring data to examine relationships at the landscape scale.
- Task 2. Development and GIS application of a morphological classification for marsh-water patterns that encompasses variation in microhabitat patterns across the landscape.
- Task 3. Assessments of nekton density associated with microhabitat patterns.

- Task 4. Refinement and application of relationships between nekton density and marsh-water patterns.

2.0 Study Area

The rationale for diversions as viable restoration measures in Louisiana is based on the concept that inputs of freshwater and suspended sediment will renourish existing marshes and contribute to the rebuilding of marsh landscapes, the magnitude of the rebuilding being dependent on the amount of sediment diverted and its retention within the system. At the time this study was initiated, the diversion at Myrtle Grove had been selected by the CWPPRA Task Force for funding, and it represented the first diversion in the center of an estuarine basin since the development of the Coast 2050 Plan (LCWCRTF & WCRA 1998). The receiving basin for the diverted waters therefore provided an excellent area both for the study and for the application of study results to the restoration planning process. The expectation is that over time a diversion at this location will prevent the continued deterioration of the marsh landscape, i.e., that the future spatial configurations of marshes and open water areas would be altered.

Historic marsh loss in this area has resulted from subsidence, elimination of freshwater and sediment inflows from the Mississippi River, alterations to basin hydrology caused by navigation channels, and local hydrologic alterations associated with networks of location canals and spoil banks (see Reed 1995 for a more detailed discussion of these factors). While the hurricanes of 2005 causes dramatic land loss in some parts of coastal Louisiana, studies show essentially no land loss in the study area resulting from Hurricanes Katrina and Rita (Barras 2006). According to project documents (www.lacoast.gov BA-33 accessed 9 October 2007), without the diversion, an additional 5,868 ha of wetland will be lost to open water in the next 20 years within the project area, and there will be a transition to more saline habitats throughout the project area.

The study area selected for this project (Figure 1) differs slightly from the project area for BA-33 (USGS-NWRC, 2003). The study area is bordered on the west by the Barataria Waterway and the eastern boundary is the Mississippi River and Bayou Grande Cheniere (recognizing that the study only encompasses the wetlands within this area). To the south, this study extends across the saline marshes on the north side of Barataria Bay as far south as Bay Batiste and Bay Sansbois, and, in the north, the boundary includes intermediate but not fresh marshes north and east of the waterbody known as the Pen. Including areas outside the project area for BA-33 allowed us to elucidate nekton use of various configurations of marsh and open water in the saline zone that is expected to extend further north in the future.

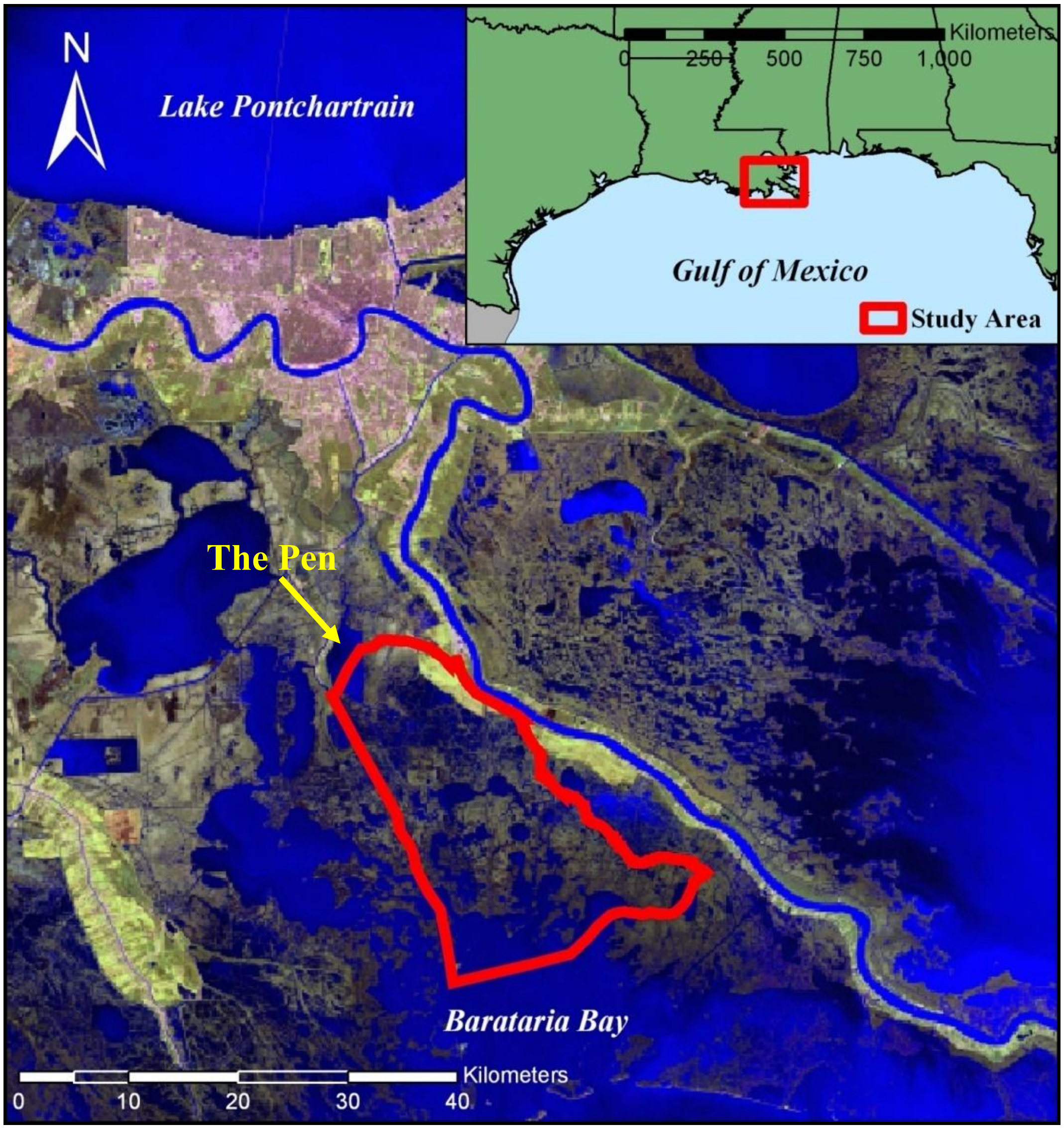


Figure 1. Study area.

3.0 Task 1. Analysis of Existing Fisheries Monitoring Data

3.1 Introduction

Data collected between 1990-2000 in the project area by the Louisiana Department of Wildlife and Fisheries (LDWF) with various gear types were used to look for trends in catches of fishery species that can be associated with current landscape patterns, with particular emphasis on marsh-water configuration and salinity. The data were examined spatially and temporally to identify significant patterns within gear types.

This task addressed two specific objectives:

1. Examine potential relationships between catch (biomass and abundance) of organisms and marsh-water patterns, and the significance of salinity on these relationships.
2. Detect overall trends in salinity throughout the Barataria Bay, temporal changes in catch, and relationship of catch to salinity, temperature, and secchi disk depth over time.

3.2 Methods and Materials

3.2.1 Source of data

We used LDWF Fisheries-Independent Monitoring (FIM) program data that were collected at established stations in Coastal Study Area (CSA) III of the Barataria Basin. These data were available from several gear types including gill nets, trammel nets, 5 m trawls, 2 m trawls, and beach seines (LDWF 2000). Only data from 2 m trawls and beach seines were used in the analyses because these gears are better quantifiers of species abundance than gill and trammel nets and these gears were used at stations with a variety of marsh-water patterns. Three of the 19 stations studied were located in our Myrtle Grove study area with the remaining located south of the study area (Figure 2).

The 2 m trawl targeted juvenile penaeid shrimps during the inshore shrimp season (Spring {March, April and May} and Summer {June, July, and August}; Tables 1 and 2) within shallow interior marsh bays and channels. This gear type was constructed of 1 cm bar mesh No. 6 nylon, the tail was constructed of 0.6 cm bar mesh No. 6 knotted nylon of 16 kg nylon, and the trawl boards were 36 cm long. The trawl was towed for ten minutes at a constant speed and in a weaving or circular track to allow the prop wash to pass on either side of the trawl (LDWF 1996). All penaeid shrimp were removed, identified to species, and counted. Up to 50 individuals of each species were measured for total length (TL) and assigned to 5 mm size categories.

The 15 m bag seine was used to sample juvenile finfish, shellfish, and other marine organisms throughout the year (Spring {March, April, and May}, Summer {June, July, and August}, Fall {September, October, and November}, and Winter {December, January, and February}; Tables 1 and 2). It was 2 m deep, with a 2 m by 2 m bag in the middle of the net, and constructed of 0.6 cm bar mesh. Soft and hard bottom areas were sampled using 30 m ropes, starting from 23-30 m offshore and pulling the seine towards shore. All organisms collected in seine samples were

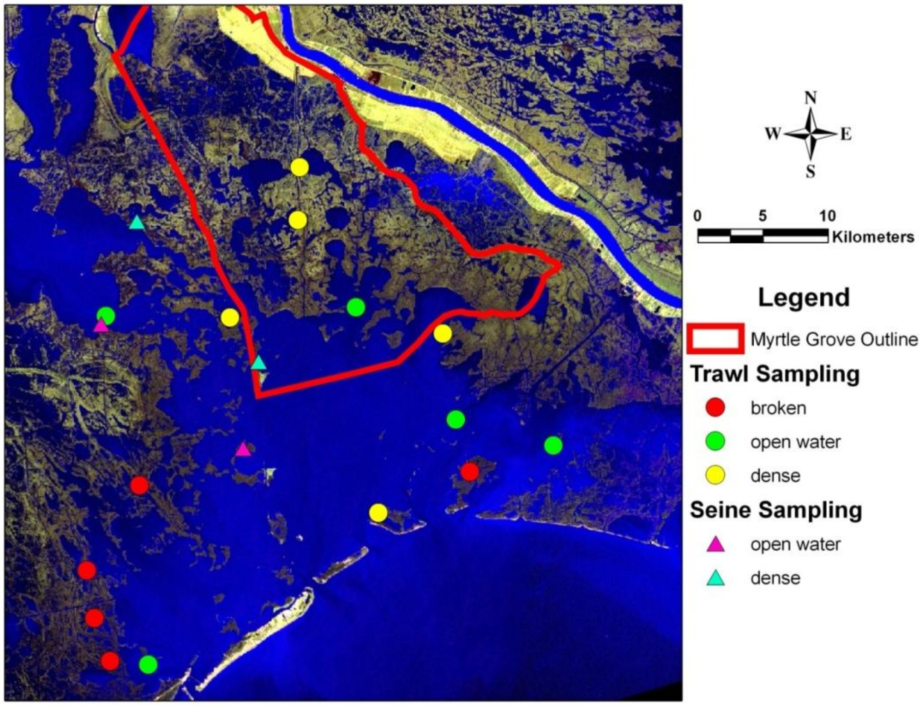


Figure 2. Location of LDWF stations used in this analysis.

identified to species and counted. Up to 30 individuals of commercially and recreationally important species were measured (TL, nearest mm).

The focus of this analysis was on abundantly collected species of commercial and recreational importance (Table 1) and only specimens ≤100 mm were analyzed for comparison with other studies of juvenile nekton. Bay anchovy was also included due to its ecological importance and abundance in samples. Although the length of anchovy was not measured in seine samples, we included all specimens in our analyses. Both numbers and biomass were used in this analysis. As in Reed et al. (2001), LDWF size data were converted to biomass using length-weight regression equations from the published literature (Appendix A; Table A1). Biomass was calculated for those species (blue crab, spotted seatrout, brown and white shrimp, and red drum) for which complete length measurement data and appropriate length-weight regression equations were available.

In the FIM program, several environmental variables (surface water temperature, surface salinity, cloud cover, wind direction and speed, and secchi disk depth) were measured at each site. Water depth at each site was determined only once at the beginning of the sampling program. In our analyses, only surface water temperature, salinity, and secchi disk depth were included.

3.2.2 Marsh-water and salinity classification

To examine whether marsh-water patterns or salinity near the LDWF stations affected catch, we developed a simple, classification scheme on a fine, spatial scale for the data. A circular 5 km^2 area was analyzed around each station; within these areas, ArcView 3.2 and Imagine were used to classify DOQQ photos (2 m accuracy; 1998 image aerial photography; Louisiana Oil Spill

Table 1. List of commercially and recreationally important species collected by LDWF in trawl and seine (1990-2000) in Barataria Basin and their abbreviations.

Gear	Species	Abbreviation
Trawl	*Farfantepenaeus aztecus* (brown shrimp)	BRS
	Litopenaeus setiferus (white shrimp)	WS
Seine	*Anchoa mitchilli* (bay anchovy)	BA
	Brevoortia patronus (gulf menhaden)	GM
	Callinectes sapidus (blue crab)	BC
	Cynoscion nebulosus (spotted seatrout)	SPS
	Farfantepenaeus aztecus (brown shrimp)	BRS
	Leiostomus xanthurus (spot)	SPO
	Litopenaeus setiferus (white shrimp)	WS
	Micropogonias undulatus (Atlantic croaker)	AC
	Mugil cephalus (striped mullet)	SM
	Sciaenops ocellatus (red drum)	RD

Coordinator's Office 1999) into water and land (i.e., marsh) coverages. The amount of marsh-water edge was measured and classified as either open water, dense, or broken. Stations having more than 86% water (less than 14% marsh) were designated as "open water." The remaining stations having <130,000 m or >130,000 m of edge were designated "dense" or "broken" marsh, respectively (Figure 2). All three marsh-water categories were represented by the trawl stations, while only "dense" and "open water" habitat categories were represented by the seine stations (Table 2). Station categories were considered fixed through time, although the image data used for categorizations were from only one year (1998) of the study period. Using classifications by the United States Geological Survey (USGS) National Wetlands Research Center (NWRC) Coastal Restoration Field Station and the Louisiana Department of Natural Resources (2000), we also classified stations as "saline" or "brackish." The three stations located inside our study area were classified as brackish (Appendix A; Table A2), with relatively little variability occurring in habitat classes for the LDWF stations located outside our study area.

Table 2. Classification of trawl and seine stations (based on Appendix A; Table A2).

LDWF Class	Salinity	No. Trawls Stations	No. Seine Stations
Open water	Brackish	2	1
	Saline	3	1
Dense marsh	Brackish	2	1
	Saline	3	1
Broken marsh	Saline	5	

3.2.3 Statistics-objective 1

Differences in biomass and abundance of species among the marsh-water categories and the significance of salinity as a covariate were examined using ANCOVA. Separate analyses were conducted for each season. For each species, only data from seasons when that species was most abundant were used in the analyses. A Type III model was used for the analyses with biomass and number treated as dependent variables, marsh-water category as a fixed factor, year as a block, and salinity as the covariate. Average species' biomass and number and parameter values for each station were used as replicates. Spring trawl samples included 5 stations in each marsh-water category, and 9 yearly averages for each station. Summer trawl samples included 3 stations in each marsh-water pattern, and 8 yearly averages for each station. Seine data included 2 stations in each marsh-water pattern and 11 yearly averages for each station in each season (Appendix A, Table A3). ANOVA was used when the assumptions of the ANCOVA were not met. Biomass and number were (ln + 1) transformed if needed to meet the homogeneity of variance assumption. In cases when this assumption was not met, either post-hoc contrasts that do not assume equal variances or the non-parametric Friedman's test was used.

3.2.4 Statistics-objective 2

<u>Changes in salinity throughout Barataria Bay</u>

To determine overall trends in Barataria Bay, we looked for changes in salinity over time throughout the salinity zones (NMFS and LDNR 2000) that were represented by the five gear types. We conducted a factor analysis of season and gear type (recoded as binary variables), and salinity within each salinity zone. Non-parametric correlations (Spearman's rho) between the resulting salinity factors (uncorrelated with season and gear) and year were tested to look for linear changes in salinity over time.

<u>Changes in environmental variables in trawl and seine samples</u>

Because our catch data were restricted to trawl and seine samples, we limited our analysis of changes in environmental variables to only the areas sampled by these gear types. We looked for linear changes in salinity, temperature, and secchi disk depth using the following method. Within both gear types, we conducted factor analyses of season, secchi disk depth, salinity, and temperature variables, saving the factor scores. We then looked for changes in secchi disk depth, salinity, and temperature (independent of each other and season) over time by testing correlations of their factor scores with year.

<u>Changes in catch over time and relationship between catch to environmental factors and time</u>

Catch (biomass and number) of species were plotted by gear type and season over time to look for temporal trends. ANOVAs with catch as the dependent variable and season as the independent variable were used to generate residual values that removed seasonal effects from catch data. Correlations between these residual values and year were used to look for changes in catch over time. We looked for linear relationships between catch and salinity, time, secchi disk depth, and temperature (unrelated to each other). Once again, we conducted factor analyses of season, secchi disk depth, salinity, and temperature variables, but this time included year in the analyses. We conducted correlations between catch (biomass and number) and factor scores representing salinity, time, secchi disk depth and temperature. These tests were used to determine if catch was individually related to salinity, secchi disk depth and temperature, even if there was no linear change in any variable during the study period. Also, we wanted to determine changes in catch over time, unrelated to the three measured environmental variables. The Dunn-Sidak correction (Sokal and Rohlf 1980) for multiple comparisons was used to test the significance of these analyses detecting changes in catch over time and relating catch to environmental factors and time. For the seine, the P-value (adjusted) = $1 - (1 - 0.05)^{1/4} = 0.0127$, because each factor was related to four variables of catch (biomass and number for each of the two shrimp species). For the trawl, P-value (adjusted) = $1 - (1 - 0.05)^{1/15} = 0.0034$, because each factor was related to fifteen variables of catch. Because we did not have information about change in marsh-water categories over the time period, changes in marsh-water categories were not considered in these analyses.

3.3 Results

3.3.1 Objective 1

Marsh-water differences and significance of salinity

<u>Trawl Data</u>
Spring
Broken marsh samples had higher numbers of brown shrimp than open water or dense marsh samples; open water and dense marsh samples contained similar numbers of brown shrimp (Appendix B; Table B1). Brown shrimp biomass was higher in broken than dense marsh. Brown shrimp biomass (but not number) was positively related to salinity. The assumption of a linear relationship between brown shrimp number and salinity was not detected in broken and dense marsh.

Summer
Brown shrimp numbers and biomass were higher in broken marsh than open water or dense marsh, and open water and dense marsh did not differ in catch (Appendix B; Table B1). White shrimp numbers were higher in broken marsh than in open water. Salinity was not related to catch of either species.

<u>Seine Data</u>
Spring
We detected no differences in catch for any species between the two marsh-water categories, although anchovy number was almost significantly higher in dense marsh (Appendix B; Table B2). Brown shrimp biomass was positively related to salinity. Although there was a relationship overall, no relationship was detected between brown shrimp biomass and salinity in either marsh-water category.

Summer
Striped mullet numbers were greater in open water than dense marsh (Appendix B; Table B2). Bay anchovy numbers were positively related to salinity. There was a relationship between bay anchovy numbers and salinity both overall and within dense marsh.

Fall
White shrimp numbers and biomass were greater in open water than dense marsh and salinity was positively related to catch (Appendix B; Table B2).

Winter
No differences in catch were detected between the two marsh-water categories, although red drum catch was almost significantly higher in open water marsh. White shrimp catch and spot number were positively related to salinity (Appendix B; Table B2).

3.3.2 Objective 2

Changes in temperature, salinity, and secchi disk depth over time

<u>All Stations</u>
Salinity increased over time in all salinity zones represented by the stations. These trends appeared to be related to the high salinity recorded during a drought that occurred 1998-2000 based on an analysis of scatter plots (Appendix B; Figure B1).

<u>Trawl Data</u>
Scores from the trawl data are listed in Appendix B, Table B3 and graphed in Figure B2. Correlations between factors scores and year indicated that salinity increased over time (again, a result of the drought). Temperature and secchi disk depth also significantly increased over time, but these were weaker trends.

<u>Seine Data</u>
Scores from the seine data are listed in Appendix B, Table B4 and graphed in Figure B3. Correlations indicated that salinity increased over time (again, a result of the drought). Although temperature appeared to decrease in Spring, overall it did not change over time.

Changes in catch over time, relationship to salinity, temperature and secchi disk depth

<u>Trawl Data</u>
Neither brown shrimp nor white shrimp catch changed over time (Appendix B; Figure B4). The year factor resulting from the factor analysis of temperature, salinity, secchi disk depth, season, and year indicated a slight association with salinity (and likewise for the salinity factor) (Appendix B; Table B5). This result indicates again the higher values for salinity that occurred during the end of the study period. Brown shrimp catch was associated with seasonal indicators of Spring, low temperatures and higher salinity but negatively related to secchi disk depth (Appendix B; Table B6). White shrimp catch was not related to any factors.

<u>Seine Data</u>
Bay anchovy number increased and striped mullet number decreased over time, and these changes were unrelated to effects of salinity, temperature, or secchi disk depth (Appendix B; Table B7). There was a slight association between salinity and year (Appendix B; Table B8), again reflecting the effects of the drought. Only white shrimp number and biomass were related to salinity (Appendix B; Table B7). Blue crab number and biomass, Atlantic croaker number, and red drum number and biomass were negatively related to temperature, an indication that these species were collected mostly in Winter. Brown shrimp catch was positively related to temperature, indicating its negative association with Winter. Spotted seatrout number and biomass were positively related to secchi disk depth.

3.4 Discussion

There were higher numbers and biomass of penaeid shrimp in the broken marsh category, but there were similarities in catch results between dense and open water marsh areas. These differences may be explained by the edge effect. While low statistical power precluded testing for trends within each marsh-water category, only catch for bay anchovy and striped mullet changed over time in seine data and this was unrelated to salinity, temperature, and secchi disk depth, indicating that trends were related to other factors. The lack of trends for other species indicates they have been resilient to any land loss and salinity changes that have occurred in mesohaline areas of Barataria Bay over the last decade. The relationships between catch and salinity for white shrimp suggest that future change in salinity could affect white shrimp populations.

3.4.1 Marsh-water differences

Brown shrimp were more abundant in broken marsh than dense or open water marsh based on LDWF trawl data. One explanation for these results is that areas classified as broken marsh contained more edge than dense or open water areas (Table 3). Marsh edge at LDWF stations increased as the proportion of open water increased up to 60% water, then declined as the proportion of open water increased beyond 70%. Broken marsh stations, with 62-70% water, had close to the maximum amount of edge, unlike Browder et al. studies (1985, 1989) which found maximum marsh edge and fishery value in marshes at 50 % water. Minello and Rozas (2002) reported that blue crab, white shrimp, and brown shrimp densities decline when shallow, nonvegetated bottom reached 70%-80% of the total area. For both gear types, dense marsh and open water areas had similar catches, and less catch than broken marsh in the trawl, perhaps because both types were >70 % water and contained little marsh edge (i.e., they are in late stages of disintegration).

Brown shrimp catch may have been higher in the broken marsh because this species depends on infaunal prey items that are abundant in edge habitats (McTigue and Zimmerman 1998). Although white shrimp are also associated with edge habitat (Minello 1999, Webb and Kneib 2002, Minello et al. 2003), this species was not strongly associated with broken marsh in our analyses. White shrimp do not rely on infaunal prey as much as brown shrimp, and LDWF data were not available for Fall when white shrimp are most abundant in the estuary.

Table 3. Amounts of edge and water in marsh-water categories by gear types.

Gear	Marsh-water	Edge (m)	%Water
Trawl	Broken	136,000-276,000	62-70
	Dense	55,000-127,000	49-85
	Open Water	8,000-37,000	90-100
Seine	Dense	63,000-70,000	70-80
	Open Water	28,000-46,000	86-90

The catches of striped mullet and white shrimp were higher in open water areas in Summer and Fall, respectively. These trends are inconsistent with findings from other studies of habitat use (Minello 1999; Webb and Kneib 2002; Minello et al. 2003). Besides both land types being at similar stages of disintegration, there are other possible explanations for these results. Red drum, blue crab, spotted seatrout, striped mullet, brown and white shrimp, bay anchovy, and spot use SAV (submerged aquatic vegetation; Sheridan 1992; Perkins-Visser et al. 1996; Eggleston et al. 1998; Rooker et al. 1998; Rozas and Minello 1998; Soto et al. 1998; Castellanos and Rozas 2001; Stunz et al. 2002; Minello et al. 2003). Oyster reefs are also utilized by some species (Zimmerman et al. 1989; Pattillo et al. 1995; Eggleston et al. 1998; Minello 1999; Harding and Mann 2001; Stunz et al. 2001; Stunz and Minello 2001). SAV and oyster reefs were not addressed in this study, and their presence could have affected habitat use. The current study (of seine and trawl data) was of a much larger scale (500 ha areas) than studies of microhabitat use. Also, seines and trawls are less efficient than the drop samplers used in microhabitat studies (Rozas and Minello 1997) and are not as reliable as more quantitative gear for determining species' abundance. Information about tidal stage, water levels, or station elevation, factors that may affect habitat use by species and addressed in microhabitat studies, was not available for seine and trawl data. Therefore, comparisons among studies are difficult. Stations available for study were not established based on the objectives of this study. Dense marsh types with less water were not well-represented by either gear types, and broken marsh was not sampled at all by seine (possibly due to difficulties in sampling with this gear). Also, there was low statistical power for the analyses due to few stations sampled (especially for the seine). Long term studies of broken marsh areas for species other than shrimp and marsh stations of varying amounts of land during seasons of importance for animals may further clarify differences among marsh types.

3.4.2 Significance of salinity

Besides high edge values, high salinities in broken marsh may have also made broken marsh more attractive to brown shrimp. Brown shrimp are thought to be associated with higher salinities than white shrimp (Gunter 1961; Gunter et al. 1964; Pattillo et al. 1995; Howe et al. 1999) and increased salinities can shift dominance from white shrimp to brown shrimp (Longley 1994; Pattillo et al. 1995). Brown shrimp biomass, but not number, was positively related to salinity in the Spring. The lack of a significant salinity effect and the failure to meet assumptions for using it as a covariate indicate that salinity may not be as important as the marsh-water effect or that it was not appropriately used as a factor. Salinity was much higher in broken marsh than other marsh-water categories (Appendix B; Table B1). We may not expect a relationship between salinity and catch in broken marsh if salinity is already higher there. However, all assumptions were met for using salinity as a covariate for brown shrimp biomass in the Spring. Therefore, the significant biomass difference among marsh-water categories indicates an edge effect. Studies of marsh stations of different marsh-water categories in combination with varying salinity ranges may further clarify the importance of these two factors. Because the trawl was not deployed in Fall, we could not determine if white shrimp, associated with edge but low salinities, was higher in the more saline broken marsh during its season of peak abundance.

Based on the analysis of seine data, brown shrimp biomass in Spring, bay anchovy number in Summer, white shrimp catch in Fall and Winter, and spot number in Winter were all positively related to salinity. The location of samples (based on distances of stations to the gulf) may have affected these results. Nekton catch may be positively related to salinity or higher in more coastal marsh types simply because higher salinity waters or coastal marsh types are closer to sources of recruitment for these species (Etherington and Eggleston 2003). ArcView's "measure" tool was used to manually measure (in segments) the distances of stations to the gulf through the closest passes. Although not statistically significant, broken and open water marsh trawl stations and open water marsh seine stations were closer to the gulf than other categories. In general for both gear types, salinity was highly correlated with distance to the gulf for each year of the study. So use of the salinity covariate as a surrogate for distance to the gulf seems reasonable. However, results of tests of linear relationships between "distance from the gulf" and catch (analogous to the linear assumption test for salinity) were not always the same as those between catch and salinity. "Distance from the gulf" was a constant factor (i.e., it did not vary because fixed stations were sampled) unlike salinity. Nonetheless, additional analyses were performed, using both "distance from the gulf" and salinity as covariates (Appendix B; Tables B9-B10. For brown shrimp biomass and bay anchovy number in the seine (Appendix B; Table B10), "distance from the gulf" had a greater effect on these species than salinity in these tests. "Distance from the gulf" (proximity to recruitment source) also was related to brown shrimp biomass (although positively in the Spring) and white shrimp catch in the trawl (Appendix B; Table B9), and brown shrimp number, blue crab catch, Atlantic croaker number, striped mullet number, and red drum number in the seine (Appendix B; Table B10). These tests also detected slightly different marsh-water and salinity effects from the first analyses that used only salinity as a covariate. When "distance from the gulf" was included as a covariate, brown shrimp biomass (in the trawl) and striped mullet number (in the seine) were not as differentiated among marsh-water types. For seine returns, there was less of a salinity effect on white shrimp catch in the Winter, and there were positive salinity effects on Atlantic croaker and negative effects on red drum number.

Significant salinity effects were detected for white shrimp and spot catch in the seine (as well as brown shrimp biomass in the trawl, as previously discussed) whether the "distance from the gulf" factor was included or not in the analysis. Gunter et al. (1964) observed that young juvenile white shrimp were most abundant at <10 ppt in Alabama and Texas, and Howe et al. (1999) did not find a positive relationship between densities and salinity. However Reid (1957) found that white shrimp densities increase with high salinity then decrease when waters freshen. Optimum values of salinity for spot are 5-36 ppt (Pattillo et al. 1995), and Rozas and Hackney (1984) observed spot within oligohaline areas in Spring. The Fall (3.6-21.1 ppt; average 11.8) and Winter (0.7-17.6 ppt; average 7.8) salinities for seine samples may be within suitable levels for these species in this part of their range.

The lack of significant relationships between catch and salinity for some species may be a reflection of where sample stations were located. Because our fixed stations located only in mesohaline areas, there were no strong spatial differences in salinity. Stations representing more of a salinity gradient may have better demonstrated the influence that salinity has on juvenile fishery species.

3.4.3 Changes over time

The main purpose of the ANCOVA and ANOVA was to detect differences in catch among marsh-water categories for each season. A secondary purpose was to determine effects of salinity. However, this was not always accomplished if salinity was not an appropriate covariate. The third objective was to look for temporal trends in catch and to determine if these trends were associated with salinity, temperature, or secchi disk depth patterns.

Salinity, temperature, and secchi disk depth changed over time in the trawl data, and salinity changed over time in the seine data. The salinity change was associated with a drought and does not indicate a permanent change.

Neither brown shrimp nor white shrimp catch increased over time in either the trawl or seine data. The relationship between salinity and brown shrimp catch (trawl) and white shrimp catch (seine) indicate that these species responded more to salinity than other species, but possibly to varying degrees.

Our analysis of trends over 11 years did not detect significant patterns that would indicate reductions in populations of fishery species due to salinity changes or land loss in the Barataria Basin. Bay anchovy, which increased, and striped mullet, which decreased, were the only species whose catch changed over time and these patterns were unrelated to salinity, temperature, or secchi disk depth trends. Bay anchovy is associated with open water, and change in catch over time could be a response to marshes reverting towards open water. Areas experiencing wetland loss may be more unstable than intact marshes. Anchovy, as an indicator of environmental stress, may be responding to this increased instability. Other studies have found temporal changes in catches of adult and/or juvenile blue crab, penaeid shrimp, spotted seatrout, gulf menhaden, red drum, Atlantic croaker, and bay anchovy (Zimmerman 1992; GBNEP 1994; Zimmerman et al. 1997; Guillory and Perret 1998; Zimmerman et al. 2000; Baltz et al. 2003). As in our study, Baltz and Chesney (1996) found few changes in the catch of common species based on an analysis of LDWF (trawl) data collected between 1972 and 1992. They also reported an increase in bay anchovy abundance, but this was in areas east and west of Barataria Bay. Baltz and Chesney (1996) hypothesize that species, in general, may be resilient to land loss because of the benefits of increased edge and submerged aquatic vegetation, high turbidity, and eutrophication.

4.0 Task 2. Development and Application of a Morphological Classification for Marsh-Water Patterns

4.1 Introduction

The recognition of patterns in marsh-water landscapes has been used in planning restoration projects for many years. Current technologies allow actual measurement of important wetland landscape attributes such as edge length and open water area in a time-effective manner. At the landscape scale, however, the detail and number of measurements required for areas >4000 ha make recognizing patterns and changes difficult. Thus, a classification of marsh-water patterns is required to characterize aspects of the study area that are important for determining fisheries use. An important development for this classification is that it can be applied quantitatively to marsh-water images of the landscape and includes specific criteria for classification application (e.g., degraded marsh will have certain marsh-water ratios with limits on the size of individual water bodies, and open lake-bay habitats will be water bodies exceeding specific size criteria). This task seeks to address the following questions:

1. What are the major categories of marsh-water patterns in the study area?
2. Are major categories of marsh-water patterns distributed similarly across salinity zones?

The marsh-water classification developed for Task 1 was designed to characterize the patterns of land and water at the km scale relative to fishery data collected in Large Open Water bodies. The focus of Task 2 was to develop and apply a finer scale classification to the marsh areas of the study area (i.e., to scale up patterns of nekton habitat identified at the <10 m scale to the study area as a whole). Quantitative classifications of marsh-water patterns are rare, even though many studies have examined changes in land-water patterns over time (e.g., Leibowitz and Hill, 1987; Evers et al., 1992; Turner, 1997; Minello and Rozas, 2002). The challenge presented by this task was to develop a consensus classification relevant to nekton use of the marsh that could be applied to the study area using GIS.

4.2 Classification Definitions

In April 2002, a group of experts was convened to discuss specific criteria that define marsh-water pattern types. Representatives from Louisiana Department of Natural Resources, US Army Corps of Engineers, Louisiana Department of Wildlife and Fisheries, and NOAA Fisheries met with the project team to discuss ways in which patterns of land and water across the Louisiana coast could be classified. The discussion focused on the way in which nekton utilize the marsh-water interface and the likely scale of gradients in nekton use of marshes away from ponds and other open water areas. As a result of the workshop, six classes were initially identified encompassing the character of the marsh and the nature of the open water bodies.

- Intact marsh (Areas of marsh that contain less than 10% water)
- Fragmented marsh with Low Density of Small Ponds[1] (Areas of marsh that contain more than 10% water and where the Small Ponds are greater than 50 m apart)

[1] Small ponds were defined as less than 30 m in diameter or 706.5 m^2 in area. These ponds were included within the two categories of Fragmented Marsh

- Fragmented marsh with High Density of Small Ponds (Areas of marsh that contain more than 10% water and where the Small Ponds are less than 50 m apart)
- Medium Ponds (Areas of water that are 30 – 400 m in diameter or 706.5 – 125,600 m^2)
- Large Ponds (Areas of water that are 400 – 1,000 m in diameter or 125,600 – 785,000 m^2)
- Lakes (Areas of water that are ≥ 1 km in diameter or 785,000 m^2)

After initial application of this classification to the study area (see Methods below) it became clear that many channelized open water bodies of the same scale as Medium and Large Ponds were being grouped with Lakes due to their hydrologic connectivity. To remedy this and allow for more explicit identification of marshes adjacent to medium and large sized water bodies, two additional classes termed 'Medium Open Water' (MOW) and 'Large Open Water' (LOW) were agreed upon by team members. Due to the variability in the distribution of Small Ponds across the landscape, it was evident that distinguishing two Fragmented Marsh categories did not provide a discriminating classification of the area. In other words, the vast majority of the Fragmented Marsh for the study area was being classified as Fragmented marsh with High Density of Small Ponds. Consequently, the team decided to use a single quantitative description of Fragmented marsh based on the views expressed in the workshop. Table 4 shows the final classification used in the analysis.

Table 4. Myrtle Grove landscape classification scheme.

Class	Definition	Abbreviation used in text
1. Solid Marsh	Areas of marsh greater than 100 m from a Small Pond.	SM
2. Fragmented Marsh	Areas of marsh within 100 m from a Small Pond	FM
3. Small Ponds	Areas of water less than 30 m in diameter or 706.5 m^2 in area	SP
4. Medium Ponds	Areas of water that are 30 – 400 m in diameter or 706.5 – 125,600 m^2	MP
5. Medium Open Water	Areas of open water that are 30 - 400 m from side to side but which connect to larger bodies of water	MOW
6. Large Ponds	Areas of water that are 400 – 1,000 m in diameter or 125,600 – 785,000 m^2	LP
7. Large Open Water	Areas of open water that are 400 – 1000 m from side to side but which connect to larger bodies of water	LOW
8. Lakes	Areas of water that are ≥ 1 km in diameter or 785,000 m^2	Lake

4.3 Methods

4.3.1 Data source

The application of the Myrtle Grove landscape classification scheme was based on aerial photography acquired under CWPPRA by the USGS Biological Resources Division, NWRC. The aerial photography was captured between February and April 2001 and scanned at 600 dpi by the USGS-NWRC. The quality of the aerial photography acquired did not meet the standards of the NWRC due to problems resulting in photos with a soft focus (USGS-NWRC, 2002). However, the data set was used as the limitations were not considered to compromise the analysis, and it was the only current data set available for use in this project. It was determined that, while not perfect, the data set could be used to develop a marsh-water classification for use in this project.

Salinity zones for the study area were determined on the basis of the vegetative community types mapped in 2001 for the study of brown marsh in Louisiana (Linscombe and Chabreck, 2001). The vegetative communities were combined into three marsh types for this study: fresh/intermediate, brackish, and saline. While vegetative communities respond to both salinity and inundation regimes, the vegetation reflects the annual pattern of salinity variation rather than the snapshot of water salinities obtained from field sampling (e.g., salinity data used in Task 1 and Task 3).

4.3.2 Analytical approach

After receipt of the scanned photography from the USGS-NWRC, the imagery was rectified using ERDAS Imagine's Orthobase. During the rectification process, the root mean square was maintained at 0.5 or less for each frame. This gives an overall positional accuracy of one meter or less. After rectification, each frame was edge matched with its neighbor to ensure there were no errors in the rectification. Once completed, the imagery was then mosaiced and clipped to the study boundary (Figure 3). Because some frames of photography had poor coloring, the mosaic was performed in an attempt to maximize the effective areas of the photography. However, as Figure 3 shows, the southern portion of the mosaic has poor coloring where land areas appear as shades of green and water as black.

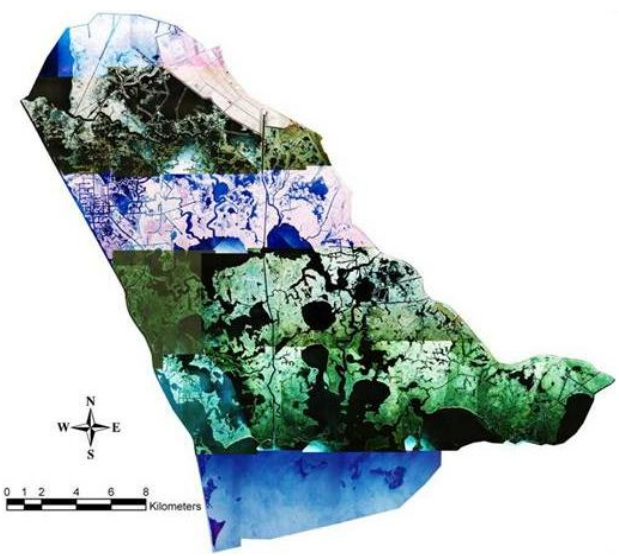


Figure 3. Mosaic of the Myrtle Grove study area from the 2001 CWPPRA photography.

After rectification, land and water were classified on the mosaic. Initially, an unsupervised ISODATA classification was applied to break the mosaic into 95 separate, unique spectral classes. Each class was then recoded as either land or water, producing a 2 class land/water image. Due to the quality of the photography, the resultant land/water image was of poor quality. To overcome this problem, the mosaic was divided into 6 separate images, each containing similar spectral characteristics. The ISODATA classification was repeated on each of the 6 images as described above. Results were better, but an additional step of manual classification and error checking was incorporated to improve the overall accuracy of the land-water classification.

To determine the pond classes, the water class was separated from the land/water classification. The water image was then passed through a clumping filter which applies a unique ID to each clump of similar 2 m x 2 m pixels. In this case, the filter applied a unique ID to each clump of water pixels, allowing the area of each water clump to be calculated. Each clump was then sorted and recoded, based on size, into one of the three classes of pond: Small, Medium, and Large Ponds. Neighborhood analysis and proximity analysis were applied to the land/water classification raster layer to allow Medium and Large Open Water to be coded based on the distance criteria (Table 5). The distance between Small Ponds was determined to distinguish Fragmented Marsh around the Small Ponds from Solid Marsh.

4.4 Results

Table 5 shows the results of the landscape classification for the Myrtle Grove Study area. Of the 46,043 ha in the study area, approximately 61% was classified as water and 39% was classified as marsh. Within the water classes, lakes occupied 13,884 ha, a vast majority of water in the study area. To some extent, the size of this category reflects the way in which the study area boundary was drawn across the northern part of Barataria Bay (Figure 1). However, it also includes some of the larger open water bodies (> 1 km across) within the marsh-dominated landscape. The Small Ponds in the study area, which were less than 30 m wide, totaled 878 ha. Medium Ponds and Large Ponds together comprised less than 1 % of the total study area. Medium Open Water and Large Open Water categories include the complex of interconnected open water and channel areas within the marsh and together comprise almost 28% of the study area.

For the Marsh Classes, Solid Marsh accounted for only 3.7% (1,723 ha) of the study area. A majority of the Solid Marsh was in the north central and the south west portions of the study area along the Barataria Bay Waterway. Most of the marsh within the study area (16,166 ha or 35.1% of the total area classified) was within 100 m of a Small Pond and was classified as Fragmented Marsh (Table 5).

The classes were also overlaid on the marsh types to show the distribution across the study area (Figure 4). Lakes were not included in the overlay since marsh types were based on vegetative communities and this categorization was not considered applicable to large, open bodies of water, i.e., Lakes. Due to the relatively small area of Medium and Large Ponds these classes were combined with the medium and Large Open Water areas to create Medium Water (MW) and Large Water (LW), respectively. Most of the Solid Marsh areas occurred in fresh/intermediate and brackish marsh types. The Fragmented Marsh area was twice as large in the brackish marsh than either fresh/intermediate or saline marshes and also made up more than half the area of the brackish marsh. The area of Small Ponds in fresh/intermediate and saline areas were approximately the same (208 ha and 254 ha), while Small Ponds in brackish marsh accounted for 417 ha. The Medium Water class dominated the fresh/intermediate marsh type of the study area. This marsh type includes the area of high land loss southwest of the Pen (Figure 1).

Table 5. The Myrtle Grove landscape classification scheme areas broken down by marsh-water classes.

Class	Hectares	Percent
Solid Marsh	1723	3.7%
Fragmented Marsh	16166	35.1%
Small Ponds	878	1.9%
Medium Ponds	349	0.8%
Medium Open Water	11990	26.0%
Large Ponds	46	0.1%
Large Open Water	1006	2.2%
Lakes	13884	30.2%
TOTAL	46043	100%

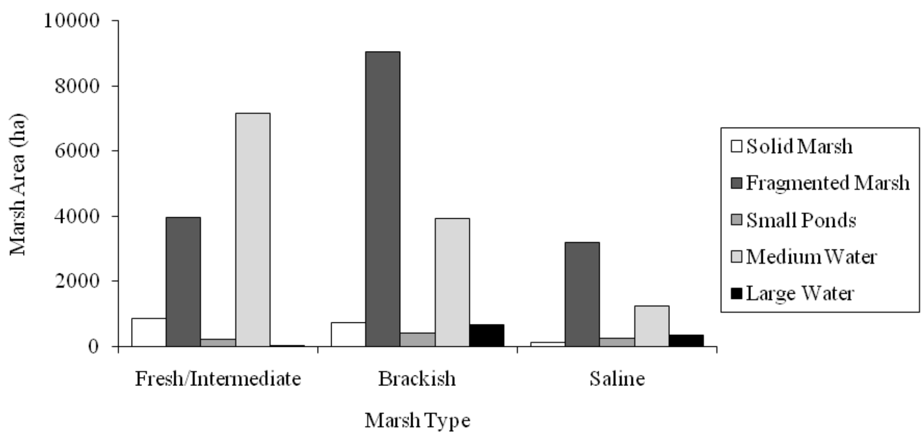


Figure 4. The distribution of marsh-water classes across marsh types in the Myrtle Grove study area. Lakes were excluded from this analysis.

4.5 Discussion

The development of the classification and application of the resulting land-water classes to the study area landscape illustrates the complexity of marsh-water patterns in coastal Louisiana. While large scale views of the coast show areas of high land loss, e.g., the area southwest of the Pen in the study area, more detailed spatial analysis shows that these apparently large areas of open water actually include fragments of marsh. In this classification, those areas were grouped into the Medium Water class since the actual open water areas were between 400 and 1000 m across. The breakup of the marsh landscape is often associated with the development of ponds. In this study, ponds were described as relatively isolated bodies of water, and the results in Table 5 show a surprisingly low total area of ponds (1273 ha or less than 3% of the study area). A much greater area of water is included in the MOW and LOW classes which include channels and connected water bodies based on their width (e.g., the maximum distance between the marshes bordering the open water). These characteristics of marsh and open water within the study area may not reflect other areas of the coast. However, the quantitative classification scheme applied here could be used in other areas to provide a more detailed description of coastal landscapes than the simple classification of land and water allows (e.g., Barras et al. 2003).

The distribution of marsh-water classes across marsh types (Figure 4) reflects the study area boundary and does not represent a complete assessment of marsh water classes across the Barataria Basin. The boundary was drawn to capture a range of marsh types within the potential influence area of a Myrtle Grove diversion. However, the differences in the character of open water areas among the marsh types indicates that land loss in coastal Louisiana does not result in the same land-water configurations in all areas. Wider application of this classification to the entire basin or to other areas of the coast will be needed to determine how representative the results are of coastal Louisiana as a whole.

5.0 Task 3. Assessments of Nekton Density Associated with Habitat Patterns

5.1 Introduction

In order to specifically relate small-scale (<10 m) patterns of habitat use by nekton to our marsh-water classification, detailed monitoring of nekton abundance/densities was necessary to quantitatively establish use patterns for the study area. Previous studies have established the general use of edge habitats by nekton, and this task focused on identifying gradients of use from marsh-water edge into both marsh and adjacent open water bodies. It sought to address the following specific questions:

1. Do nekton densities vary among major habitat types (e.g., shallow nonvegetated bottom (SNB), submerged aquatic vegetation (SAV), emergent vegetation) within the shallow estuarine areas of the Myrtle Grove project area?
2. Are nekton densities over SNB (in ponds, lakes, embayments) related to the size of the water body or to the distance from the marsh shoreline?
3. Is the relationship between animal density and distance to the marsh edge the same among marsh types?
4. Does shoreline slope or marsh surface elevation influence the distribution of nekton within marsh vegetation?
5. Are nekton densities in marsh vegetation or on SNB influenced by proximity to SAV?
6. Where distance-to-source-of-recruits (e.g., tidal passes to the gulf) are constant, does salinity affect nekton densities in SNB, marsh, and SAV habitat types?

5.2 Methods

We sampled nekton within and adjacent to ponds of three sizes (small < 40 m diameter, medium ~ 250 m-350 m diameter, and large > 750 m diameter) located in three different marsh types (intermediate, brackish, and saline). Four representative stations were chosen within each of these three marsh types. Ponds were randomly selected from aerial photography to ensure that our sample sites included the range of pond sizes that occur within intermediate, brackish, and saline marsh zones of the Barataria Estuary (Figure 5). Two different habitat types were sampled (emergent marsh and pond bottom) in each marsh type. Emergent vegetation within intermediate and brackish marshes was dominated by *Spartina patens*. *Spartina alterniflora* dominated the vegetation of saline marsh. Pond sample sites either contained SAV (all in intermediate areas) or lacked vegetation entirely (SNB in brackish and saline areas).

Our sampling design called for collecting a total of 180 samples each in Spring and Fall from randomly selected sites at various distances from the shoreline in marsh vegetation and within ponds (Table 6). Marsh samples were collected from emergent vegetation in all marsh types. Collections occurred adjacent to Small and Medium Ponds only, because most shorelines of Large Ponds were eroded, and the marsh surface was not available to nekton. Pond samples sites were selected using random numbers (0-360^o) to identify compass bearings around the pond periphery. The distance from shore was determined using a hand held laser range finder. We collected all samples at high tide during a week of tropical tides, April 26-May 2 and September 13-19, 2002. No samples were collected in waters greater than 50 m from the marsh edge. We

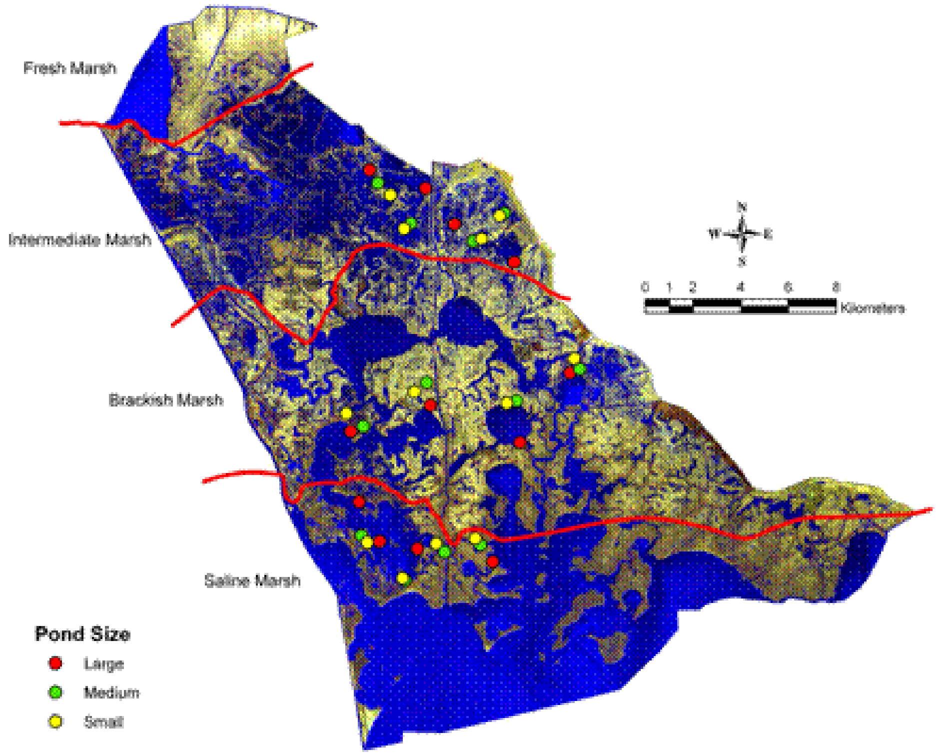


Figure 5. Nekton sample locations. Colored circles show sample locations on large (red), medium (green), and small (yellow) ponds. Red lines depict boundaries separating the four marsh types.

Table 6. Myrtle Grove sampling design showing the number of replicate samples taken twice (in April-May and September 2002) at each habitat type. Total number of samples planned for each marsh vegetation type, pond size, and distance category and the overall total also are given.

Marsh Type	**Pond Size**	**Distance From Shoreline**						**SUM**
		3 m Marsh	1 m Marsh	1 m Pond	5 m Pond	20 m Pond	50 m Pond	
Saline	Large			4	4	4	4	16
Saline	Medium	4	4	4	4	4	4	24
Saline	Small	4	4	4	4	4		20
Brackish	Large			4	4	4	4	16
Brackish	Medium	4	4	4	4	4	4	24
Brackish	Small	4	4	4	4	4		20
Intermediate	Large			4	4	4	4	16
Intermediate	Medium	4	4	4	4	4	4	24
Intermediate	Small	4	4	4	4	4		20
	Totals=	24	24	36	36	36	24	**180**

assume that density data collected at the 50 m mark are representative of the deeper regions of the lakes and ponds. Samples were collected using 1-m^2 drop samplers (Zimmerman et al. 1984) because this gear is effective in dense emergent vegetation, and the catch efficiency of this enclosure device does not appear to vary substantially with habitat characteristics typical of shallow estuarine areas (Rozas and Minello 1997). The samplers were 1.14-m-diameter cylinders that we dropped from a boom attached to shallow-draft boats. We used two boats and crews of three persons each to collect nekton samples. Each boat (unpowered) was allowed to drift until the cylinder was over a sample site or two persons positioned the cylinder over a sample site by slowly pushing from the boat's stern. When released from the boom, the cylinder rapidly entrapped organisms within a 1-m^2 sample area.

After the cylinder was dropped, we measured water temperature, dissolved oxygen, salinity, and turbidity using the methods described by Minello and Zimmerman (1992). The spatial location of each sample site was determined using a GPS unit. We determined water depth at each sample site by averaging five depth measurements taken within the sampler. We also measured the distance from the middle of the sample area to the nearest marsh-water interface. At marsh sites, plant stems were clipped at ground level, counted (dead and alive combined), and removed from the cylinder. If SAV was present at pond sites, we identified the species of plants present and estimated coverage (0-100%) by placing a grid inside the sampler and counting the number of squares containing vegetation.

After measuring the environmental variables, we captured nekton trapped in the drop sampler by using dip nets and filtering the water pumped out of the enclosure through a 1-mm-mesh net. When the sampler was completely drained, any animals remaining on the bottom were removed by hand. Samples were preserved in formalin and returned to the laboratory for processing.

In the laboratory, the samples were sorted, and animals were identified to lowest feasible taxon. We used the nomenclature of Perez-Farfante and Kensley (1997) for penaeid shrimps and identified species using the protocol described in Rozas and Minello (1998). Forty-three specimens of *Farfantepenaeus* and eight other penaeids could not be reliably identified either because of their size (total length 13-18 mm) or because they were damaged; these shrimps were assigned as brown shrimp *F. aztecus* (Ives) or pink shrimp *F. duorarum* (Burkenroad) based on the proportion of identified species in each sample. Animals that could not be reliably identified were not used in size analyses. Total length (TL) of fishes and shrimps and carapace width (CW) of crabs were measured to the nearest mm. We determined the biomass for each species by pooling individuals in a sample and measuring wet weight to the nearest 0.1g.

5.3 Statistical Analyses

We used Analysis of Variance (ANOVA) on transformed (ln+1) density data to examine density patterns of abundant fishes and decapod crustaceans. This transformation was used to remove the relationship between the mean and variance present in untransformed density data (Milliken and Johnson 1992). Separate analyses were conducted for 1) data from Small and Medium Ponds with associated marsh sites and 2) data from ponds only (all sizes). Analyses of data from Small and Medium Ponds that included marsh sites were conducted using a 3-way ANOVA model that included the main effects of marsh type (Levels=Saline, Brackish, and Intermediate), pond size (Levels=Small and Medium), and habitat type (Levels=Marsh and Pond); data collected from Large Ponds were excluded from these analyses to avoid potential problems with using an unbalanced statistical design with empty cells. Samples taken in different replicate ponds and at different distances from the marsh edge in each pond were considered replicates in these analyses. Environmental characteristics (salinity, water temperature, dissolved oxygen, water depth, turbidity, distance to shoreline, SAV coverage, and stem density) also were examined using untransformed data and this same ANOVA model.

Separate analyses of pond data were conducted to examine distributional patterns of numerically abundant taxa using a 2-way ANOVA model with main effects of marsh type (Levels= Saline, Brackish, and Intermediate) and pond size (Levels=Small, Medium, and Large). These analyses excluded all data collected from marsh sites. We examined differences in size of selected species within the study area using untransformed data and a 2-way ANOVA. This model included the main effects of marsh type (Levels=Saline, Brackish, and Intermediate) and habitat type (Levels=Marsh and Pond), and the analysis excluded the data from Large Ponds.

Comparisons of means in tests of main effects with more than two levels were based on the Games-Howell multiple range test and a 0.05 significance level (Day and Quinn 1989). All tabular and graphical data presented in this section are untransformed means. We conducted these statistical analyses using SuperANOVA (Version 5 Ed., Abacus Concepts, Inc., Berkeley, California, 1989).

5.4 Results

We identified a total of 14 crustacean species (1,515 individuals, 922g) and 32 fish species (2,532 individuals, 599g) from 180 samples collected in April-May 2002 (Appendix C; Tables C1-C2) and 13 crustacean species (3,085 individuals, 661g) and 24 fish species (6,389 individuals, 1,405g) from 180 samples taken in September 2002 (Appendix C; Tables C3-C4). Ten species comprised most (Spring=77.5%, Fall=74.7%) of the crustaceans collected in our samples. Similarly, only 13 species accounted for most (Spring=84.7%, Fall=94.0%) of the fishes we collected (Table 7).

Animal density patterns among marsh and habitat types varied by species (Appendix C; Table C5; Figures C1-C10). Several taxa, including three fishery species, were more abundant in saline and brackish marshes than in intermediate marsh (Appendix C; Figures C11-C13). In Spring, when brown shrimp were abundant, their densities were higher at saline than intermediate sites (Appendix C; Figure C12). In Fall, blue crab densities were higher at saline and brackish sites than intermediate sites (Appendix C; Figure C13), and densities of white shrimp were higher at saline than intermediate sites (Appendix C; Figure C14). In Spring, heavy marsh crabs also were more abundant in saline and brackish areas than intermediate areas, and squareback marsh crabs were more numerous in saline than brackish and intermediate areas. Naked goby were more abundant in brackish and saline than intermediate areas in Fall. In contrast to this pattern, a number of resident estuarine species were more abundant in intermediate areas than saline or brackish marsh types. In Spring, brackish grass shrimp densities were higher at intermediate than saline sites. In Fall, sheepshead minnow, rainwater killifish, and sailfin molly were more abundant in intermediate than brackish and saline areas, and bayou killifish were more numerous in intermediate than saline areas.

Table 7. List of abundant crustaceans and fishes collected using the drop sampler in the Fall and Spring seasons. Relative abundance (percentage of total crustaceans or total fishes) also is given for each species and season.

	Species	Relative Abundance	
		Spring	Fall
Crustaceans	*Palaemonetes pugio* (daggerblade grass shrimp)	25.3%	18.9%
	Rhithropanopeus harrisii (harris mud crab)	14.5%	16.4%
	Farfantepenaeus aztecus (brown shrimp)	11.9%	1.6%
	Callinectes sapidus (blue crab)	8.5%	26.2%
	Palaemonetes intermedius (brackish grass shrimp)	5.4%	3.2%
	Uca longisignalis (gulf marsh fiddler crab)	4.0%	1.7%
	Sesarma reticulatum (heavy marsh crab)	3.8%	1.5%
	Eurypanopeus depressus (flatback mud crab)	2.3%	<1.0%
	Sesarma cinereum (squareback marsh crab)	1.8%	<1.0%
	Litopenaeus setiferus (white shrimp)	<1.0%	5.2%
Fishes	*Cyprinodon variegatus* (sheepshead minnow)	26.5%	14.6%
	Lucania parva (rainwater killifish)	22.8%	37.7%
	Gobiosoma bosc (naked goby)	8.2%	15.4%
	Brevoortia patronus (gulf menhaden)	5.9%	<1.0%
	Syngnathus scovelli (gulf pipefish)	4.7%	<1.0%
	Anchoa mitchilli (bay anchovy)	4.5%	5.7%
	Menidia beryllina (inland silverside)	4.3%	<1.0%
	Myrophis punctatus (speckled worm eel)	2.9%	1.0%
	Fundulus pulvereus (bayou killifish)	2.2%	4.1%
	Fundulus grandis (gulf killifish)	1.7%	<1.0%
	Microgobius gulosus (clown goby)	1.5%	2.2%
	Poecilia latipinna (sailfin molly)	<1.0%	10.5%
	Adinia xenica (diamond killifish)	<1.0%	2.8%

5.4.1 Vegetation and nekton density

Most abundant species were closely associated with sites that contained vegetation structure, either emergent marsh vegetation or SAV in ponds. Four decapod crustaceans (white shrimp, gulf marsh fiddler crab, heavy marsh crab, and squareback marsh crab) and three killifishes (gulf, bayou, and diamond) were strongly associated with emergent marsh vegetation; their mean densities were higher in emergent marsh than over pond bottom in each marsh type where they occurred (Appendix C; Table C5). Daggerblade grass shrimp, brackish grass shrimp, rainwater killifish, sheepshead minnow, and sailfin molly were generally more abundant in marsh vegetation within saline and brackish areas, but these species were more abundant in intermediate ponds where SAV was prevalent than in intermediate marsh vegetation (Appendix C; Table C5).

Several species were generally more abundant in ponds than within marsh vegetation. Bay anchovy, clown goby, speckled worm eel, and gulf pipefish were more abundant over pond

bottom than within emergent marsh in each of the marsh types where they occurred. In addition, gulf menhaden was collected only in ponds (Appendix C; Table C5).
The effect of habitat type (marsh versus pond) significantly interacted with marsh type for 13 species (Appendix C; Table C5). Most of these species exhibited one of two common distributional patterns: 1) within saline and brackish areas, animals were more abundant in marsh vegetation than in ponds, and 2) within the intermediate area, animals were either more abundant in ponds or densities in marsh and ponds were similar. Mean densities of daggerblade grass shrimp (Appendix C; Figures C7, C11), rainwater killifish (Appendix C; Figures C5, C10), blue crab (Fall, Appendix C; Figure C13), sheepshead minnow (Fall), and sailfin molly (Fall) were higher in saline and brackish marsh than ponds, but higher in ponds than marsh within the intermediate area. Brackish grass shrimp and sheepshead minnow showed a similar pattern in Spring, but densities of these two species in saline marsh and ponds were not significantly different. Brackish grass shrimp was not collected from saline marsh and ponds. Gulf marsh fiddler crab, heavy marsh crab, gulf killifish (Spring), and diamond killifish (Fall) had higher densities in saline and intermediate marsh than ponds, but these species either were not collected, or very few individuals were taken, in intermediate habitat types; therefore, densities between marsh and ponds were similar. Squareback marsh crab showed a similar pattern in Spring, although this species was not taken in brackish and intermediate habitat types. Bayou killifish (Fall) was much more abundant in brackish and intermediate marsh than ponds; the difference in marsh and pond mean densities for this species in the saline area was less, even though it was not collected in saline ponds. In Spring, gulf pipefish densities were higher in intermediate ponds than marsh, but pipefish densities were low in saline and brackish areas and differed little between these habitat types.

Habitat type also interacted with pond size for seven species (Appendix C; Table C5). Blue crab (Spring), gulf marsh fiddler crab (Fall), and bayou killifish (Fall) were generally more abundant in marsh vegetation than ponds, but differences in marsh and pond densities for these species was greater at Small Ponds than Medium Ponds. Rainwater killifish (Spring) was more abundant in marsh than ponds at Small Ponds but was more abundant in ponds than marsh at Medium Ponds. Mean densities of heavy marsh crab (Spring) and daggerblade grass shrimp (Fall) in marsh and ponds differed more at Medium Ponds than at Small Ponds. Gulf pipefish (Spring) was generally more numerous in ponds than marsh, but differences in its abundance between these habitat types was greater at medium than Small Ponds, even though this species was not collected in marsh adjacent to Small Ponds.

5.4.2 Effects of marsh type and pond size

In our initial analyses that included samples from marsh vegetation, marsh type interacted significantly with pond size for four species (Appendix C; Table C5). The distribution of these species between Small and Medium Ponds changed with marsh type. Brown shrimp (Spring) and naked goby (Fall) were more abundant in saline and brackish Medium Ponds than Small Ponds, but their numbers were similar in intermediate medium and Small Ponds. Daggerblade grass shrimp in Fall was more abundant in brackish Medium Ponds than Small Ponds, but densities were similar in Medium and Small Ponds within saline and intermediate areas. Rainwater killifish in Spring was more abundant in saline and brackish small than Medium Ponds, but more numerous in medium than Small Ponds in the intermediate area.

Based on our analyses of only pond data (excluding data from marsh sites), both marsh type and pond size were important in explaining the distribution of most species (Appendix C; Table C6). In Fall, densities of blue crab and naked goby were higher in saline and brackish than intermediate ponds. Harris mud crabs were more numerous in saline and brackish than intermediate ponds in both Spring and Fall. Bay anchovy were more abundant in saline than intermediate ponds in Spring, but densities of this species did not differ by marsh type in Fall. In contrast, daggerblade grass shrimp, brackish grass shrimp, rainwater killifish, gulf pipefish (Spring only), sailfin molly (Fall only), and clown goby (Fall only) densities were higher in intermediate than saline and brackish ponds. Sheepshead minnow densities in Spring were higher in intermediate ponds than brackish ponds, but densities in intermediate and saline ponds were not significantly different. However, in Fall, sheepshead minnow densities were higher in intermediate than saline and brackish ponds.

Densities of most species were higher in Large and Medium Ponds than in Small Ponds (Appendix C; Table C6). Species that exhibited this pattern included brown shrimp (Spring), blue crab, gulf pipefish (Spring), speckled worm eel (Spring), and bay anchovy (Fall). Harris mud crab and naked goby (Spring) were not only more abundant in Large and Medium than Small Ponds, but also more numerous in medium than Small Ponds. Only one species, sheepshead minnow, had higher densities in Small Ponds than Large Ponds (Appendix C; Table C6).

Significant marsh type * pond size interactions were detected for six species (Appendix C; Table C6). Harris mud crab within saline and brackish areas was most abundant in Large Ponds, but within the intermediate area, densities of this species were relatively low and therefore similar among pond sizes. Sheepshead minnow in Spring was most numerous in Small Ponds within saline and brackish areas, but abundant in both Small and Medium Ponds within the intermediate area. In Fall, this species was most abundant in intermediate Small Ponds, but in saline and brackish areas, their densities were low and similar among pond sizes. In Spring, rainwater killifish within the saline area was most abundant in Small Ponds, but within brackish and intermediate areas, most numerous in Medium Ponds. Inland silverside (Spring) also was most abundant in Small Ponds within the saline area, but within brackish and intermediate areas, their densities were low and similar among pond sizes. In Spring, gulf pipefish within the intermediate area was most abundant in Large Ponds, but densities of this species were low and similar among pond sizes in saline and brackish areas. In Fall, marsh grass shrimp within the intermediate area was most abundant in Small Ponds, but in saline and brackish areas few individuals were collected, and mean densities were similar among pond sizes.

5.4.3 Environmental characteristics

Our analyses also detected significant differences in environmental characteristics among marsh types and between pond sizes and habitat types (Appendix C; Table C7, Figures C15-C28). As expected, mean salinity generally decreased across marsh types with distance up estuary. In Spring, mean salinities were significantly higher at saline than brackish or intermediate sites (Appendix C; Figure C27); in Fall, saline sites had significantly higher mean salinities than brackish sites, and brackish sites had higher salinities than intermediate sites (Appendix C; Figure 28). Mean turbidity levels in Spring were higher at brackish than intermediate sites (Appendix C; Figure C20), and mean dissolved oxygen concentrations in Fall were higher in intermediate than saline sites (Appendix C; Figure C24). Mean SAV cover was significantly higher in intermediate than saline or brackish ponds, and mean stem density of marsh plants was higher at brackish and intermediate than saline sites.

Several environmental variables differed with pond size (Appendix C; Table C7). Medium ponds were deeper, had higher dissolved oxygen levels, and had greater SAV coverage (Spring only) than Small Ponds.

Marsh and pond sites also differed in environmental characteristics (Appendix C; Table C7). In general, pond sample sites were deeper (Appendix C; Figures C15, C21), were located farther from the shoreline (Appendix C; Figures C16, C22), and had higher dissolved oxygen concentrations (Appendix C - Figures C18, C24) than marsh sites. In Fall, pond sites also had higher mean water temperatures than marsh sites (Appendix C; Figure C25). In Spring, mean turbidity was higher at marsh sites than in ponds.

Three environmental variables had significant marsh type * pond size interactions (Appendix C; Table C7). Although dissolved oxygen concentrations were higher in Medium than Small Ponds, differences in mean concentrations between pond sizes varied with marsh type. Mean dissolved oxygen levels differed between Small and Medium Ponds by >2ppm in the intermediate area, but by only about 1ppm in brackish and saline areas. Mean water temperature was higher in Small than Medium Ponds in the intermediate area, but similar between pond sizes in saline and brackish areas. SAV coverage within the intermediate area was higher in Medium than Small Ponds, but sample sites within saline and brackish areas did not contain SAV.

Significant marsh type * habitat type interactions were detected for dissolved oxygen concentration and water temperature (Appendix C; Table C7). Mean dissolved oxygen concentrations were considerably higher in ponds than marsh within the intermediate area, but only differed by about 1ppm in ponds and marsh within saline and brackish areas. Water temperature (Spring only) was higher in ponds than marsh within the intermediate area, but was similar between these habitat types in saline and brackish areas.

Water depth and distance to shoreline were the only environmental variables with significant pond size * habitat type interactions (Appendix C; Table C7). The relationship (in water depth and distance to shoreline) between marsh and pond was not consistent across pond sizes. In each case, the difference in means of the variable between pond and marsh sites was much greater at Medium Ponds than at Small Ponds.

5.4.4 Nekton size

The size of some of the animals we collected also varied by marsh and habitat type (Appendix C; Table C8, Figures C29-C31). Brown shrimp collected in Spring within intermediate areas were significantly larger than those taken in saline and brackish areas (Appendix C; Table C8, Figure C29). Although the mean size of white shrimp and blue crab collected in Fall were not significantly different among marsh types, mean sizes generally increased up estuary and reflected the same pattern shown by brown shrimp (Appendix C; Table C8, Figures C30-C31). White shrimp and blue crab taken from marsh sites were significantly larger than specimens collected at pond sites; the size of brown shrimp did not differ by habitat type (Appendix C;

Table C8, Figures C30-C31). A significant marsh type * habitat type interaction was detected only for white shrimp (p=0.0302). The mean size of white shrimp differed between marsh and pond sites more within the brackish than saline area, and the ANOVA model for this analysis contained an empty cell for intermediate marsh (i.e., no data).

5.4.5 Density modeling for landscape analyses on abundant fishery species

Our objectives in this analysis were to describe patterns of density for common juvenile fishery species in relation to the marsh/water edge. The marsh edge is a focal point for many species (Baltz et al. 1993, Minello and Rozas 2002, Stunz et al. 2002), and high densities along this interface are common. Landscape changes, therefore, that alter the amount of marsh edge can affect the abundance of these species. In Galveston Bay, Minello and Rozas (2002) reported that densities of these species peaked within marsh vegetation just inside the marsh/water interface (at the vegetated edge) and declined rapidly as you moved into the marsh vegetation. In a subsequent study, Minello et al. (in press) documented a similar decline in density from the vegetated marsh edge out into shallow nonvegetated open water. Regression models were developed to predict densities of nekton species based on these patterns (Figure 6). Using these models and a GIS analysis of the marsh landscape, it is possible to make population estimates for these fishery species (Minello and Rozas 2002, Rozas et al., 2005a).

Analyses of the density data from the Barataria Estuary indicated that density patterns were more complex than those reported for Galveston Bay, and they varied with species, pond size, and marsh type. Attempts to predict densities in the inner marsh and in open water of ponds based on mean densities in the vegetated marsh edge were unsuccessful and regressions of predicted versus actual densities, even when statistically significant, only explained less than 9% of the variability in nekton density. Because of these differences, we analyzed densities in the Barataria Estuary separately for patterns in marsh vegetation and in open water of ponds using Analysis of Variance (ANOVA) models that included a factor for distance from the marsh edge (DISTCAT). The distances examined included 1 m and 3 m into the marsh vegetation and 1 m, 5 m, 20 m, and 50 m out into open water or ponds. As noted earlier, samples were not collected on the vegetated marsh surface in Large Ponds, because most shorelines of these ponds were eroded, and the vegetated marsh surface often was not available to nekton. Also, we could not collect 50-m pond samples in Small Ponds, because their diameter was 30-40 m. These sampling restrictions made statistical analyses unbalanced, and provided additional rationale for analyzing vegetated marsh samples separately from pond samples. Pond bottom in intermediate marsh was covered with SAV and was nonvegetated in other marsh types. A ln+1 transformation was used in the ANOVAs to remove the relationship between the mean and variance present in untransformed data (Milliken and Johnson 1992). Comparisons of means were based on the Games-Howell multiple range test at a 0.05 significance level (Day and Quinn 1989).

<u>Blue Crab Densities in Marsh Vegetation</u>
Blue crabs were most abundant in the Fall, and our analysis of abundance patterns was based only on our Fall samples. In marsh vegetation, there was a significant main effect of distance to the marsh edge (from 1 m to 3 m) and a significant interaction between marsh type and this distance effect (Appendix C; Table C9). These results indicate that the decline in density away from the marsh edge changed in relation to marsh type. These declines were much steeper than

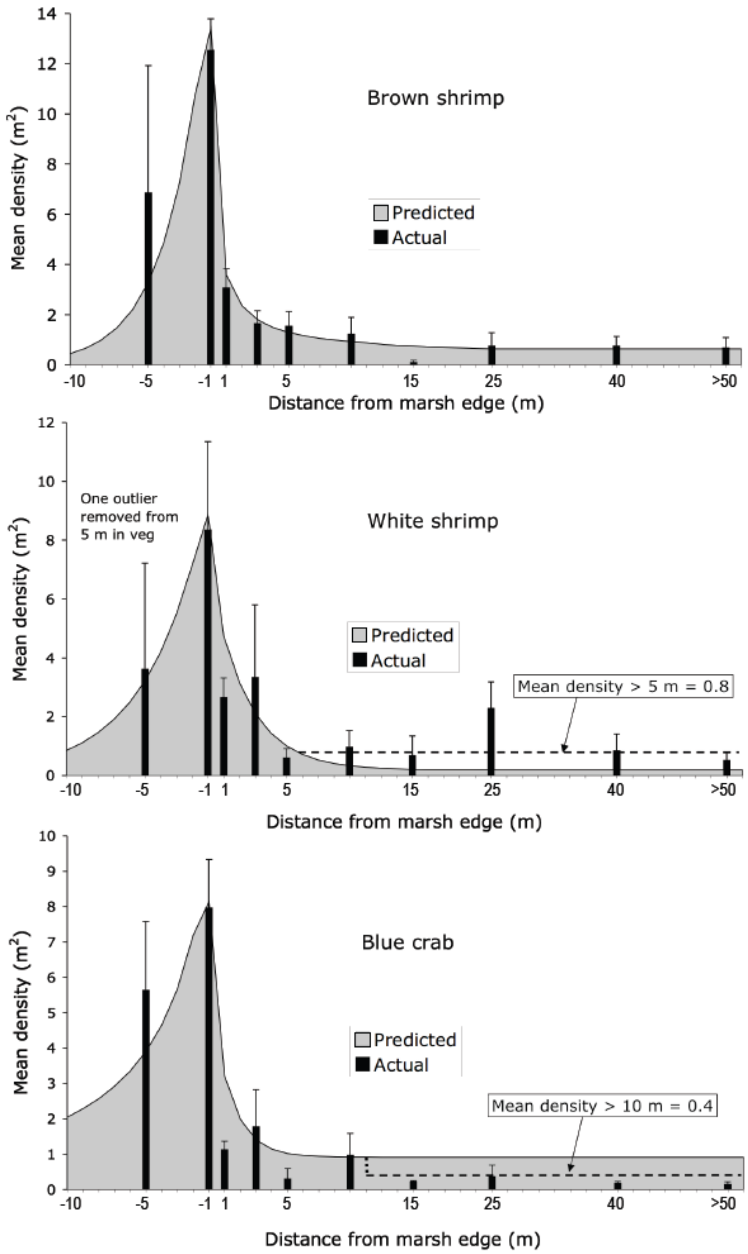


Figure 6. Modeled nekton densities (+/- SE) from Galveston Bay, Texas on vegetated (left of 0) and nonvegetated (right of 0) bottom in relation to the marsh edge. Values are means of monthly means (April-November) from high salinity marshes. The solid line and shaded area represent initial modeled (predicted) densities. The dashed lines for white shrimp and blue crabs represent mean densities in open water used in final models. Histograms are mean densities used for validation (from Minello et al., in press).

those predicted from the Galveston Model for blue crab (Minello and Rozas 2002), which predicts a decline of 37% from 1 m to 3 m into the marsh. In the Barataria Estuary, we recorded an 82.6% decline in blue crab densities from saline marsh, a 67% decline from brackish marsh, and a 100% decline from intermediate marsh. Very low blue crab densities distinguished intermediate marsh; in fact, blue crabs were only found at the 1 m location in the medium sized ponds (Appendix C; Figure C13).

The main effect of marsh type was highly significant in the ANOVA, and mean blue crab densities were 6.75 per m^2 (SE=1.733) in saline marsh, 7.31 per m^2 (SE=1.916) in brackish marsh, and 0.06 per m^2 (SE= 0.062) in intermediate marsh. A Games-Howell means comparison (0.05 significance level) on the log transformed data indicated that there was no significant difference in densities between saline and brackish marsh, but both were significantly higher than densities in intermediate marsh. When we removed the intermediate marsh data from the analysis, the interaction between marsh type and distance from the edge was not significant (P=0.22). Pond size was also significant in the analysis (Appendix C; Table C9), and overall blue crab densities were lower in vegetation surrounding Small Ponds (3.08 per m^2, SE=0.913) than in Medium Ponds (6.33 per m^2, SE=1.669). In saline and brackish ponds of both sizes, there was an average decline in density of 75% from 1 m to 3 m into marsh vegetation.

Blue Crab Densities in Ponds

Blue crabs were abundant in Fall pond samples. Densities were significantly affected by marsh type, pond size, and distance from the marsh edge (Appendix C; Table C10). In addition, the effect of distance from the marsh interacted with marsh type, and declines in density away from the marsh edge were not as apparent in intermediate marsh, most likely because of the presence of SAV throughout these marsh ponds. This conclusion was supported when we removed the intermediate marsh data from the analysis and found that both marsh type and the marsh type * distance interaction were no longer significant (Appendix C; Table C11). In saline and brackish marshes, mean densities of blue crabs were 12.88 per m^2 (SE=0.256) at 1 m from the marsh, 6.21 (SE=1.466) at 5 m, 2.08 (SE=0.521) at 20 m, and 1.99 (SE=0.544) at 50 m. A Games-Howell multiple range test (0.05 level) indicated that the 1 m and 5 m means were not significantly different and the 20 m and 50 m means were not significantly different. The effect of pond size was also significant, and mean densities were 9.12 per m^2 (SE=2.848) in Large Ponds, 6.91 (SE=1.829) in Medium Ponds, and 1.08 per m^2 (SE=0.361) in Small Ponds. The Games-Howell test indicated that densities in Small Ponds were significantly lower than those in Medium and Large Ponds (Medium and Large Pond densities were not significantly different). Blue crab densities in intermediate marsh ponds (all SAV) were relatively low and not significantly affected by pond size or distance from marsh vegetation.

Brown Shrimp Densities in Marsh Vegetation

Brown shrimp densities in marsh vegetation were similar in the Spring and Fall, and both seasons were included in our density analysis. Although brown shrimp were collected in intermediate marsh ponds, none were found in intermediate marsh vegetation, and these data were omitted from this analysis. Season was not a significant factor in the ANOVA (Appendix C; Table C12), but densities were significantly affected by marsh type, pond size, and distance to the marsh edge. The decline in density with distance to the edge varied with pond size, as indicated by a significant interaction between these factors. In medium sized ponds, the decline in density was relatively steep from 1.69 per m^2 at 1 m from the edge to 0.19 per m^2 at 3 m from the edge. This density decline was 89% and substantially steeper than the decline of 56% predicted by the Galveston Model for brown shrimp. In Small Ponds, brown shrimp densities were low and identical at both distances (0.12 per m^2). There was a significant marsh type * pond size interaction, and medium sized saline ponds had higher densities than the other three marsh type/pond size combinations. As noted above, no brown shrimp were collected in intermediate marsh vegetation (Appendix C; Figures C8, C12).

<u>Brown Shrimp Densities in Ponds</u>
Brown shrimp were significantly more abundant in ponds in the Spring, but Season did not significantly interact with other factors in the analysis (Appendix C; Table C13). Brown shrimp were relatively evenly distributed over pond bottoms, and distance from the marsh edge was not a significant factor in the ANOVA. Pond size, however, significantly affected density. Mean densities were 0.97 per m^2 (SE=0.163) in Large Ponds, 0.77 per m^2 (SE=0.149) in Medium Ponds, and 0.14 per m^2 (SE=0.053) in Small Ponds; a Games-Howell multiple range test (0.05 significance level) indicated that densities were not significantly different in Medium and Large Ponds, but these densities were significantly higher than those in Small Ponds.

<u>White Shrimp Densities in Marsh Vegetation</u>
White shrimp were only collected in the Fall. No white shrimp were collected in intermediate marsh vegetation (Appendix C; Figure C14), and this marsh type was omitted from the density pattern analysis. There was a significant effect of distance from the marsh edge in the ANOVA, and this effect did not interact with marsh type or pond size (Appendix C; Table C14). The mean density of white shrimp was 6.38 per m^2 (SE=2.797) at 1 m from the marsh edge and 0.25 per m^2 (SE=0.194) at 3 m from the edge. This decline in density of 96% was much steeper than the decline predicted by the Galveston Bay model (46%).

<u>White Shrimp Densities in Ponds</u>
Overall densities of white shrimp in marsh ponds were low, and the patchy distribution of this species caused variances to be high and the power of our statistical analyses to be low. Only distance from the marsh edge was significant in the ANOVA (Appendix C; Table C15). A Games-Howell multiple range test (0.05 significance level) could not detect any differences among the four distances, but densities were 0 at all 20 m and 50 m sampling locations. Mean white shrimp densities at 1 m from the marsh were 1.25 per m^2 (SE=0.868) and 0.28 per m^2 (SE=0.152) at 5 m from the marsh edge. Only one white shrimp was collected in all of the intermediate marsh samples. If we omitted this marsh type, mean white shrimp densities were 1.88 per m^2 (SE=1.291) at 1 m from the marsh and 0.38 per m^2 (SE=0.224) at 5 m from the marsh.

5.4.6 Water depth

An analysis of water depths in samples can be used as a surrogate for examining bottom elevation if we assume that water levels were stable throughout sampling periods. A 4-way ANOVA on the entire data set indicated that season was not a significant factor, but water depth was affected by marsh type, pond size, and distance to the marsh edge (Appendix C; Table C16). Highly significant interactions between this distance effect and pond size and marsh type indicated that bottom profiles from the marsh surface to 50 m into open water differed with these factors. These water depth profiles for different marsh types indicate a compressed range of water depths in intermediate marsh (Appendix C; Figure C32). Differences in water depth between distances also appeared lower (shallow bottom slope) in Small Ponds and increased as pond size increased (Appendix C; Figure C33).

We were particularly interested in the slope of the vegetated marsh surface and conducted an additional ANOVA that only included marsh samples. This analysis also showed significant main effects of marsh type, pond size, and distance from the marsh edge, but 2-way interactions were not significant, indicating that the marsh slope did not vary with these factors (Appendix C; Table C17). Mean water depth in samples appeared to increase with salinity and was 14.2 cm (SE=1.08) in intermediate marsh, 17.8 cm (SE=1.45) in brackish marsh, and 19.7 cm (SE=1.39) in saline marsh. Water depth was greater in marsh around Small Ponds (19.2 cm, SE=1.16) than in marsh adjacent to Medium Ponds (15.3 cm, SE=1.00).

Survey data collected at our study ponds were consistent with the results from our analysis of water depths measured at nekton sample sites (Figure 7). The relative elevation of the marsh surface and the bottom of Medium and Large Ponds generally decreased down the estuary from intermediate to saline marshes. Therefore, saline marsh flooded more deeply than brackish and intermediate marshes, and brackish marsh flooded more deeply than intermediate marsh. Similarly, saline ponds were deeper than brackish and intermediate ponds, and brackish ponds were deeper than intermediate ponds.

5.5 Discussion

This analysis of nekton in the Barataria Bay Estuary was designed to compare nekton density patterns with landscape patterns of salinity and marsh-water. Marsh type, pond size, habitat type, and distance to shoreline were all found to be important variables related to nekton density and characterizing fishery habitat. Nekton density patterns in the estuary reflected landscape patterns defined by these habitat variables.

Based on fine-scale (m^2) measurements from field sampling, the saline and brackish marsh zones of the estuary appeared to provide more habitat support for most fishery species than the intermediate marsh zone. Except for gulf menhaden, the intermediate marsh zone supported relatively low densities of fishery species within vegetation. Marsh densities of brown shrimp, white shrimp, and blue crab were much higher in saline and brackish than intermediate habitat types. Densities of brown shrimp and white shrimp in ponds were similar among the marsh types. Pond densities of blue crabs were lower in intermediate marsh, even though beds of submerged vegetation, which would seem to provide valuable habitat for these species, were extensive in intermediate ponds. Spotted seatrout was infrequently collected at saline and brackish sample sites, but this species was entirely absent from intermediate marsh samples. These patterns seem to contradict the importance placed on low-salinity areas by Thomas (1999), based on an analysis of data collected by the Louisiana Department of Wildlife and Fisheries (LDWF). Thomas (1999) reported that coastal habitats with salinities <10 psu supported the highest abundance of brown shrimp, white shrimp, spotted seatrout, and blue crab. We did not observe high densities of fishery species in low salinity (<10 psu) areas. In our study, salinities in Spring were low (<7 psu) throughout the study area, and densities of brown shrimp and blue crab also were relatively low; during Fall, when salinities were <10 psu only in the intermediate marsh zone, white shrimp, blue crab, and Spotted seatrout were more abundant in the brackish and saline marsh zones where salinities were 10 psu or higher.

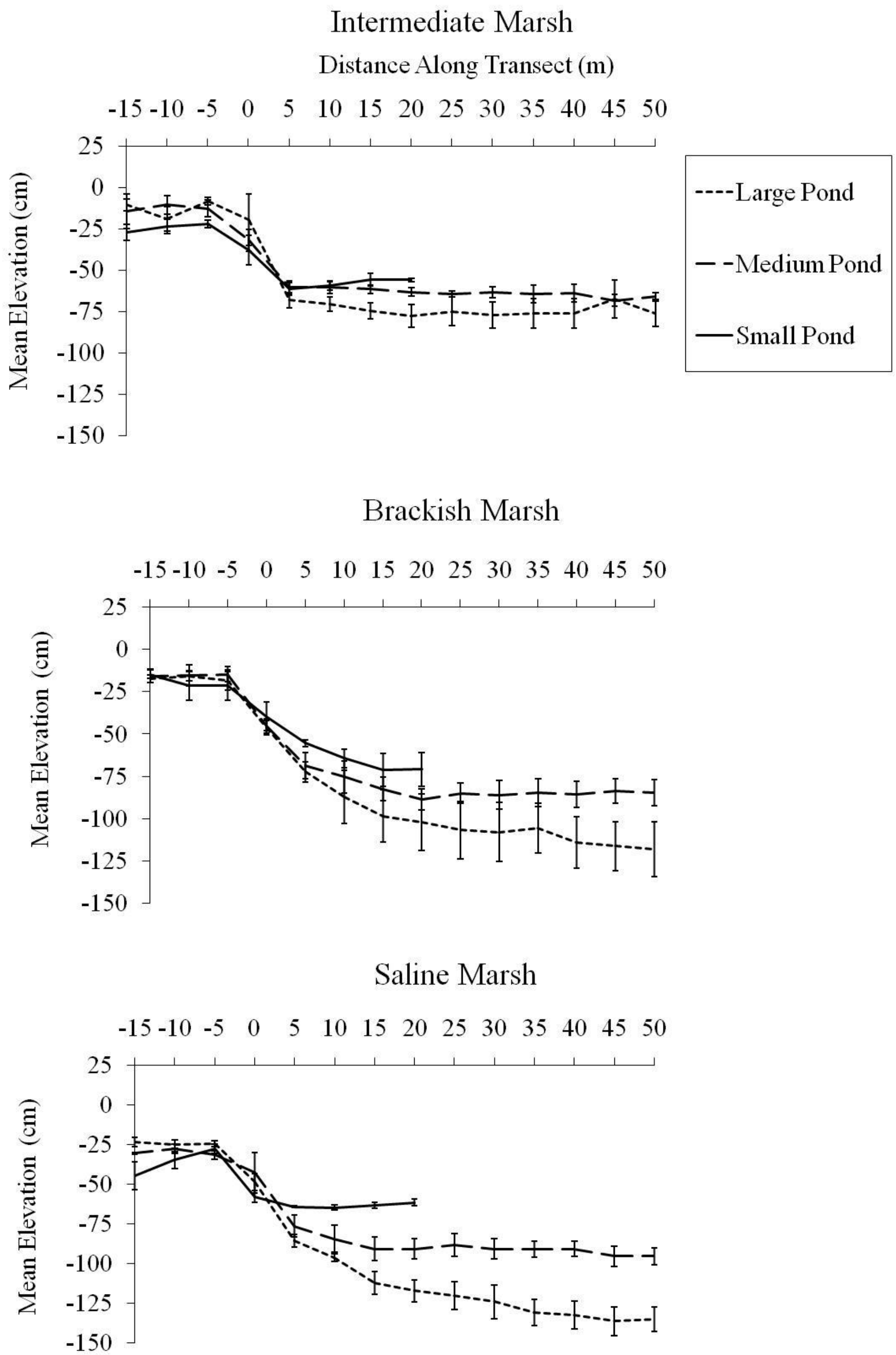


Figure 7. Marsh surface and pond bottom profiles based on a field survey of the study ponds. Mean relative elevations are shown at 5 m intervals. The marsh shoreline (interface between emergent vegetation and pond) is designated as 0. Negative numbers represent distances on the marsh surface from the shoreline. Positive numbers are distances from the shoreline into the pond.

Habitat value also varied with pond size. Habitat types associated with Small Ponds (diameter < 40 m) supported lower densities of most species, including fishery species, than habitat types associated with larger ponds. Marsh ponds do function as nursery areas for fishery species if they are well connected with adjacent waterways (Rogers et al. 1992, Rozas and Zimmerman 2000). For example, Medium and Large Ponds in our study area had a high degree of waterways, and Fall blue crab densities were relatively high in these ponds, especially within 1 m of the marsh edge. Ponds that lack this hydraulic connectivity, however, support relatively few organisms because limited tidal exchange restricts recruitment (Rozas and Minello 1999), and animals confined within isolated ponds are subjected to severe environmental conditions and competition for food (Dunson et al. 1993, Rowe and Dunson 1995, Layman et al. 2000). Most of the Small Ponds included in our study were connected to adjacent waterways by narrow, shallow channels that may have restricted tidal exchange; and these ponds had higher mean water temperatures, lower dissolved oxygen concentrations, and less SAV (in Spring) than larger ponds in our study area. Small ponds also were shallower than larger ponds, and at low tide, the nekton in these Small Ponds may have been more vulnerable to stranding or to predation by wading birds (Kneib 1982, Master 1992). Sheepshead minnow, a species that often dominates the assemblage of high marsh ponds (Rowe and Dunson 1995), was the only species in our study that seemed to thrive in Small Ponds. Other studies also have documented that small, isolated marsh ponds generally contain few fish species and assemblages dominated by cyprinodontids, fundulids, poeciliids, and atherinids (Ross and Doherty 1994, Layman et al. 2000). These characteristic pond residents are generally very tolerant of the extreme environmental conditions (e.g., low dissolved oxygen concentration, high temperature and salinity) that commonly exist in Small Ponds (Rowe and Dunson 1995).

Vegetation structure was an important habitat characteristic in our study area, and many species were closely associated with either emergent vegetation or SAV as has been documented in numerous other studies (see review by Minello et al. 2003). Several species showed a high degree of fidelity for emergent marsh vegetation. Densities of white shrimp, gulf marsh fiddler crab, heavy marsh crab, squareback marsh crab, gulf killifish, bayou killifish, and diamond killifish were higher in emergent vegetation than within ponds. Other species (e.g., daggerblade grass shrimp, brackish grass shrimp, rainwater killifish, sheepshead minnow, and sailfin molly) could be classified as facultative marsh taxa; densities of these species were higher in emergent vegetation of saline and brackish marshes than saline and brackish ponds where SAV was absent, but their densities were higher in the SAV of intermediate ponds than in adjacent marsh vegetation. In contrast to most other studies on nekton distribution in salt marshes (Minello et al. 2003), we did not detect a significant difference during Spring in brown shrimp abundance between marsh and pond habitat types. Densities of brown shrimp were relatively low in both marsh and pond habitat types, likely in response to the relatively low salinities within all three marsh zones (saline <7 psu, brackish and intermediate <5 psu) when samples were collected. These relatively low densities are similar to those documented in other studies of similar habitat types and salinities in Louisiana (Rozas and Reed 1993, Rozas and Minello 1999).

Brown shrimp, white shrimp, and blue crab that use the marsh surface are concentrated near the marsh edge (1-2 m from the shoreline), and these species have relatively low densities in the marsh interior (Minello et al. 1994, Peterson and Turner 1994, Minello 1999, Rozas and Zimmerman 2000, Minello and Rozas 2002). In our study, densities of these fishery species, however, dropped off much more steeply with distance into the marsh than was reported for Galveston Bay (Minello and Rozas 2002). Our data show that interior marsh is used less, relative to shoreline marsh, in Barataria Bay than is the case for Galveston Bay. A possible explanation for this pattern is that the slopes of Barataria Bay marshes are steeper, and therefore, interior marshes there are higher in elevation than those in Galveston Bay. High marshes generally contained much lower densities of fishery species than low marshes in Galveston Bay (Rozas and Zimmerman 2000). Alternatively, the spatial distribution of these species across the marsh surface may be related to their overall density; animals may be compelled to move into the marsh interior only after some threshold density is reached at the marsh edge, which presumably is the preferred habitat type. Densities of fishery species within the marsh edge of our study area were relatively low compared to densities in this habitat type reported from Galveston Bay, and these densities may have been too low to compel most organisms to move into the interior marsh.

The size of brown shrimp, white shrimp, and blue crab differed by both marsh type and habitat type. In general, the size of individuals increased with distance up the estuary. We also found that white shrimp and blue crab were larger in marsh than ponds, perhaps because new recruits settle first in ponds, and later move into emergent vegetation as small juveniles. A similar pattern of larger crustaceans in marsh than in ponds has been reported in South Texas (Rozas and Minello (1998) and at other locations in Louisiana (Castellanos and Rozas 2001, Rozas et al. 2005b).

6.0 Task 4. Refinement of Relationship between Nekton Density and Marsh-Water Patterns

6.1 Introduction

This task combines the findings of the GIS application of marsh-water classification (Task 2) with the findings of the field study of patterns of nekton density (Task 3). By combining these two approaches new spatially-explicit density models are developed. These models provide tools for estimating fishery population sizes in the Myrtle Grove project area and simulating changes in fisheries value within the area associated with different marsh-water patterns and salinity regimes. This task seeks to address the following specific questions:

1. Do populations of fishery species vary across categories of marsh-water pattern?
2. How do changes in marsh-water pattern affect the populations of fishery species?

6.2 Models of Nekton Use

We used ANOVA results on the densities of nekton collected to assign mean densities for microhabitats in the coastal landscape, based on distance from the marsh/water interface. In Large Ponds, we assumed no use of the marsh edge vegetation, because of the commonly found eroded shorelines and the relatively high elevation of the marsh surface. In Medium and Small Ponds, densities of nekton were generally highest just along the edge of the vegetation, dropping off rapidly with distance into the vegetation.

<u>Blue Crabs - Marsh Vegetation</u> – Blue crab densities declined with distance from the marsh edge, and we assigned different densities to 2-m wide bands of vegetation. In saline and brackish marshes, we used mean densities observed at 1 m from the marsh edge to assign a density of 15.5 per m^2 in Medium Ponds and 7.0 per m^2 in Small Ponds for the band of vegetation 0-2 m from the marsh edge (Table 8). We then used an average decline rate of 75% to calculate densities at 2-4 m, 4-6 m, and 6-8 m from the marsh edge. We assigned a density of 0 for all distances greater than 8 m from the marsh edge. In intermediate marsh, we assigned a mean density of blue crabs of 0.1 per m^2 for the 0-2 m band of vegetation and 0 for the remaining marsh vegetation.

<u>Blue Crabs - Marsh Ponds</u> – Our analysis of distribution patterns in marsh ponds allowed us to develop estimates of blue crab densities in saline and brackish marshes for the following categories: Small Ponds, 0-10 m from marsh vegetation (1.4 per m^2); Small Ponds, > 10 m from marsh vegetation (0.5 per m^2); medium and Large Ponds, 0-10 m from marsh vegetation (13.6 per m^2); and medium and Large Ponds, > 10 m from marsh vegetation (2.4 per m^2). In intermediate marsh ponds, we assigned blue crabs a density of 0.9 per m^2.

<u>Brown Shrimp - Marsh Vegetation</u> – In intermediate marsh vegetation, we assumed brown shrimp densities of 0, based on our collections in these systems. In saline and brackish marshes, densities varied with pond size and marsh type. In Small Ponds, we assigned a brown shrimp density of 0.1 per m^2 for vegetation from 0-4 m away from the edge and a density of 0 for the remaining marsh surface (Table 8). In saline marsh, we assigned a mean density for brown

Table 8. Estimated densities of blue crabs, brown shrimp, and white shrimp in different microhabitats for use in GIS analysis.

Blue crab

Marsh Type	**Pond Size**	**Distance from the Marsh/Pond Edge** – **Marsh Densities** > 8 m	6-8 m	4-6 m	2-4 m	0-2 m	**Pond Densities** 0-10 m	>10 m
Saline	Small	0	0.1	0.5	1.9	7	1.4	0.5
Saline	Medium	0	0.3	1.1	4.2	15.5	13.6	2.4
Saline	Large	0	0	0	0	0	13.6	2.4
Brackish	Small	0	0.1	0.5	1.9	7	1.4	0.5
Brackish	Medium	0	0.3	1.1	4.2	15.5	13.6	2.4
Brackish	Large	0	0	0	0	0	13.6	2.4
Intermediate	Small	0	0	0	0	0.1	0.9	0.9
Intermediate	Medium	0	0	0	0	0.1	0.9	0.9
Intermediate	Large	0	0	0	0	0	0.9	0.9

Brown shrimp

Marsh Type	**Pond Size**	**Distance from the Marsh/Pond Edge** – **Marsh Densities** > 8 m	6-8 m	4-6 m	2-4 m	0-2 m	**Pond Densities** 0-10 m	>10 m
Saline	Small	0	0	0	0.1	0.1	0.1	0.1
Saline	Medium	0	0	0	0.3	2.9	0.9	0.9
Saline	Large	0	0	0	0	0	0.9	0.9
Brackish	Small	0	0	0	0.1	0.1	0.1	0.1
Brackish	Medium	0	0	0	0.1	0.5	0.9	0.9
Brackish	Large	0	0	0	0	0	0.9	0.9
Intermediate	Small	0	0	0	0	0	0.1	0.1
Intermediate	Medium	0	0	0	0	0	0.9	0.9
Intermediate	Large	0	0	0	0	0	0.9	0.9

White shrimp

Marsh Type	**Pond Size**	**Distance from the Marsh/Pond Edge** – **Marsh Densities** > 8 m	6-8 m	4-6 m	2-4 m	0-2 m	**Pond Densities** 0-10 m	>10 m
Saline	Small	0	0	0	0.3	6.4	0.8	0
Saline	Medium	0	0	0	0.3	6.4	0.8	0
Saline	Large	0	0	0	0	0	0.8	0
Brackish	Small	0	0	0	0.3	6.4	0.8	0
Brackish	Medium	0	0	0	0.3	6.4	0.8	0
Brackish	Large	0	0	0	0	0	0.8	0
Intermediate	Small	0	0	0	0	0	0.8	0
Intermediate	Medium	0	0	0	0	0	0.8	0
Intermediate	Large	0	0	0	0	0	0.8	0

shrimp of 2.9 per m^2 at 0-2 m from the marsh edge and 0.3 per m^2 at 2-4 m from the marsh edge, representing an 89% decline in density with distance from the edge. We assumed densities would decline at a similar rate as you moved farther into the marsh, and assigned densities of 0 for any marsh farther from the edge than 4 m. In brackish marsh, we also used an 89% decline, but the mean density of brown shrimp in the 0-2 m band of vegetation was lower than in saline marsh. We assigned a mean density of 0.5 per m^2 at 0-2 m from the marsh edge, 0.1 per m^2 at 2-4 m from the marsh edge.

Brown Shrimp - Marsh Ponds – Our analysis of brown shrimp densities in ponds supported a relatively simple model of density patterns. Since no effect of distance from the marsh edge was apparent in the data, we assigned an overall mean density to pond bottom. In Large and Medium Ponds, this density was 0.9 per m^2. In Small Ponds, the density was 0.1 per m^2.

White Shrimp - Marsh Vegetation – We assigned densities to marsh vegetation based on mean values from our samples. In intermediate marsh vegetation, we assigned densities of 0 to all marsh vegetation. In saline and brackish marshes, we assigned a mean density for white shrimp of 6.4 per m^2 at 0-2 m from the marsh edge and 0.3 per m^2 at 2-4 m from the marsh edge, representing the 96% decline in density with distance from the edge observed in our samples. We assumed densities would decline at a similar rate as you moved farther into the marsh, and assigned densities of 0 for any marsh farther from the edge.

White Shrimp - Marsh Ponds - No white shrimp were collected in ponds at distances greater than 5 m from the marsh vegetation, so we assigned densities of 0 in open water away from the marsh. In the zone from 0-10 m from the marsh, we used the mean of our 1 m and 5 m samples in all marsh types (0.8 per m^2) to represent white shrimp densities.

6.3 Application of Nekton Density Models to Study Area Landscape

6.3.1 Landscape scale mapping of nekton microhabitats

To apply the nekton models for each microhabitat at the landscape scale it was necessary to identify concentric bands adjacent to water bodies of various sizes. Using the land/water classification raster layer from Task 2, concentric bands were constructed adjacent to water bodies along the water/marsh edge. The bands were created at 2 meter wide intervals, extending up to 10 m into the marsh. Additionally, a 10 m wide band was extended from the water/marsh edge into the water to distinguish near-shore waters from open water. This configuration was adapted from the nekton density patterns found in microhabitats from Task 3. Models were then developed to perform neighborhood analysis and proximity analysis on the land/water classification raster layer. The resultant images from the model were used to group water bodies and associated bands into the open water classes shown in Table 4. This was performed using a binary decision tree classifier that defined a hypothesis for each class category based upon rules and confidence limits applied to each of the variables. The decision procedure involved three processes, 1) determining the available inputs (i.e., bands, marsh, and water), 2) determining the distance between water bodies, and 3) determining the overlap distance between water body bands for different water body types. The last step was important for water bodies that were closer than the 20 m, i.e., insufficient distance for the complete set of bands around both. The image data was then classified by moving down the tree and sequentially subdividing it according to the decision framework until each hypothesis was satisfied resulting in each image pixel being classified. The resulting classification subdivided the Small and Medium Ponds and open water bodies by the six band intervals and by the remaining area beyond the 0-10 m waterward band (>10 m waterward). Due to the relatively small area of Large Ponds, this category was grouped with Large Open Water and renamed Large Water (LW) as in Task 2.

Likewise, Medium Ponds and Medium Open Water were grouped and renamed Medium Water (MW). The 2 m wide bands were not applied to marsh vegetation around LW because nekton densities were negligible in those microhabitats.

6.3.2 Distribution of nekton microhabitats

Once the concentric bands representing the microhabitats were mapped, the area of marsh or open water in each marsh type and within each microhabitat was calculated. The results of this are shown in Appendix D, Table D1. Note that for MW and LW the >10 m area in the open water includes the entire area of those water bodies greater than 10 m from a marsh. Further examination of these data indicates differences occur in the distribution of microhabitats across marsh types.

For both brackish and fresh/intermediate marshes in the study area, the area of nekton microhabitats is greatest in Medium Water (MW) while in saline marshes the area in MW is only slightly greater than in Small Ponds (SP, Figure 8). Brackish marshes have greater area in SP microhabitats than either saline or fresh/intermediate marshes.

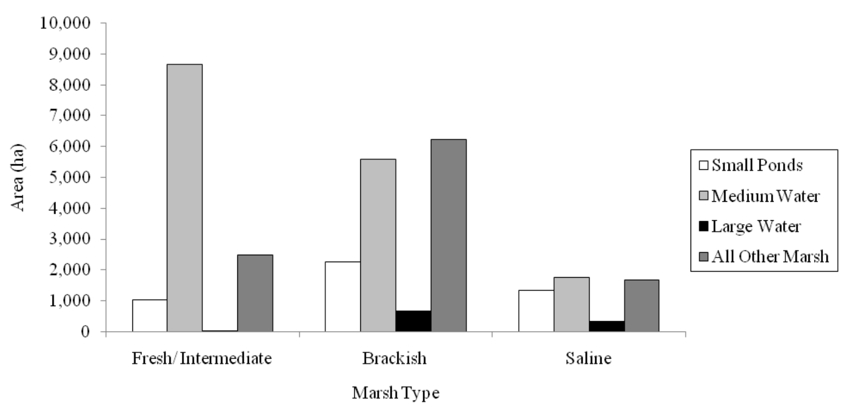


Figure 8. Total area of microhabitats associated with each marsh type. Open water habitat classes (Small Ponds, Medium Water, Large Water) include microhabitats within the open water and the adjacent marsh up to 10 m from the marsh edge. All other marsh refers to the area beyond the 2 m interval marsh bands.

Examining the open water (0-10 m, > 10 m) and vegetated (0-2 m, 2-4 m, etc.) bands separately for each microhabitat reveals differences in the proportion of each band's area (Appendix D, Table D1). The distribution of bands exclusively within open water varied considerably across marsh types. In fresh/intermediate marsh, of the open water bands, 97% was classified Medium Water and only 3% was Small Ponds. Within the brackish marsh, the distribution was 78% Medium Water, 13% Large Water, and 8% Small Ponds. Small Ponds within saline marsh had the greatest proportion of all marsh types totaling 39% of open water. As with the other marsh types, Medium Water dominated with 67% of the open water microhabitat. Unlike the open water bands, the distribution of bands exclusively in the vegetation was similar across the marsh types. The combination of Small Pond and Medium Water microhabitat bands extending 2 m into the marsh were 35%, 31%, and 33% of the total vegetative bands in fresh/intermediate, brackish, and saline, respectively (Appendix D; Table D1).

6.4 The Influence of Marsh-Water Configuration on Fishery Populations

6.4.1 Abundance of nekton within study area

The densities from the nekton model (Table 8) were applied to the area of each microhabitat within each marsh type (Appendix D; Table D1) to calculate nekton abundance across the study area (Appendix D; Table D2). Field studies were conducted only in ponds, but we assumed that densities for Medium and Large Ponds could be applied to MOW and LOW classes, respectively, and results for ponds and open water classes are presented as combined totals for MW and LW classes. A summary of these abundances is in Table 9.

Table 9. Population abundance of blue crab, brown shrimp, and white shrimp within microhabitats associated with each open water class by marsh types.

Marsh Type	Open Water Class		Area (ha)	Nekton Abundance		
				Blue crab	Brown shrimp	White shrimp
Fresh/Intermediate	Small Ponds		1,031.6	2,093,505	207,876	1,662,819
Fresh/Intermediate	Medium Water		8,657.9	65,001,213	64,410,930	17,746,896
Fresh/Intermediate	Large Water		35.5	319,259	319,259	65,315
		Total	9,725.0	67,413,977	64,938,064	19,475,030
Brackish	Small Ponds		2,274.1	50,393,068	1,281,072	37,211,662
Brackish	Medium Water		5,585.3	404,363,696	38,562,347	51,176,426
Brackish	Large Water		668.4	37,645,478	6,015,305	1,543,190
		Total	8,527.8	492,402,242	45,858,724	89,931,278
Saline	Small Ponds		1,347.1	32,690,369	811,061	24,539,414
Saline	Medium Water		1,759.6	138,819,945	17,210,198	18,203,504
Saline	Large Water		347.6	22,228,224	3,128,760	991,776
		Total	3,454.3	193,738,538	21,150,019	43,734,694

The fishery species present in fresh/intermediate marsh were abundant in the water microhabitats with less than 1% of the modeled populations directly supported by vegetation. In contrast, 30% of the blue crab population, 9% of brown shrimp, and 78% of white shrimp were found within the vegetation of brackish marsh. Saline marshes showed a similar pattern as brackish marsh in that 34% of the blue crab population, 32% of brown shrimp, and 81% of white shrimp were found within the vegetation (Appendix D; Figure D1). Comparable modeling studies have been conducted in other Louisiana wetlands by Rozas and Minello (1999, 2001) and in both natural and created saline marshes of Galveston Bay by Minello and Rozas (2002) and Rozas et al. (2005a); and these population estimates are quite variable (Appendix D; Table D3).

Blue crab densities were highest in Fall, and we used these data to model abundance patterns. If we had included Spring blue crab densities in the analysis, the overall population abundance estimates would have been substantially lower and more comparable to shrimp abundances. Our focus in this study, however, was not on estimating overall population size but on comparing the differences in nekton populations among the different marsh types and on examining the important landscape characteristics that contribute most to the populations. Within the overall study area, blue crab population estimates in brackish and saline marshes were much higher than in fresh/intermediate marsh. Within these marsh types, the greatest contribution to population estimates came from Medium Water (MW; Appendix D; Table D2); these microhabitats supported about 75% of the blue crab population, and the band of open water from the marsh edge out to 10 m appeared particularly important for this species.

White shrimp populations showed a similar trend in their distribution as blue crabs, with much of the population supported by Medium Water in brackish and saline marsh types. All of these population estimates were substantially lower than previous estimates from Louisiana and Texas (Appendix D; Table D3). In saline and brackish marshes, most white shrimp (67% of total population) occurred within the 2 m band of vegetation in Small Ponds and MW. This apparent importance of marsh edge vegetation contrasts with abundance patterns of blue crab and brown shrimp.

Brown shrimp population estimates were relatively similar for the three marsh types examined. These estimates are within the range of other estimates from low salinity marshes in Louisiana but are substantially lower than estimates for wetlands in Galveston Bay, Texas (Appendix D; Table D3).

6.4.2 Nekton distribution across the landscape

To calculate the density of nekton for the entire landscape including areas of marsh not included in the microhabitats, the marsh-water classes from Task 2 were overlaid on the nekton microhabitats. In the resulting analysis, four nekton-use classes were created: Solid Marsh, Fragmented Marsh (including Small Ponds and associated microhabitats), Medium Water (including MOW, MP, and microhabitats), and Large Water (including LOW, LP, and associated microhabitats). Note that these differ slightly from the classes derived in Task 2 in that they include the vegetated microhabitats used by nekton that surround the open water bodies as well as the actual open water. The nekton abundances derived for the microhabitats (Appendix D, Table D2) were then applied to these broader nekton use classes to calculate the density of nekton for the area within each class. This analysis was conducted for each marsh type. The results of this analysis are shown in Table 10. We then combined these for all of the habitat classes in a marsh type to estimate landscape population densities (Figure 9).

Table 10. Density of nekton across the Myrtle Grove landscape in each marsh classification.

	Marsh Type	**Individuals/ha**			
		Solid Marsh	Fragmented Marsh + Small Ponds	Medium Water	Large Water
Blue crab	Fresh/ Intermediate	4	721	7508	9000
Blue crab	Brackish	2	6383	72398	56325
Blue crab	Saline	1	11232	78894	63940
Brown shrimp	Fresh/ Intermediate	0	72	7440	9000
Brown shrimp	Brackish	0	162	6904	9000
Brown shrimp	Saline	0	279	9781	9000
White shrimp	Fresh/ Intermediate	3	573	2050	1841
White shrimp	Brackish	1	4713	9163	2309
White shrimp	Saline	1	8431	10345	2853

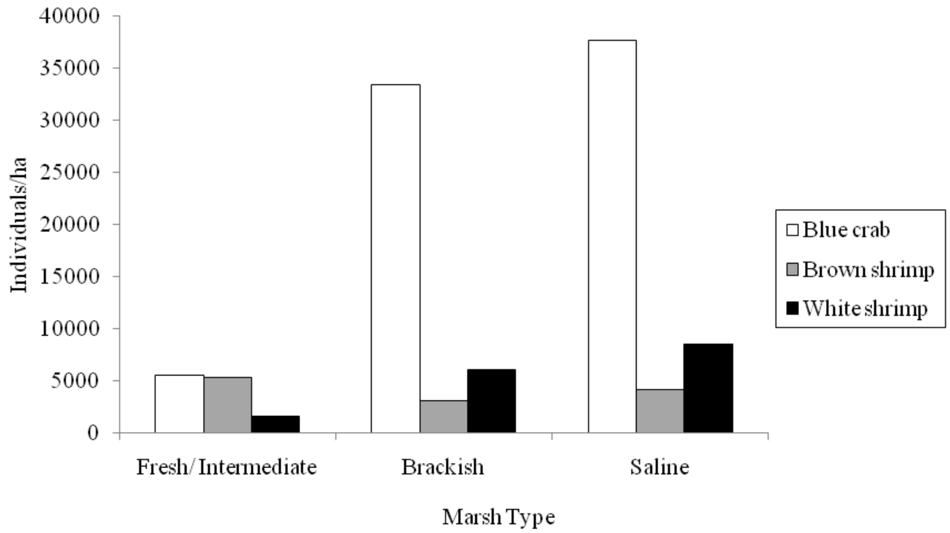


Figure 9. Population density of nekton from all microhabitats combined by marsh type in the Myrtle Grove Study area.

At the landscape scale, the highest densities of blue crabs were present in brackish and saline marshes (Figure 9). Higher densities of blue crabs were present in Medium and Large Water compared to Fragmented Marsh for all marsh types (Figure 10*a*). Densities of blue crabs in Solid Marsh are less than 5 per ha in all marsh types. The classification scheme and the nekton densities associated the microhabitats adjacent to the marsh-water interface should result in an absence of nekton in the Solid Marsh class. The values for SM in Table 10 that show total area of nekton microhabitat in SM being less than 1 hectare result from very minor registration errors in the overlay of marsh class and microhabitat classifications.

The densities of blue crabs in Fragmented Marsh (and the included Small Ponds) were almost ten times higher in brackish marsh (6,383 per ha) than in fresh/intermediate marsh (721 per ha) and were highest in saline marshes (over 11,000 per ha). For all nekton-use classes except Solid Marsh, where densities are extremely low, fresh/intermediate marshes have the lowest densities and saline marshes the highest densities of blue crabs.

As discussed in Task 3, relatively few brown shrimp were found in the study area during our sampling periods. Consequently, the low values shown in Table 8 are reflected in the relatively low landscape scale densities in Figure 10*b*. Table 8 also shows the density of brown shrimp to be the same across LW with no distinction between the 10 m of water closest to the marsh vegetation and the greater than 10 m, and to be the same for each marsh type. The densities in LW at the landscape scale are thus the same for each marsh type (Table 10). In Fragmented Marsh, however, densities in fresh/intermediate marsh were approximately 44% and 26% of brackish and saline marsh, respectively (Table 10). Overall, densities in Fragmented marsh were less than 5% of either LW or MW, regardless of marsh type (Figure 10*b*).

Landscape densities of white shrimp were highest in saline marsh and lowest in fresh/intermediate marsh (Figure 9). The patterns across nekton-use classes and marsh types for white shrimp are markedly different from blue crab and brown shrimp. At the landscape scale

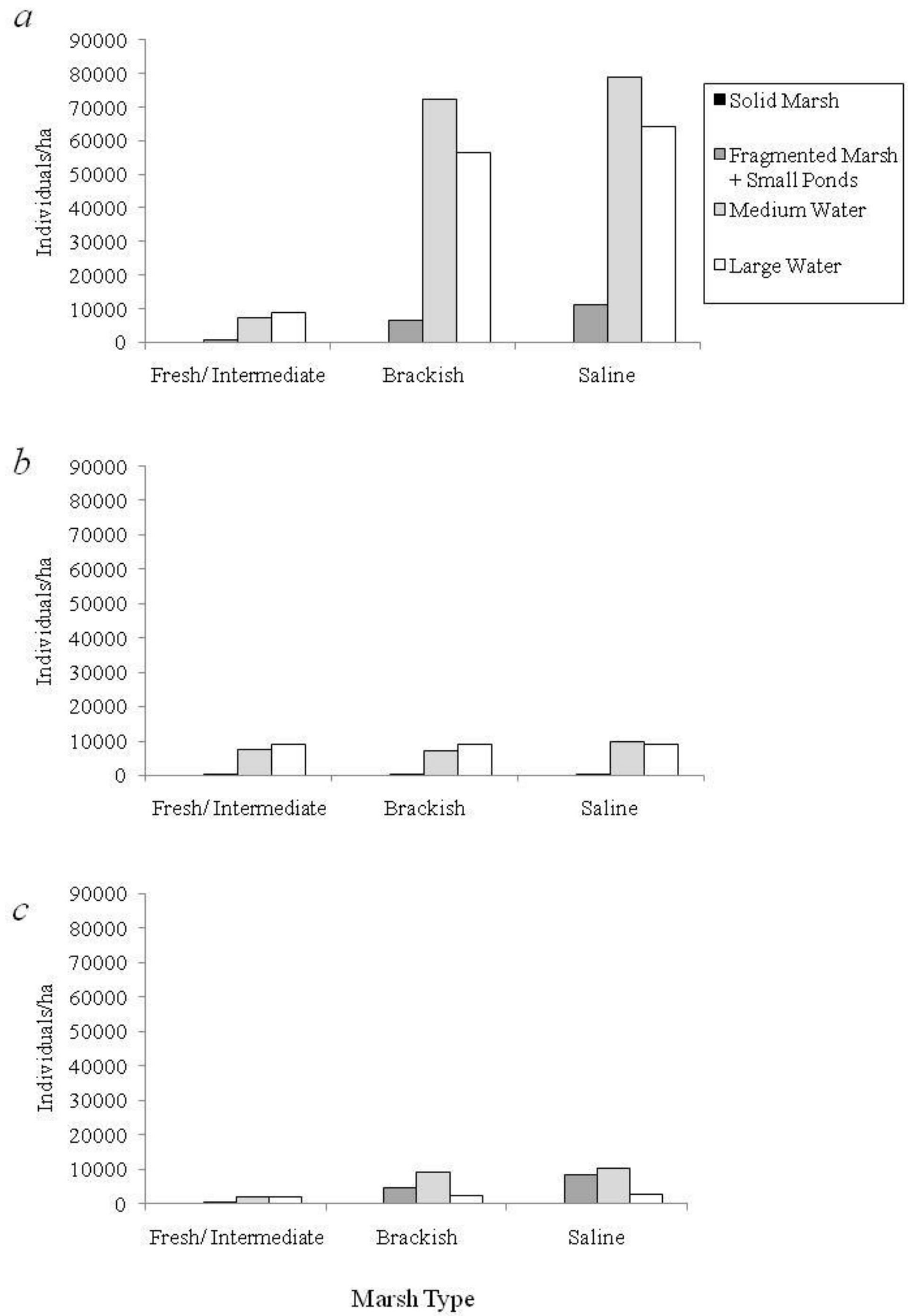


Figure 10. Landscape scale densities of (*a*) blue crab, (*b*) brown shrimp, and (*c*) white shrimp for each nekton-use class and marsh type.

densities in brackish marsh are highest in MW (Figure 10*c*). At 9,163 per ha this density is >20% that estimated for the other nekton-use classes in brackish marsh combined. MW has the highest densities in each marsh type. In brackish and saline marshes, Fragmented Marsh (including Small Ponds) has higher densities than LW. In fresh/intermediate marshes, this pattern is reversed but densities are lower across all nekton-use classes in this marsh type.

7.0 Implications for Restoration

Despite extremely high rates of land loss in the late 20th century and dramatic landscape change during the 2005 hurricane season, the coast of Louisiana still includes extensive areas of coastal marsh, shallow ponds, and bays that provide important habitat for many estuarine dependent species. This study has documented the large populations of fishery species supported by the marshes as they currently exist, and has enumerated many other ecologically important species of nekton within the study area. This study not only made such assessments of habitat use but also associated them directly with the landscape scale characteristics of the marsh-water mosaic and examined the use of existing fishery independent data for the system to assess differences in catch associated with marsh-water patterns. This section addresses the overall goal of the study – to inform restoration planners and resource managers about the potential consequences of landscape change and alterations in salinity patterns on nekton abundance.

One important aspect of this analysis is the linkage of the small scales at which nekton utilize the features of marshes and ponds and the landscape scale at which coastal restoration planning and resource management must occur. Table 8 shows the particular association of nekton with habitats close to the marsh-water interface around Small and Medium Ponds, but, as discussed above, there are some important variations in species use related to water quality characteristics and tidal connectivity (Appendix D; Table D1). Most Small and Medium Ponds in the study area are considered to be a result of ongoing land loss since the early 20th century (see Reed, 1995 and Day et al., 2000 for an assessment of factors contributing to land loss) while many of the Large Ponds and lakes are likely a result of the original deltaic land building processes where open water bodies remain between minor distributary channels. The surveys of water depths in study ponds (Figure 7) shows that, in brackish and saline marsh types smaller ponds are shallower than Medium Ponds. Some studies suggest that ponds expand and deepen over time due to wave action and increased tidal connectivity (Kemp et al., 1999).

Importantly, the goal of many restoration projects is to increase marsh-water ratios at the landscape scale. In the classification terminology used in this study, this would mean a shift away from broken (Task 1) or fragmented (Task 2) marsh to marsh with fewer ponds and little edge (termed solid or dense in this study). The implications of such a shift for the fishery species examined here are illustrated by Table 10 in section 6. In all marsh types, Fragmented Marsh with embedded Small Ponds have lower densities of blue crabs, brown shrimp, and white shrimp than Medium and Large Water areas. However, analysis in Task 4 indicates that Solid Marsh supports relatively few nekton. This seems to contrast with the findings of Task 1 where similar densities were found associated with dense and open water marshes and higher densities were found in broken marsh. This is likely due to the difference in the scale of analysis and the classification used, as these relative terms of open water and dense marsh were applied to areas where the marshes were already deteriorated.

A shift to a more Solid Marsh landscape, here defined as a decrease in the density of ponds, could lead to a decrease in the abundance of these species within a given area. Differences among open water areas shown in Figure 10 also have implications for restoration. This study has shown the value of Medium Water areas and their immediately adjacent marsh for nekton. Restoration actions which not only reduce the amount of Fragmented Marsh but which also decrease the relative proportion of open water areas between 30 and 400 m across could reduce the abundance of blue crabs, brown shrimp and white shrimp within a given area. However, most conceptual models of land loss suggest that Fragmented Marsh would ultimately deteriorate to open water if no restoration actions are taken.

Our models predict that a reduction in open water and marsh edge could reduce fishery populations. However, the effect of river diversions, such as that planned for the Myrtle Grove area, will have a direct effect on salinity distribution, possibly changing marsh type, as well as the marsh-water configuration. To the extent that diversions freshen the estuary and expand the area of fresh-intermediate marsh at the expense of saline and brackish marsh, we should expect reductions in populations of the fishery species (brown shrimp, white shrimp, blue crab) included in our population analysis. Importantly, the fresh/intermediate, brackish, and saline marsh types used in this analysis are based on vegetation types rather than the actual water salinities. Nekton abundance is driven not by the marsh vegetative community but by water salinity (and other water quality variables) and marsh-water configuration. In particular, shrimp production in Louisiana appears related to seasonal salinity and temperature patterns (Ford and St. Amant 1971; Barrett and Ralph 1977). This study used vegetative communities rather than water salinity to categorize the study area due to the availability of landscape scale rather than point data and the large interannual and seasonal fluctuations in salinity in Louisiana estuaries. While vegetative communities reflect the long-term salinity characteristics of an area, they are also influenced by inundation frequency and duration (Pennings and Callaway, 1992). Classifying estuarine areas into vegetation communities can also mask high seasonal variations in salinities that occur within marsh types. For example, *Spartina alterniflora* is found in many areas of Louisiana that are essentially fresh during the Spring but > 20 ppt in the Fall such as Old Oyster Bayou and Cocodrie. Therefore, the timing and operation of freshwater inputs from diversions will be an important determinant of changes in marsh type.

The young of fishery species show distinct seasonal abundance patterns in estuaries that are consistent from year to year. For example, the abundance of juvenile brown shrimp, gulf menhaden, spot, striped mullet, and southern flounder peak in Spring (March-May), whereas young blue crab, spotted seatrout, and white shrimp are most abundant in late Summer through Fall (August-November). These seasonal patterns of abundance are well documented for various locations in the northern Gulf of Mexico (King 1971, Rogers and Herke 1985, Rakocinski et al. 1992, Livingston 1997, Akin et al. 2003, Rozas et al. 2007) and should be considered when developing operational plans for river diversions. For example, the use of estuarine nursery areas by young brown shrimp peaks in Spring at the same time that water and sediment is most available in the Mississippi River for routing through structures for wetland restoration. Freshwater inflows can lower salinity and water temperature, which may influence the distribution, growth, and productivity of brown shrimp in estuaries (Zein-Eldin and Aldrich 1965, Ford and St. Amant 1971, Saoud and Davis 2003). Therefore, the potential for a conflict between restoration and fishery production is high for brown shrimp. It may be possible to manage the volume and timing of inflows from diversions to maintain favorable salinity conditions for brown shrimp and other fishery species during their critical nursery periods that would mitigate potential negative impacts.

For small diversions like BA-33, any sediment diverted would be delivered to and captured within the upper estuary near the diversion. This could result in some shallowing of marsh ponds; but, in landscape terms, the effect would primarily be to prevent further deterioration of the marsh landscape and reverse a trend towards Fragmented Marsh. As populations in fresh/intermediate areas are already relatively low, such changes to landscape patterns and salinity regime in the upper estuary (fresh/intermediate zone) likely would have little effect on fishery populations (or at least much less effect than in brackish/saline zones) based on our study results.

Far-field effects of the diversion into the brackish and saline zones will also depend upon the magnitude and timing of diversion inflows. Should the influence of nutrients and/or sediments from the diversion extend into lower parts of the estuary, then, over the long term, the diversion could prevent an increase in open water classes at the expense of Fragmented Marsh. This study has shown that such an increase in open water could increase populations within a given area and restoration could reduce any such effects.

Minimizing any reduction in fishery support will require the use of restoration methods that are matched to specific needs of locations within the estuary. For example, sediment introductions and high freshwater flows should be used directly in the fresh/intermediate zone where need is great and potential impacts to fisheries would be less. The timing of diversions could also be adjusted. Freshwater diversions could be operated to vary flows annually and seasonally to mimic fluctuations in river flooding that the delta plain likely experienced prior to river management. The structure could be operated to deliver high-pulsed flows perhaps once every five years when the river is at flood stage, and, in other years, pulsed flows would be allowed only in Winter-early Spring but these diversions would not occur at full capacity. Fisheries may suffer during high flow years, but benefits (e.g., increased fishery production) would accrue during the other four years, and over the long term, marsh loss would likely be reversed. Whether such a strategy would provide beneficial far field effects to the brackish/saline zones by stopping or reversing marsh loss, but not changing the landscape patterns (i.e., converting high edge areas to Solid Marsh), requires a more detailed examination of sediment distribution from diversions of different magnitudes and improved predictions of potential marsh response. As restoration proceeds in an adaptive management context, it must include monitoring the effects of river diversions, and adjusting operations to learn more about effects on landscape, salinity, and fishery populations.

Interpretation of the results of this study must take into account the limitations of any analysis based on a single year assessment of nekton distribution. For example, densities of brown shrimp from our field samples were relatively low overall, likely due to the low salinity present when these samples were collected in 2002. In October 2005, we collected 60 samples in saline marshes farther down the estuary where salinities averaged 22‰ and documented many more brown shrimp. Mean densities of brown shrimp in marsh 1 m and 3 m from shore and within ponds 1 m, 5 m, 20 m, and 50 m from shore were 5.6, 0.7, 13.9, 3.1, 1.7, and 2.1 m^{-2}, respectively. Had salinities been higher in 2002, we likely would have collected higher densities of brown shrimp. The few brown shrimp collected during 2002 made it difficult to discern any distributional pattern, and model development was based on fewer data than expected. The marsh classification is also based on a snapshot of the landscape in 2001, and calculation of nekton abundance is dependent upon the number and size of ponds in the landscape. However, the classification of solid and Fragmented Marsh can be generally applied and landscape characteristics are less likely to vary from year to year, except under direct impacts of major hurricanes.

The modeling in this study has been limited to three important fishery species. However, the effects of diversions and other restoration actions will also be felt by other ecologically important species in the estuary. Task 1 of this study found direct positive relationships between salinity levels and brown shrimp, white shrimp, Spot, and Atlantic croaker, suggesting a change in abundance with diversions, and analysis indicated that bay anchovy numbers may have increased with land loss, suggesting their abundance may decrease with effective restoration in the estuary.

A fuller understanding of the effect of diversions on nekton and fishery abundance requires a focus on salinity regimes within the estuary as well as other water quality variables and must consider the potential of eutrophication and low dissolved oxygen conditions. This study has highlighted the effect of marsh-water configurations on nekton populations. It shows that the nature of the landscape provides an important structural back drop to further investigations of the more dynamic aspects of nekton habitat utilization. It has also illustrated the complexity of nekton response to restoration using diversions. Restoration planning must more explicitly consider the relationships between nekton and both the physical structure and the dynamic water quality conditions in Louisiana estuaries to better predict the consequences of restoration actions for fisheries.

8.0 Literature Cited

Akin, S., K.O. Winemiller, and F.P. Gelwick. 2003. Seasonal and spatial variations in fish and macrocrustacean assemblage structure in Mad Island marsh estuary, Texas. *Estuarine, Coastal and Shelf Science* 57: 269-282.

Baltz, D.M., C. Rakocinski, and J.W. Fleeger. 1993. Microhabitat use by marsh-edge fishes in a Louisiana estuary. *Environmental Biology of Fishes* 36: 109-126.

Baltz, D.M., and E.J. Chesney. 1996. Spatial and temporal patterns in the distribution and abundance of fishes and macroinvertebrates in coastal Louisiana: shrimp bycatch species in fishery-independent trawl samples. The final report submitted to the U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Southeast Regional Center, Marine Fisheries Initiative (MARFIN) Project NA37FF044-01. 63 pp.

Baltz, D.M., R.G. Thomas, and E.J. Chesney. 2003. Spotted seatrout habitat affinities in Louisiana. *In*: P.L. Lutz (ed). Biology of the Spotted Seatrout. CRC Marine Biology Series.

Barras, J.A. 2006. Land area change in coastal Louisiana after the 2005 hurricanes-a series of three maps: U.S. Geological Survey Open-File Report 06-1274.

Barras, J., S. Beville, D. Britsch, S. Hartley, S. Hawes, J. Johnston, P. Kemp, Q. Kinler, A. Martucci, J. Porthouse, D. Reed, K. Roy, S. Sapkota, and J. Suhayda. 2003. Historical and projected coastal Louisiana land changes: 1978-2050. USGS Open File Report 03-334. 39 pp. (Revised January 2004).

Barrett, B.B., and E.J. Ralph. 1977. Environmental conditions relative to shrimp production in coastal Louisiana along with shrimp catch data for the Gulf of Mexico. Louisiana Department of Wildlife and Fisheries, New Orleans (USA). Seafood Division.

Beck, M.W., K.L. Heck, Jr., K. Able, D. Childers, D. Eggleston, B.M. Gillanders, B. Halpern, C. Hays, K. Hoshino, T. Minello, R. Orth, P. Sheridan, and M. Weinstein. 2001. The identification, conservation and management of estuarine and marine nurseries for fish and invertebrates. *Bioscience* 51: 633-641.

Beckman, D.W., C.A. Wilson, and A.L. Stanley. 1988. Age and growth of red drum, *Sciaenops ocellatus*, from offshore waters of the northern Gulf of Mexico. *Fishery Bulletin* 87: 17-28.

Browder, J.A., H.A. Bartley, and K.S. Davis. 1985. A probabilistic model of the relationship between marshland-water interface and marsh disintegration. *Ecological Modeling* 29: 245-260.

Browder, J.A., L.N. May, A. Rosenthal, J.G. Gosselink, and R.H. Baumann. 1989. Modeling future trends in wetland loss and brown shrimp production in Louisiana using thematic mapper imagery. *Remote Sensing of the Environment* 28: 45-59.

Castellanos, D.L., and L.P. Rozas. 2001. Nekton use of submerged aquatic vegetation,marsh, and shallow nonvegetated bottom in the Atchafalaya River Delta, a Louisiana tidal freshwater ecosystem. *Estuaries* 24: 184-197.

Christmas, J.W., W. Langley, and T. VanDevender. 1976. Investigations of commercially important penaeid shrimp in Mississippi. Gulf Coast Research Laboratory, Ocean Springs, Mississippi. 66 pp.

Clark, R.D., T.J. Minello, J.D. Christensen, P.A. Caldwell, M.E. Monaco, and G.A. Matthews. 1999. Modeling nekton habitat use in Galveston Bay, Texas. NOAA/NOS Biogeography Program Technical Report Number 17. 69 pp.

Clark, R.D., J.D. Christensen, M.E. Monaco, P.A. Caldwell, G.A. Matthews, and T.J. Minello. 2004. A habitat-use model to determine essential fish habitat for juvenile brown shrimp (*Farfantepenaeus aztecus*) in Galveston Bay, Texas. *Fishery Bulletin, U.S.* 102: 264-277. (http://galveston.ssp.nmfs.gov/publications/pdf/849.pdf)

Day, R.W., and G.P. Quinn. 1989. Comparison of treatments after an analysis of variance in ecology. *Ecological Monographs* 59: 433-463.

Day, J.W. Jr., G.P. Shaffer, L.D. Britsch, D.J. Reed, S.R. Hawes, and D.R. Cahoon. 2000.Pattern and process of land loss in the Mississippi Delta: a spatial and temporal analysis of wetland habitat change. *Estuaries* 23: 425-438.

Deegan, L.A., J.E. Hughes, and R.A. Rountree. 2000. Salt marsh ecosystem support of marine transient species. *In*: M.P. Weinstein and D.A. Kreeger (ed). Concepts and controversies in tidal marsh ecology. Kluwer Academic Publishers, Dordrecht, The Netherlands. 333-365 pp.

Dunson, W.A., P. Friacano, and W.J. Sadinski. 1993. Variation in tolerance to abiotic stresses among sympatric salt marsh fish. *Wetlands* 13: 16-24.

Eggleston, D.B., L.L. Etherington, and W.E. Elis. 1998. Organism response to habitat patchiness: Species and habitat dependent recruitment of decapod crustaceans. *Journal of Experimental Marine Biology and Ecology* 223: 111-132.

Etherington, L.L., and D.B. Eggleston. 2003. Spatial dynamics of large-scale, multistage crab (*Callinectes sapidus*) dispersal: determinants and consequences for recruitment. *Canadian Journal of Fisheries and Aquatic Sciences* 60: 873-887.

Evers, D.E., J.G. Gosselink, C.E. Sasser, and J.M. Hill. 1992. Length-weight relations for three commercially important penaeid shrimp of the Gulf of Mexico. *Transactions of the American Fisheries Society* 100: 584-586.

Ford, T.B., and L.S. St. Amant. 1971. Management guidelines for predicting brown shrimp, *Penaeus aztecus*, production in Louisiana. *Proceedings in the Gulf and Caribbean Fisheries Institute* 23: 149-161.

Fry, B., D.M. Baltz, M.C. Benefield, J.W. Fleeger, A. Gace, H.L. Haas, and Z.J. Quinones-Rivera. 2003. Stable isotope indicators of movement and residency for brown shrimp (*Farfantepenaeus aztecus*) in coastal Louisiana marshscapes. *Estuaries* 26: 82-97.

GBNEP (Galveston Bay National Estuary Program). 1994. The state of the bay: a characterization of the Galveston bay Ecosystem. GBNEP-44. Webster, Texas. 232 pp.

Guillory, V. and S. Hein (unpublished) Lateral spine variability and weight-size and carapace width-size regressions in blue crab (*Callinectes sapidus*). Unpublished manuscript, Louisiana Department of Wildlife and Fisheries, Baton Rouge.Guillory, V. and W.S. Perret. 1998. History, management, status, and trends in the Louisiana blue crab fishery. *Journal of Shellfish Research* 17: 413-424.

Gunter, G. 1961. Habitat of juvenile shrimp (family Penaeidae). *Ecology* 42: 598-600.

Gunter, G., J.Y. Christmas, R. Killebrew. 1964. Some relationships of salinity to population distributions of motile estuarine organisms, with special reference to penaeid shrimp. *Ecology* 45: 181-185.

Harding, J.M., and R. Mann. 2001. Oyster reefs as fish habitat: opportunistic use of restored reefs by transient fishes. *Journal of Shellfish Research* 20: 951-959.

Harrington, R.A., G.C. Matlock, and J.E. Weaver. 1979. Standard-total length, total length-whole weight, and dressed-whole weight relationships for selected species from Texas bays. Texas Parks and Wildlife Department Technical Series 26.

Hein, S., C. Dugas, and J. Shepard. 1980. Total length-standard length and length-weight regressions for Spotted seatrout, *Cynoscion nebulosus*; red drum, *Scieanops ocellata*; and black drum, *Pogonias cromis*, in south-central Louisiana. Louisiana Department of Wildlife and Fisheries Technical Bulletin No. 31.

Howe, J.C., R.K. Wallace, and F.S. Rikard. 1999. Habitat utilization by postlarval and juvenile penaeid shrimps in Mobile Bay, Alabama. *Estuaries* 22: 971-979.

Kemp, G.P., J.W. Day Jr., D.J. Reed, D.R. Cahoon, and M. Wang. 1999. Sedimentation, consolidation and surface elevation in two salt marshes of the Mississippi River Deltaic Plain: Geotechnical aspects of wetland loss. *In*: L.P. Rozas,

J.A. Nyman, C.E. Proffitt, N.N. Rabalais, D.J. Reed, and R.E. Turner (eds.). Recent research in coastal Louisiana: Natural system function and response to human influence. Louisiana Sea Grant College Program, Baton Rouge, LA.

King, B.D., III. 1971. Study of migratory patterns of fish and shellfish through a natural pass. Texas Parks and Wildlife Department, Technical Series No. 9, Austin. 54 pp.

Kneib, R.T. 1982. The effects of predation by wading birds (Ardeidae) and blue crabs (*Callinectes sapidus*) on the population size structure of the common mummichog, *Fundulus heteroclitus*. *Estuarine, Coastal and Shelf Science* 14: 159-165.

Layman, C.A., D.E. Smith, and J.D. Herod. 2000. Seasonally varying importance of abiotic and biotic factors in marsh-pond fish communities. *Marine Ecology Progress Series* 207: 155-169. Leibowitz, S.G., and J.M. Hill. 1987. Spatial analysis of coastal land loss. *In*: R.E. Turner and D.R. Cahoon (eds.). Causes of wetland loss in the coastal Central Gulf of Mexico. Volume II Technical Narrative. Final report submitted to Minerals Management Service, New Orleans, LA. Contract No. 14-12-0001-30252. OCS Study/MMS 87-0120. 400 pp.

Linscombe, G. and R. Chabreck. 2001. 2001 Louisiana Coastal Marsh-Vegetative Type Map. Louisiana Department of Wildlife and Fisheries, Fur and Refuge Division, and the U.S. Geological Survey National Wetlands Research Center. (http://Brownmarsh.net/data/III_7.htm)

Livingston, R.J. 1997. Trophic response of estuarine fishes to long-term changes in river runoff. *Bulletin of Marine Science* 60: 984-1004.

Longley, W.L. (ed.). 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods for determination of needs. Texas Water Development Board and Texas Parks Wildlife Department, Austin, TX. 386 pp.

Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority. 1998. Coast 2050: Toward a Sustainable Louisiana. Louisiana Department of Natural Resources. Baton Rouge, LA. 161 pp.

Louisiana Department of Wildlife and Fisheries. 1996. Marine Fisheries Division Field Procedures Manual. Version No. 96-1, June 1996, Louisiana Department of Wildlife and Fisheries, Office of Fisheries, Marine Fisheries Division. 25 pp.

Louisiana Department of Wildlife and Fisheries. 2000. Office of Fisheries, Marine Fisheries Division, Database. Louisiana Oil Spill Coordinator's Office (LOSCO). 1999. Color Infrared Orthophoto 50: 1. MrSID compressed, UTM 15 NAD83, LOSCO.

Master, T.L. 1992. Composition, structure, and dynamics of mixed-species foragingaggregations in a southern New Jersey salt marsh. *Colonial Waterbirds* 15: 66-74.
McTigue, T.A. and R.J. Zimmerman. 1998. The use of infauna by juvenile *Penaeus aztecus* Ives and *Penaeus setiferus* (Linnaeus). *Estuaries* 21: 160-175.
Milliken, G.A. and D.E. Johnson. 1992. Analysis of Messy Data. Volume 1: Designed Experiments. Chapman and Hall, London. 473 pp.
Miltner, R.J., S.W. Ross, and M.H. Posey. 1995. Influence of food and predation on the depth distribution of juvenile Spot (*Leiostomus xanthurus*) in tidal nurseries. *Canadian Journal of Fisheries and Aquatic Sciences* 52: 971-982.
Minello, T.J. and R.J. Zimmerman. 1992. Utilization of natural and transplanted Texas salt marshes by fishes and decapod crustaceans. *Marine Ecology Progress Series* 90: 273-285.
Minello, T.J., R.J. Zimmerman, and R. Medina. 1994. The importance of edge for natant macrofauna in a created salt-marsh. *Wetlands* 14: 184-198.
Minello, T.J. and J.W. Webb. 1997. Use of natural and created Spartina alterniflora salt marshes by fishery species and other aquatic fauna in Galveston Bay, Texas, USA.*Marine Ecology Progress Series* 151: 165-179.
Minello T. 1999. Nekton densities in shallow estuarine habitats of Texas and Louisiana and the identification of essential fish habitat. In: Benaka, L.R. (ed.) Fish Habitat: Essential Fish Habitat and Rehabilitation. Bethesda (MD): American Fisheries Society. 43-75 pp.
Minello, T.J. and L.P. Rozas. 2002. Nekton in Gulf coast wetlands: fine-scale distributions, landscape patterns, and restoration implications. *Ecological Applications* 12: 441-455.
Minello, T.J., K.W. Able, M.P. Weinstein, and C.G. Hays. 2003. Salt marshes as nurseries for nekton: testing hypotheses on density, growth, and survival through meta-analysis. *Marine Ecology Progress Series* 246: 39-59.
Minello, T.J., G.A. Matthews, P. Caldwell, and L.P. Rozas (in press). Population and production estimates for decapod crustaceans in wetlands of Galveston Bay, Texas. Transactions of the American Fisheries Society.
National Marine Fisheries Service and the Louisiana Department of Natural Resources. 2000. Delta building diversion at Myrtle Grove, candidate project for the tenth priority list of the Coastal Wetlands Planning, Protection and Restoration Act proposed by National Marine Fisheries Service and the Louisiana Department of Natural Resources. Wetland Value Assessment.
Pattillo, M., L.P. Rozas, and R.J. Zimmerman. 1995. A review of salinity requirements for selected invertebrates and fishes of U.S. Gulf of Mexico estuaries. A final report to the Environmental Protection Agency, Gulf of Mexico Program.
Pennings, S.C. and R.M. Callaway. 1992. Salt Marsh Plant Zonation: The Relative Importance of Competition and Physical Factors. *Ecology* 73: 681-690.
Perkins-Visser, E., T.G. Wolcott, and D.L. Wolcott. 1996. Nursery role of seagrass beds: enhanced growth of juvenile blue crabs (*Callinectes sapidus* Rathbun). *Journal of Experimental Marine Biological Ecology* 198: 155-173.
Peterson, G.W. and R.E. Turner. 1994. The value of salt-marsh edge vs. interior as a habitat for fish and decapod crustaceans in Louisiana tidal marsh. *Estuaries* 17: 235-262.
Perez-Farfante, I. and B. Kensley. 1997. Penaeoid and sergestoid shrimps and prawns of the world: Keys and diagnoses for the families and genera. Mémoires du Museum National d'Historie Naturelle, Tome 175, Paris, France.

Rakocinski, C.F., D.M. Baltz, and J.W. Fleeger. 1992. Correspondence between environmental gradients and the community structure of marsh-edge fishes in a Louisiana estuary. *Marine Ecology Progress Series* 80: 135-148.

Reed, D.J. (ed.). 1995. Status and Historical Trends of Hydrologic Modification, Reduction in Sediment Availability, and Habitat Loss/Modification in the Barataria and Terrebonne Estuarine Systems. BTNEP Publ. No. 20, Barataria-Terrebonne National Estuary Program Thibodaux, LA. 338 pp. plus appendices.

Reed, D.J., M.J. Peterson, L.P. Rozas, and P. Caldwell. 2001. Projecting the effects of management actions on fisheries species in the Vermillion-Atchafalaya coastal bays. Final Report submitted to U.S. Army Corps of Engineers, New Orleans District.

Reid, G.K. 1957. Biologic and hydrologic adjustment in a disturbed Gulf coast estuary. *Limnology and Oceanography* 2: 198-212.

Rogers, B.D., and W.H. Herke. 1985. Estuarine-dependent fish and crustacean movements and weir management. *In*: Bryan, C.F., P.J. Zwank, R.H. Chabreck (eds.). Fourth Coastal marsh and Estuary Management Symposium, Louisiana State University Agricultural Center, Baton Rouge. 201-219 pp.

Rogers, B.D., W.H. Herke, and E.E. Knudsen. 1992. Effects of three different water-control structures on the movements and standing stocks of coastal fishes and macrocrustaceans. *Wetlands* 12: 106-120.

Rooker, J.R., S.A. Holt, M.A. Soto, and G.J. Holt. 1998. Postsettlement patterns of habitat use by sciaenid fishes in subtropical seagrass meadows. *Estuaries* 21: 318-327.

Ross, S.T. and T.A. Doherty. 1994. Short-term persistence and stability of barrier island fish assemblages. *Estuarine, Coastal and Shelf Science* 38: 49-67.

Rowe, C.L. and W.A. Dunson. 1995. Individual and interactive effects of salinity and initial fish density on a salt marsh assemblage. *Marine Ecology Progress Series* 128: 271-278.

Rozas, L.P. and C.T. Hackney. 1984. Use of oligohaline marshes by fishes and macrofaunal crustaceans in North Carolina. *Estuaries* 7: 213-224.

Rozas, L.P. and D.J. Reed. 1993. Nekton use of marsh-surface habitats in Louisiana (USA) deltaic salt marshes undergoing submergence. *Marine Ecology Progress Series* 96: 147-157.

Rozas, L.P. and T.J. Minello. 1997. Estimating densities of small fishes and decapods crustaceans in shallow estuarine habitats: a review of sampling design with focus on gear selection. *Estuaries* 20: 199-213.

Rozas, L.P. and T.J. Minello. 1998. Nekton use of salt marsh, seagrass, and nonvegetated habitats in a south Texas (USA) estuary. *Bulletin of Marine Science* 63: 481-501.

Rozas, L.P. and T.J. Minello. 1999. Effects of structural marsh management on fishery species and other nekton before and during a Spring drawdown. *Wetlands Ecology and Management* 7: 121-139.

Rozas, L.P. and R.J. Zimmerman. 2000. Small-scale patterns of nekton use among marsh and adjacent shallow nonvegetated areas of the Galveston Bay Estuary, Texas (USA). *Marine Ecology Progress Series* 193: 217-239.

Rozas, L.P. and T.J. Minello. 2001. Marsh terracing as a wetland restoration tool for creating fishery habitat. *Wetlands* 21: 237-341.

Rozas, L.P., P. Caldwell, and T.J. Minello. 2005a. The fishery value of salt marsh restoration projects. *Journal of Coastal Research* S140: 37-50.

Rozas, L.P., T.J. Minello, I. Munuera-Fernandez, B. Fry, and B. Wissel. 2005b. Macrofaunal distributions and habitat change following Winter-Spring releases of freshwater into Breton Sound Estuary, Louisiana (USA). *Estuarine, Coastal and Shelf Science* 65: 319-336.

Rozas, L.P., T.J. Minello, R.J. Zimmerman, and P. Caldwell. 2007. Nekton populations long-term wetland loss, and the effect of recent habitat restoration in Galveston Bay, TX (USA). *Marine Ecology Progress Series* 344: 119-130.

Saoud, I.P. and D.A. Davis. 2003. Salinity tolerance of brown shrimp *Farfantepenaeus aztecus* as it relates to postlarval and juvenile survival, distribution, and growth in estuaries. *Estuaries* 26: 970-974.

Sheridan, P.F. 1992. Comparative habitat utilization by estuarine macrofauna within the mangrove ecosystem of Rookery Bay, Florida. *Bulletin of Marine Science* 50: 21-39.

Sokal, R.R. and F.J. Rohlf. 1980. Biometry. WH Freeman, New York. 859 pp.

Soto, M.A., J.G. Holt, S.A. Holt, and J. Rooker. 1998. Food habits and dietary overlap of newly settled red drum (*Sciaenops ocellatus*) and Atlantic Croaker (*Micropogonias undulatus*) from Texas seagrass meadows. *Gulf Research Reports* 10: 41-55.

Stunz, G.W., P.S. Levin, and T.J. Minello. 2001. Selection of estuarine nursery habitats by wild-caught and hatchery-reared juvenile red drum in laboratory mesocosms. *Environmental Biology and Ecology* 260: 13-25.

Stunz, G.W., and T.J. Minello. 2001. Habitat related predation on juvenile wild-caught and hatchery-reared juvenile red drum *Sciaenops ocellatus* (Linnaeus). *Journal of Experimental Marine Biology and Ecology* 260: 13-25.

Stunz, G.W., T.J. Minello, and P.S. Levin. 2002. A comparison of early juvenile red drum densities among various habitat types in Galveston Bay, Texas. *Estuaries* 25: 76-85.

Thomas, R.G. 1999. Fish habitat and coastal restoration in Louisiana. *In*: Benaka, L.R. (ed.). Fish Habitat: Essential Fish Habitat and Habitat Rehabilitation. American Fisheries Society Symposium 22, Bethesda, MD, USA, 240-251 pp.

Turner, R.E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. *Transactions of the American Fisheries Society* 106: 411-416.

Turner, R.E. 1997. Wetland Loss in the Northern Gulf of Mexico: Multiple Working Hypotheses. *Estuaries* 20: 1-13.

U.S. Army Corps of Engineers. 2004. Louisiana Coastal Area Comprehensive Coastwide Ecosystem Restoration Study. U.S. Army Corps of Engineers, New Orleans, LA. Available online: http://www.lca.gov/nearterm/main_report1.aspx.

USGS National Wetlands Research Center Coastal Restoration Field Station and Louisiana Department of Natural Resources. 2000. Myrtle Grove Diversion Habitat Analysis. *In*: R. Sweeney (Contact). Delta building diversion at Myrtle Grove, candidate project for the tenth priority list of the Coastal Wetlands Planning, Protection and Restoration Act, proposed by National Marine Fisheries Service and Louisiana Department of Natural Resources, Wetland Value Assessment, November 20, 2000.

USGS-NWRC. 2002. Coastal Louisiana Scanned Aerial Photography Metadata. Lafayette, LA. 6 pp.

USGS-NWRC. 2003. Project boundary map for Delta Building Diversion at Myrtle Grove (BA-33). Map ID USGS-NWRC 2003-11-130. August 27, 2003.

Webb, S.R. and R.T. Kneib. 2002. Abundance and distribution of juvenile white shrimp *Litopenaeus setiferus* within a tidal marsh landscape. *Marine Ecology Progress Series* 232: 213-223.

Zein-Eldin, Z.P. and D.V. Aldrich. 1965. Growth and survival of postlarval *Penaeus aztecus* under controlled conditions of temperature and salinity. *Biological Bulletin* 129: 199-216.

Zimmerman, R.J. and T.J. Minello. 1984. Densities of *Penaeus aztecus*, *Penaeus Setiferus*, and other natant macrofauna in Texas salt marsh. *Estuaries* 7: 421-433.

Zimmerman, R.J., T.J. Minello, and G. Zamora Jr. 1984. Selection of vegetated habitat by brown shrimp, *Penaeus aztecus*, in a Galveston Bay salt marsh. *Fishery Bulletin* 82: 325-336.

Zimmerman, R.T., T. Minello, T. Baumer, and M. Castiglione. 1989. Oyster reef as habitat for estuarine macrofauna. NOAA Technical Memorandum, NMFS-SEFC-249. 16 pp.

Zimmerman, R.J. 1992. Global warming: effects of sea level rise on shrimp fisheries. 58-73 pp. *In*: Baxter, K.N. and L. Scott-Denton (eds.). Proceedings of the Southeast Fisheries Science Center Shrimp Resource Review. NOAA Technical Memorandum, NMFS-SEFSC-299. 186 pp.

Zimmerman, R.J., J.M. Nance, and J.A. Williams. 1997. Trends in shrimp catch in the Hypoxic area of the northern Gulf of Mexico. 64-75 pp. *In*: Proceedings of the 1st Gulf of Mexico Hypoxia Management Conference, EPA-55-R-97-001. U.S. Environmental Protection Agency, Gulf of Mexico Program Office, Stennis Space Center, MS 39529-6000.

Zimmerman, R.J., T.J. Minello, and L.P. Rozas. 2000. Salt marsh linkages to productivity of penaeid shrimps and blue crabs in the northern Gulf of Mexico. *In*: Weinstein, M.P. and D.A. Kreeger (eds.). Concepts and controversies in tidal marsh ecology. Kluwer Academic Publishers, Dordrecht, The Netherlands. 293-314 pp.

List of Appendixes A-D Tables

List of Appendixes A-D Figures

APPENDIX A - Task 1 Methods and Materials

Table A1. Summary of available length/weight regressions for the species of concern in this study. All regressions are in mm total length (TL) and grams wet weight (W). NGOM= northern Gulf of Mexico and na= not available.

Species	Regressions	Size range, N	Reference and state
Spotted seatrout	logW = -5.192 + 3.062 (log TL) Sexes combined, no test	44-902 mm TL N=na	Harrington et al. 1979; TX
Red drum	logW = -5.1197 + 3.0523 (log TL) Sexes combined, no test* * no significant difference in sexes for fish 620 - 1040 mm FL	14 - 1135 mm TL, N=302	Hein et al. 1980; LA Beckman et al. 1988; NGOM (Offshore AL- TX)
Blue crab	logW = -3.524 + 2.653 (log CW) Immature Females, sig. diff in size, sex (used for females 18-113 mm CW)	18 - 156 mm CW, N=461	Guillory and Hein unpub.; LA
	logW = -3.355 + 2.591 (log CW) Immature Males, sig diff in size, sex (used for males 23-96 mm CW)	23 - 130 mm CW, N=201	
	logW = -3.217 + 2.531 (log CW) Mature Males, sig. diff. in size, sex (used for males >96 mm CW)	96 - 196 mm CW; N=983	
	logW = -3.083 + 2.446 (log CW) Sexes and sizes combined, sig. differences (used when sex not determined)	18 - 196 mm CW, N=2,185	
Brown shrimp	logW = -4.978 + 2.938 (log TL) Sexes combined, no sig. diff.	45 - 239 mm TL, N=3,412	Fontaine and Neal 1971; TX
	logW = -5.1444 + 3.0087 (log TL) Sexes combined, no test* *this equation used for shrimp 30-44 mm TL	30 - 104 mm TL, N=15	Christmas et al. 1976; MS
White shrimp	logW = -5.665 + 3.247 (log TL) Sexes combined, no sig. diff.	70 - 214 mm TL; N=2,090	Fontaine and Neal 1971; TX
	logW = -4.8049 + 2.818 (log TL) Sexes combined, no test* *this equation used for shrimp 30-69 mm TL	30 - 104 mm TL, N=15	Christmas et al. 1976; MS

Table A2. Classifications of LDWF trawl and seine stations by DOQQ, USGS National Wetlands Research Center Coastal Restoration Field Station and Louisiana Department of Natural Resources, and Myrtle Grove Classification.

	From DOQQ (this study Task 1)		From USGS	From Myrtle Grove Classification (this study Task 2)								
Trawl Station	Marsh-water Configuration	Land/Water Ratio	Salinity Designation	Landscape class	Water (ha)	Land (ha)	Land/Water Ratio	Dense marsh (ha)	Low pond density broken marsh (ha)	High pond density Broken marsh (ha)	Small ponds (ha)	Other water (ha)
6	Dense	0.20	Saline									
9	Open Water	0	Saline									
20	Broken	0.42	Saline									
22	Open Water	0.07	Saline									
23	Broken	0.32	Saline									
26	Dense	0.72	Brackish	Lake	280	220.7	0.79	23.6	39.5	157.5	4.7	275.2
27	Dense	1.04	Brackish	Lake	253	247.7	0.98	30.9	65.4	151.3	2.6	250.4
28	Dense	0.36	Saline									
29	Open Water	0.04	Brackish									
30	Broken	0.60	Saline									
31	Broken	0.54	Saline									
33	Dense	0.17	Saline									
37	Broken	0.58	Saline									
40	Open Water	0.10	Brackish	Lake	464.7	36	0.08	0.45	0.16	35.4	2.1	462.5
52	Open Water	0.01	Saline									
Seine Station												
342	Open Water	0.11	Saline									
343	Dense	0.23	Saline									
344	Dense	0.41	Brackish									
345	Open Water	0.16	Brackish									

Table A3. Distribution of replicate samples over years and seasons at each marsh-water (open water, dense, broken) and salinity (brackish, saline) classifications for both the trawl and seine gear types.

		No. of replicate Trawl Samples					No. of replicate Seine Samples			
		Open water		Dense		Broken	Open water		Dense	
Year	Season	Brackish	Saline	Brackish	Saline	Saline	Brackish	Saline	Brackish	Saline
1990	Spring	2	3	2	3	5	1	1	1	1
	Summer						1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1991	Spring						1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1992	Spring	2	3	2	3	5	1	1	1	1
	Summer						1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1993	Spring						1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1994	Spring	2	3	2	3	5	1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1995	Spring	2	3	2	3	5	1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1996	Spring	2	3	2	3	5	1	1	1	1
	Summer						1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1997	Spring	2	3	2	3	5	1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1998	Spring	2	3	2	3	5	1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
1999	Spring	2	3	2	3	5	1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1
2000	Spring	2	3	2	3	5	1	1	1	1
	Summer	1	2		3	3	1	1	1	1
	Fall						1	1	1	1
	Winter						1	1	1	1

APPENDIX B – Task 1 Results

Table B1. Mean values for species' (numbers and biomass (g)) and environmental variables and standard errors (SE) collected during Spring and Summer (1990-2000) in 3 marsh-water categories from the trawl. The P values for the factors (marsh-water (Mw), year (Yr), and covariate (salinity (Sal.) are from a 2-way ANOVA or ANCOVA. ANCOVA was used when the test of preliminary assumptions of linearity between catch and covariates (NS=nonsignificant; Sig.*= 0.05<P<0.10; Sig.**=P<0.05) and of equal slopes (the Mw*sal interaction) were met. 5 stations represented each marsh-water type. Average species' biomass and number and salinity values for each station were used as replicates. Biomass, number, and environmental variables were ln+1 transformed if needed to meet assumption of homogeneity of variance, else they were left untransformed. The contrast p-values are from post-hoc tests (with Bonferroni correction) of predicted values from the ANCOVA or ANOVA between: 1) broken and dense, 2) broken and open water, and 3) dense and open water marsh types. If the homogeneity of variance assumption was not met, post-hoc contrasts that do not assume equal variances were used. Species' abbreviations as in Table 1. Bold type indicates significance at the 0.05 level.

Taxon		Broken	Dense	Open Water	Equal Slopes test	Linearity Assumption test	Significance of Effects			Contrast values			Test used
	Spring	Mean(S.E.)	Mean(S.E.)	Mean (S.E.)			Mw	Yr	Salinity	1	2	3	
BRS number		170.91(23.20)	68.72(9.64)	96.15(14.10)	.678	Sig.** overall NS for broken NS for dense Sig.** for open water	**.000**	**.000**	.149+	**.000**	**.000**	1.00	ANCOVA
BRS biomass		362.33(44.18)	142.73(26.70)	229.49(37.35)	.129	Sig.** overall Sig.** for broken Sig.* for dense Sig.** for open water	**.036**	**.000**	**.003+**	**.038**	.155	1.00	ANCOVA
Env. variables													
WC.		1.42(0.04)	1.88(0.17)	1.63(0.12)			**.017**	**.000**		**.032**	.295	.554	ANOVA
Sal.		17.10(0.74)	10.64(0.82)	13.87(0.86)			**.000**	**.000**		**.000**	**.017**	**.023**	ANOVA
Temp.		23.33(.22)	23.93(0.29)	23.63(0.25)			**.048**	**.000**		**.042**	.673	.613	ANOVA
	Summer												
BRS number		40.45(5.2)	23.75(4.16)	15.77(3.22)	.319	NS	**.000**	**.000**		**.005**	**.000**	.159	ANOVA
BRS biomass		112.79(15.63)	68.49(11.44)	44.6(7.22)	.529	NS	**.000**	**.003**		**.014**	**.000**	.354	ANOVA

WS number	5.75(2.02)	4.94(1.66)	0.27(0.10)	.361 (but with non-homogenous variance)	Sig. * overall NS for broken NS for dense NS for open water	**.032**	.796	1.00	**.046**	.111	ANOVA
WS biomass	7.49(3.02)	5.61(2.03)	0.47(0.22)	.331 (but with non-homogenous variance)	Sig.** overall Sig.* for broken NS for dense NS for open water	.055	.336				ANOVA
Env. variables											
WC.	1.39(.0.06)	1.46(0.09)	1.50(0.07)			.521	**.007**				ANOVA
Sal.	14.17(1.24)	10.08(1.29)	12.07(1.42)			**.005**	**.000**	**.003**	.248	.304	ANOVA
Temp.	28.88(0.27)	29.22(0.20)	29.12(0.24)			.453	**.000**				ANOVA

Table B2. Mean values for species' catch (numbers and biomass (g)) and environmental variables and standard errors (SE) collected during Spring, Summer, Fall and Winter (1990-2000) in 2 marsh-water categories from the seine. The P values for the factors (marsh-water (Mw), year (Yr), and covariate (salinity (Sal.) are from a 2-way ANOVA, ANCOVA, or the Friedman's Test. ANCOVA was used when the tests of preliminary assumption of linearity between catch and salinity (NS=nonsignificant; Sig.*= 0.05<P<0.10; Sig.**=P<0.05) and equal slopes test (the Mw*sal interaction) were met. 2 stations represented each marsh-water type. Average species' biomass and number and salinity values/station/season/year were used as replicates in the ANOVA or ANCOVA. Biomass and number were ln+1 transformed if needed to meet assumption of homogeneity of variance, else they were left untransformed. When the homogeneity of variance assumption was not met, the Friedman's test was used. Species' abbreviations as in Table 1. Bold type indicates significance at the 0.05 level.

Taxon	Dense	Open Water	Equal slopes test	Linearity Assumption test	Significance of Effects			Test used
	Mean (S.E.)	Mean (S.E.)			Mw	Yr	Salinity	
Spring								
BA number	181.49(60.49)	73.13(23.31)	.879	NS	.051	**.009**		ANOVA
GM number	66.16(36.75)	111.84(64.42)	.635	NS	.304	**.000**		ANOVA
BC number	2.33(0.75)	1.52(0.59)	.238	NS	.108	**.003**		ANOVA
BC biomass	7.60(2.36)	8.46(3.82)	.191	NS	.810	**.003**		ANOVA
SPO number	0.82(0.39)	2.38(1.02)	.764	NS overall Sig.* for dense NS for open water	.271	.149	.171+	ANCOVA
AC number	9.55(3.75)	9.72(4.00)	.807	NS	.977	**.000**		ANOVA
SM number	1.23(0.94)	0.38(0.15)	.817	NS	.639	**.014**		ANOVA
BRS number	24.55(6.54)	18.03(5.01)	.909	NS	.356	**.000**		ANOVA
BRS biomass	30.34(8.35)	28.64(8.32)	.774	Sig.*overall NS for dense NS for open water	.117	**.000**	**.005+**	ANCOVA
Env. variables								
WC.	1.51(0.14)	1.77(.018)			.366			Friedman's
Sal.	6.94(1.07)	8.44(1.10)			**.001**			Friedman's
Temp.	22.52(0.47)	22.16(0.70)			.366			Friedman's

	Summer								
BA number		64.23(24.39)	177.54(69.78)	.055	Sig.*overall Sig.* for dense NS for open water	.687	**.000**	**.001+**	ANCOVA
GM number		38.44(28.79)	11.96(4.42)	.594	NS	.814	.389		ANOVA
SM number		0.83(0.32)	1.86(0.58)	.785	NS	**.040**	**.000**		ANOVA
BRS number		4.33(1.86)	3.99(1.55)	.619 (but with non-homogenous variance)	NS	.527			Friedman's
BRS biomass		10.62(4.32)	11.49(4.27)	.442 (but with non-homogenous variance)	NS	.527			Friedman's
Env. variables									
WC.		2.10(.0.21)	1.95(.18)			.522	**.000**		ANOVA
Sal.		6.91(1.19)	8.38(1.47)			**.007**			Friedman's
Temp.		29.70(0.22)	29.74(0.27)			.366			Friedman's
	Fall								
BA number		29.63(8.15)	30.73(9.12)	.633	NS	.908	**.003**		ANOVA
SPS number		0.45(0.18)	0.35(0.15)	.725 (but with non-homogenous variance)	NS	.317			Friedman's
SPS biomass		1.50(0.67)	0.99(0.49)	.926 (but with non-homogenous variance)	NS	.317			Friedman's
WS number		8.09(6.87)	18.11(10.4)	.225	Sig.**overall Sig.* for dense Sig.** for open water	**.006**	**.002**	**.000+**	ANCOVA
WS biomass		8.47(6.58)	25.29(14.44)	.471	Sig.**overall Sig.* for dense Sig.** for open water	**.007**	**.003**	**.000+**	ANCOVA
RD number		0.18(0.10)	1.70(1.35)	.146	NS	.094	**.001**		ANOVA
RD biomass		0.09(0.05)	0.17(0.08)	.606 (but with non-homogenous variance)	NS	.705			Friedman's
Env. variables									
WC.		2.22(0.17)	2.02(0.14)			.089	**.000**		ANOVA
Sal.		11.41(1.02)	12.15(1.17)			.366			Friedman's

Temp.		22.64(0.35)	22.03(0.63)			.366			Friedman's
	Winter								
BA number		25.63(9.49)	26.39(9.41)	.127	NS	.953	.226		ANOVA
BC number		5.09(1.37)	4.28(0.91)	.102	NS overall NS for dense Sig.* for open water	.594	.176	.118+	ANCOVA
BC biomass		11.20(4.04)	9.06(3.19)	.619	NS	.641	**.046**		ANOVA
SPO number		0.08(0.04)	3.61(2.46)	.075	Sig.**overall NS for dense Sig.** for open water	.120	.238	**002**+	ANCOVA
AC number		14.69(5.85)	16.42(5.50)	**.026**	Sig.**overall NS for dense Sig.** for open water	.366			Friedman's
SM number		2.84(2.41)	2.09(1.07)	.726	Sig.*overall NS for dense NS for open water	.761	.451	.121+	ANCOVA
WS number		0.48(0.22)	1.11(0.54)	.996	Sig.**overall Sig.**for dense Sig.*for open water	.450	.368	**.003+**	ANCOVA
WS biomass		0.39(0.17)	1.25(0.59)	.719	Sig.**overall Sig.**for dense Sig.*for open water	.276	.377	**.002+**	ANCOVA
RD number		0.62(0.26)	2.24(1.15)	.300 (but with non-homogenous variance)	Sig.*overall NS for dense NS for open water NS	.058			Friedman's
RD biomass		0.67(0.24)	1.74(0.48)	.712	NS	.058			Friedman's
Env. variables									
WC		1.87(0.10)	1.78(0.13)			.371	**.000**		ANOVA
Sal.		7.35(0.75)	8.33(1.05)			.366			Friedman's
Temp.		14.25(0.32)	14.37(0.38)			.583	**.000**		ANOVA

Table B3. Resulting uncorrelated factor matrix for trawl variables. Numbers represent correlations (loadings) between variables and factors. Factors 1, 2, and 3 were considered to represent temperature and Summer, secchi disk depth, and salinity, respectively. These factors were used to test for changes in salinity, temperature and secchi disk depth over time.

	Factor			
	1	2	3	4
Secchi Disk Depth	-.063	**.989**	-.132	.012
Salinity	-.085	-.133	**.987**	-.022
Temperature	**.858**	.047	-.087	.504
Spring	-.995	.074	.061	-.006
Summer	**.995**	-.074	-.061	.006

Table B4. Resulting uncorrelated factor matrix for seine variables. Numbers represent correlations (loadings) between variables and factors. Factors 1, 4, and 5 were considered to represent temperature and Summer, salinity, and secchi disk depth, respectively. These factors were used to test for changes in salinity, temperature and secchi disk depth over time.

	Factor					
	1	2	3	4	5	6
Secchi Disk Depth	.059	.091	.072	-.040	**.991**	-.001
Salinity	-.008	.043	.151	**.987**	-.041	-.001
Temperature	**.989**	.003	-.006	-.026	.062	.131
Fall	.025	.167	**.967**	.172	.088	-.004
Spring	.028	**-.980**	-.160	-.055	-.103	-.003
Summer	**.770**	.430	-.432	-.048	.035	-.181
Winter	**-.817**	.387	-.378	-.070	-.019	.187

Table B5. Resulting uncorrelated factor matrix for trawl variables. Numbers represent correlations (loadings) between variables and factors. Factors 1, 2, 3, and 4 were considered to represent temperature and Summer, secchi disk depth, year, and salinity respectively. These factors were used to test for relationships between these variables and catch.

	Factor				
	1	2	3	4	5
Secchi Disk Depth	-.064	**.989**	.021	-.131	.011
Salinity	-.097	-.142	.213	**.962**	-.014
Temperature	**.890**	.052	-.001	-.078	.446
Year	.027	.022	**.979**	.201	-.001
Spring	**-.994**	.072	-.019	.055	.059
Summer	**.994**	-.072	.019	-.055	-.059

Table B6. Results of non-parametric correlations between species' catch (numbers (n) and biomass (b)) and uncorrelated factors of temperature, salinity, secchi disk depth and time for 1990-2000 trawl collections (Table B5). For the correlations, average species' biomass and number and salinity values/station/season/year were used. Species abbreviations as in Table 1. Bold type indicates significance at the 0.05 level after the Dunn-Sidak correction.

	Spearman's rho/ P-value			
	BRSn	BRSb	WSn	WSb
Factor 1 (Temperature and Summer)	**-.431/ .000**	**-.267/ .000**	.143/ .232	.177/ .136
Factor 2 (Secchi disk depth)	**-.302/ .000**	**-.331/ .000**	-.211/ .075	-.198/ .096
Factor 3 (Year)	.072/ .300	.070/ .318	.004/ .971	-.002/ .988
Factor 4 (Salinity)	**.264/ .000**	**.363/ .000**	.182/ .127	.208/ .080

Table B7. Results of non-parametric correlations between species' catch (numbers (n) and biomass (b)) and uncorrelated factors of temperature, salinity, secchi disk depth, and time for 1990-2000 seine collections (Table B8). For the correlations, average species' biomass and number and salinity values/station/season/year were used. Species abbreviations as in Table 1. Bold type indicates significance at the 0.05 level after the Dunn-Sidak correction.

	Spearman's rho/ P-value														
	BAn	GMn	BCn	BCb	SPSn	SPSb	SPOn	ACn	SMn	BRSn	BRSb	WSn	WSb	RDn	RDb
Factor 1 (Temperature and Summer)	.180/ .017	.107/ .158	**-.441/ .000**	**-.239/ .001**	-.065/ .395	-.093/ .222	-.047/ .535	**-.353/ .000**	.040/ .602	**.288/ .000**	**.361/ .000**	.030/ .692	.025/ .744	**-.388/ .000**	**-.402/ .000**
Factor 4 (Salinity)	.020/ .791	-.053/ .489	.193/ .011	.146/ .054	.110/ .147	.121/ .112	.218/ .004	-.064/ .403	.122/ .108	.084/ .266	.100/ .190	**.368/ .000**	**.374/ .000**	.087/ .255	.077/ .308
Factor 5 (Secchi Disk Depth)	-.076/ 317	-.145/ .056	-.028/ .716	-.098/ .195	**.251/ .001**	**.244/ .001**	-.138/ .068	-.047/ .536	.064/ .400	-.179/ .018	-.182/ .016	.046/ .549	.043/ .571	.180/ .017	.161/ .033
Factor 6 (Year)	**.398/ .000**	-.155/ .040	.047/ .537	-.096/ .208	-.137/ .071	-.152/ .045	.016/ .829	.163/ .031	**-.264/ .000**	.169/ .025	.170/ .025	.013/ .870	.019/ .802	.147/ .052	.120/ .114

Table B8. Resulting uncorrelated factor matrix for seine variables. Numbers represent correlations (loadings) between variables and factors. Factors 1, 4, 5, and 6 represent temperature , salinity, secchi disk depth, and year, respectively. These factors were used to test for relationships between these variables and catch.

	Factor						
	1	2	3	4	5	6	7
Year	-.006	.000	-.012	.140	-.035	**.989**	-.001
Secchi Disk Depth	.060	.092	.072	-.037	**.990**	-.035	-.000
Salinity	-.008	.043	.157	**.975**	-.039	.147	-.001
Temperature	**.988**	.003	-.006	-.024	.060	-.017	.138
Fall	.025	.167	**.967**	.169	.086	-.012	-.004
Spring	.028	**-.980**	-.161	-.054	-.102	.004	-.003
Summer	.772	.430	-.431	-.049	.034	.014	-.175
Winter	**-.818**	.387	-.379	-.067	-.018	-.030	.181

Table B9. Mean values for species' (numbers and biomass (g)) and environmental variables and standard errors (SE) collected during Spring and Summer (1990-2000) in 3 marsh-water categories from the trawl. The P values for the factors (marsh-water (Mw), year (Yr), and covariates (salinity (Sal.) and distance from the gulf (dfg)) are from a 2-way ANOVA or ANCOVA. ANCOVA was used when the test of preliminary assumptions of linearity between catch and covariates (NS=nonsignificant; Sig.*= 0.05<P<0.10; Sig.**=P<0.05) and of equal slopes were met. 5 stations represented each marsh-water type. Average species' biomass and number and salinity values/station/season/year were used as replicates. Biomass, number, and environmental variables were ln+1 transformed if needed to meet assumption of homogeneity of variance, else they were left untransformed. The contrast p-values are from post-hoc tests (with Bonferroni correction) of predicted values from the ANCOVA or ANOVA between: 1) broken and dense, 2) broken and open water, and 3) dense and open water marsh types. If the homogeneity of variance assumption was not met, post-hoc contrasts that do not assume equal variances were used. Species' abbreviations as in Table 1. Bold type indicates significance at the 0.05 level.

Taxon		Broken	Dense	Open water	Equal Slopes test	Linearity Assumption test (Sal.)	Linearity Assumption test (Dfg.)	Significance of Effects				Contrast Values			Test used
	Spring	Mean(S.E.)	Mean(S.E.)	Mean (S.E.)				Mw	Yr	Sal.	Dfg	1	2	3	
BRS number		170.91(23.20)	68.72(9.64)	96.15(14.10)	.678	Sig.** overall NS for broken NS for dense Sig.** for open water	NS	**.000**	**.000**	.149+		**.000**	**.000**	1.00	ANCOVA
BRS biomass		362.33(44.18)	142.73(26.70)	229.49(37.35)	.479	Sig.** overall Sig.** for broken Sig.* for dense Sig.** for open water	Sig.** overall NS for broken NS for dense NS for open water	.062	**.000**	**.001+**	**.048+**				ANCOVA
Env. variables															
Secchi		1.42(0.04)	1.88(0.17)	1.63(0.12)				**.017**	**.000**			**.032**	.295	.554	ANOVA
Sal.		17.10(0.74)	10.64(0.82)	13.87(0.86)				**.000**	**.000**			**.000**	**.017**	**.023**	ANOVA
Temp.		23.33(.22)	23.93(0.29)	23.63(0.25)				**.048**	**.000**			**.042**	.673	.613	ANOVA

	Summer														
BRS number		40.45(5.2)	23.75(4.16)	15.77(3.22)	**.016**	NS	NS overall NS for broken * for dense NS for open water	**.000**	**.000**		.933+	**.010**	**.000**	.087	ANCOVA
BRS biomass		112.79(15.63)	68.49(11.44)	44.6(7.22)	.076	NS	Sig.**overall NS for broken Sig.**for dense NS for open water	**.000**	**.002**		**.014-**	**.014**	**.000**	.354	ANCOVA
WS number		5.75(2.02)	4.94(1.66)	0.27(0.10)	.090	Sig. * overall NS for broken NS for dense NS for open water	Sig.**overall Sig.**for broken Sig.**for dense NS for open water	**.003**	.397	.138-	**.000-**	1.00	**.008**	**.019**	ANCOVA
WS biomass		7.49(3.02)	5.61(2.03)	0.47(0.22)	.049	Sig.** overall Sig.* for broken NS for dense NS for open water	Sig.**overall Sig.**for broken Sig.**for dense NS for open water	**.015**	.219	.269-	**.000-**	1.00	**.022**	.090	ANCOVA
Env. variables															
Secchi		1.39(.0.06)	1.46(0.09)	1.50(0.07)				.521	**.007**						ANOVA
Sal.		14.17(1.24)	10.08(1.29)	12.07(1.42)				**.005**	**.000**			**.003**	.248	.304	ANOVA
Temp.		28.88(0.27)	29.22(0.20)	29.12(0.24)				.453	**.000**						ANOVA

Table B10. Mean values for species' catch (numbers and biomass (g)) and environmental variables and standard errors (SE) collected during Spring, Summer, Fall and Winter (1990-2000) in 2 marsh-water categories from the seine. The P values for the factors (marsh-water (Mw), year (Yr), and covariates (salinity (Sal.) and distance from the gulf (dfg)) are from a 2-way ANOVA, ANCOVA, or the Friedman's Test. ANCOVA was used when the tests of preliminary assumption of linearity between catch and the covariate(s) (NS=nonsignificant; Sig.*= 0.05<P<0.10; Sig.**=P<0.05) and equal slopes were met. 2 stations represented each marsh-water type. Average species' biomass and number and salinity values/station/season/year were used as replicates in the ANOVA or ANCOVA. Biomass and number were ln+1 transformed if needed to meet assumption of homogeneity of variance, else they were left untransformed. When the homogeneity of variance assumption was not met, the Friedman's test was used. Species' abbreviations as in Table 1. Bold type indicates significance at the 0.05 level.

Taxon		Dense	Open water	Equal Slopes test	Linearity Assumption test (Sal.)	Linearity Assumption test (dfg)	Significance of Effects				Test used
	Spring	Mean (S.E.)	Mean (S.E.)				Mw	Yr	Sal.	Dfg	
BA number		181.49(60.49)	73.13(23.31)	.862	NS	NS	.051	**.009**			ANOVA
GM number		66.16(36.75)	111.84(64.42)	.354	NS	NS	.304	**.000**			ANOVA
BC number		2.33(0.75)	1.52(0.59)	.083	NS	NS overall NS for dense Sig.**for open water	**.034 (but with nonhomogenous variance)**	**.001**		**.016-**	ANCOVA
BC biomass		7.60(2.36)	8.46(3.82)	.264	NS	Sig.**overall NS for dense Sig.**for open water	.198	**.007**		**.003-**	ANCOVA
SPO number		0.82(0.39)	2.38(1.02)	.764	NS overall Sig.* for dense NS for open water	NS	.271	.149	.171+		ANCOVA
AC number		9.55(3.75)	9.72(4.00)	.708	NS	Sig.*overall NS for dense NS for open water	.599	**.000**		**.010-**	ANCOVA
SM number		1.23(0.94)	0.38(0.15)	.885	NS	NS overall NS for dense Sig.* for open water	.440	**.011**		.106-	ANCOVA
BRS number		24.55(6.54)	18.03(5.01)	.717	NS	NS overall Sig.*for dense NS for open water	.125	**.000**		**.005-**	ANCOVA

BRS biomass		30.34(8.35)	28.64(8.32)	.881	Sig.*overall NS for dense NS for open water	Sig.*overall Sig.** for dense NS for open water	.190	**.000**	.794-	.173-	ANCOVA
Env. variables											
Secchi		1.51(0.14)	1.77(.018)				.366				Friedman’s
Sal.		6.94(1.07)	8.44(1.10)				**.001**				Friedman’s
Temp.		22.52(0.47)	22.16(0.70)				.366				Friedman’s
	Summer										
BA number		64.23(24.39)	177.54(69.78)	.232	Sig.*overall Sig.* for dense NS for open water	Sig.**overall Sig.** for dense Sig.* for open water	.628	**.000**	.654-	**.033-**	ANCOVA
GM number		38.44(28.79)	11.96(4.42)	.821	NS	Sig.**overall NS for dense NS for open water	.556	.330		.062-	ANCOVA
SM number		0.83(0.32)	1.86(0.58)	.556	NS	Sig.*overall NS for dense NS for open water	.077	**.000**		**.032-**	ANCOVA
BRS number		4.33(1.86)	3.99(1.55)	.109 (but with non-homogenous variance)	NS	Sig.*overall NS for dense Sig.** for open water	.527				Friedman’s
BRS biomass		10.62(4.32)	11.49(4.27)	.173 (but with non-homogenous variance)	NS	Sig.**overall NS for dense Sig.** for open water	.527				Friedman’s
Env. variables											
Secchi		2.10(.0.21)	1.95(.18)				.522	**.000**			ANOVA
Sal.		6.91(1.19)	8.38(1.47)				**.007**				Friedman’s
Temp.		29.70(0.22)	29.74(0.27)				.366				Friedman’s

	Fall										
BA number		29.63(8.15)	30.73(9.12)	.819	NS	Sig.**overall NS for dense NS for open water	.908	**.003**			ANOVA
SPS number		0.45(0.18)	0.35(0.15)	.725 (but with non-homogenous variance)	NS	NS	.317				Friedman’s
SPS biomass		1.50(0.67)	0.99(0.49)	.926 (but with non-homogenous variance)	NS	NS	.317				Friedman’s
WS number		8.09(6.87)	18.11(10.4)	.274	Sig.**overall Sig.* for dense Sig.** for open water	Sig.**overall NS for dense Sig.* for open water	**.006**	**.006**	**.029+**	.575+	ANCOVA
WS biomass		8.47(6.58)	25.29(14.44)	.412	Sig.**overall Sig.* for dense Sig.** for open water	Sig.**overall NS for dense Sig.* for open water	**.007**	**.010**	**.044+**	.642+	ANCOVA
RD number		0.18(0.10)	1.70(1.35)	.146	NS	NS	.094	**.001**			ANOVA
RD biomass		0.09(0.05)	0.17(0.08)	.606 (but with non-homogenous variance)	NS	NS	.705				Friedman’s
Env. variables											
Secchi		2.22(0.17)	2.02(0.14)				.089	**.000**			ANOVA
Sal.		11.41(1.02)	12.15(1.17)				.366				Friedman’s
Temp.		22.64(0.35)	22.03(0.63)				.366				Friedman’s
	Winter										
BA number		25.63(9.49)	26.39(9.41)	.029	NS	NS	.953	.226			ANOVA
BC number		5.09(1.37)	4.28(0.91)	.159	NS overall NS for dense Sig.* for open water	NS overall NS for dense Sig.**for open water	.598	.214	.604+	.950+	ANOVA
BC biomass		11.20(4.04)	9.06(3.19)	.492	NS	NS	.641	**.046**			ANOVA

SPO number	0.08(0.04)	3.61(2.46)	.305	Sig.**overall NS for dense Sig.** for open water	Sig.**overall NS for dense Sig.*for open water	.076	.153	**.017**+	.175+	ANCOVA
AC number	14.69(5.85)	16.42(5.50)	.101	Sig.**overall NS for dense Sig.** for open water	Sig.**overall NS for dense Sig.**for open water	.366	**.000**	**.039+**	.460+	ANCOVA
SM number	2.84(2.41)	2.09(1.07)	.726	Sig.*overall NS for dense NS for open water	NS	.317				Friedman's
WS number	0.48(0.22)	1.11(0.54)	.544	Sig.**overall Sig.**for dense Sig.*for open water	Sig.**overall Sig.**for dense Sig.**for open water	.446	.471	.198+	.859+	ANCOVA
WS biomass	0.39(0.17)	1.25(0.59)	.493	Sig.**overall Sig.**for dense Sig.*for open water	Sig.**overall Sig.**for dense Sig.**for open water	.257	.440	.109+	.655+	ANCOVA
RD number	0.62(0.26)	2.24(1.15)	.124	Sig.*overall NS for dense NS for open water	Sig.*overall NS for dense NS for open water	.120	**.000**	**.016-**	**.005-**	Friedman's
RD biomass	0.67(0.24)	1.74(0.48)	.712	NS		.058				Friedman's
Env. variables										
Secchi	1.87(0.10)	1.78(0.13)				.371	**.000**			ANOVA
Sal.	7.35(0.75)	8.33(1.05)				.366				Friedman's
Temp.	14.25(0.32)	14.37(0.38)				.583	**.000**			ANOVA

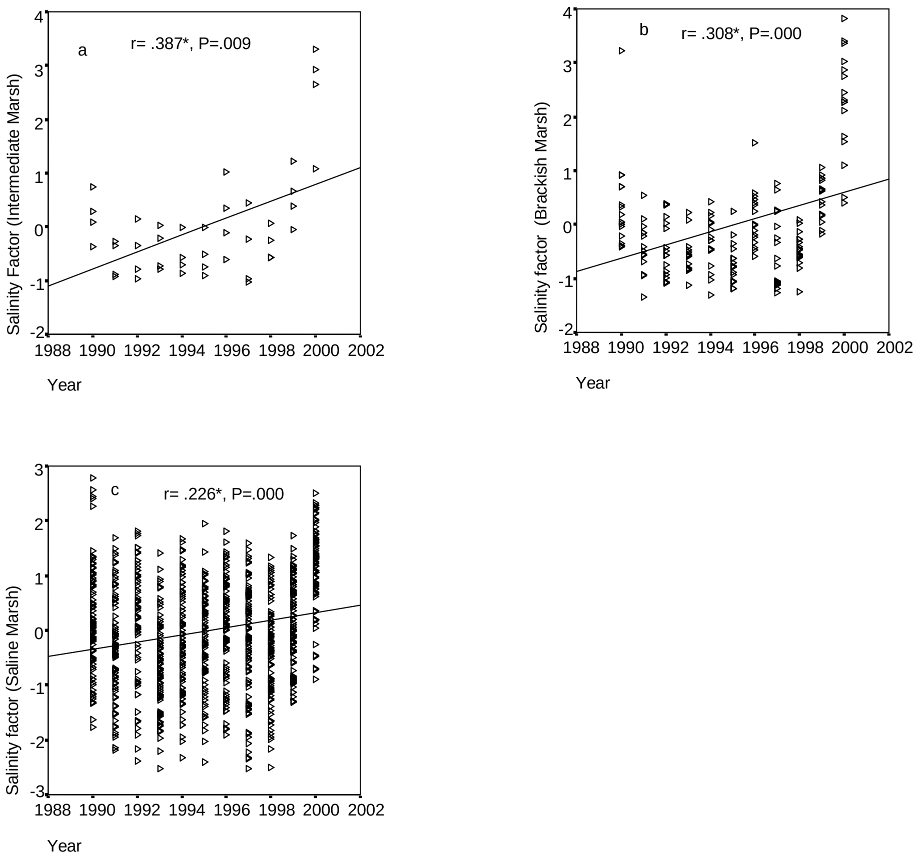


Figure B1. Scatterplots of salinity factors (uncorrelated to gear type and season; from seine, 6' and 16'trawl, gillnet and trammel nets) for each salinity zone and year. * indicates significant correlation (Spearman's rho) at the 0.05 level.

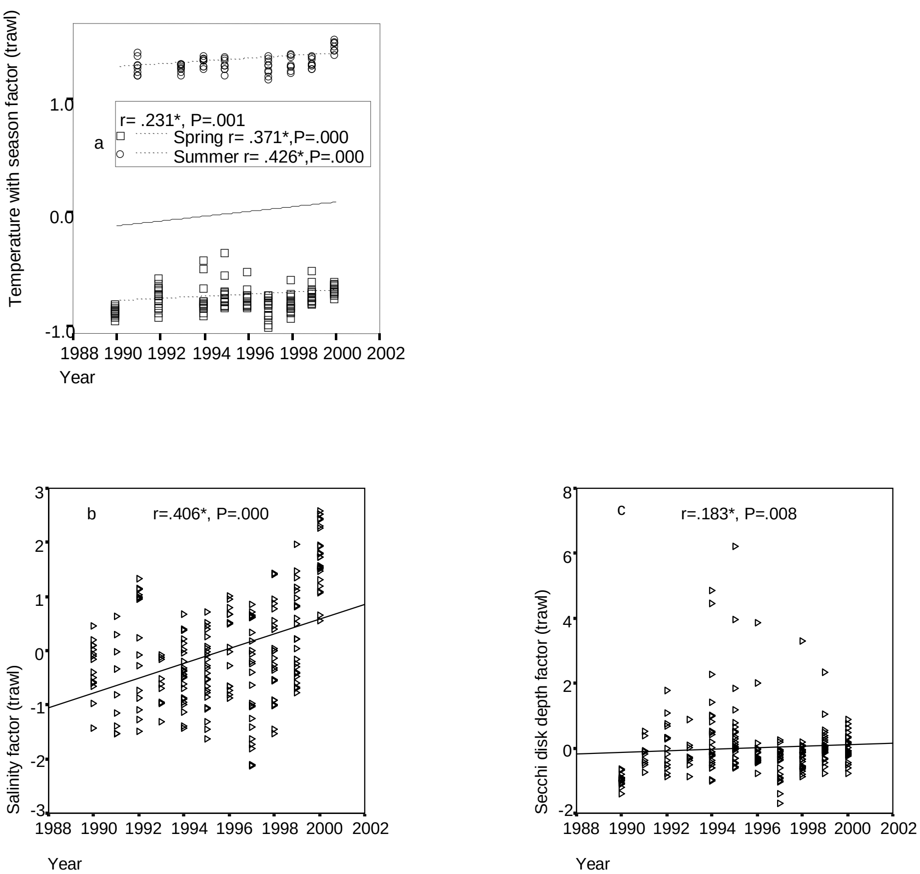


Figure B2. Scatterplots of temperature, salinity, and secchi disk depth factor scores (uncorrelated to each other and season; from trawl data) and year. * indicates significant correlation (Spearman's rho) at the 0.05 level.

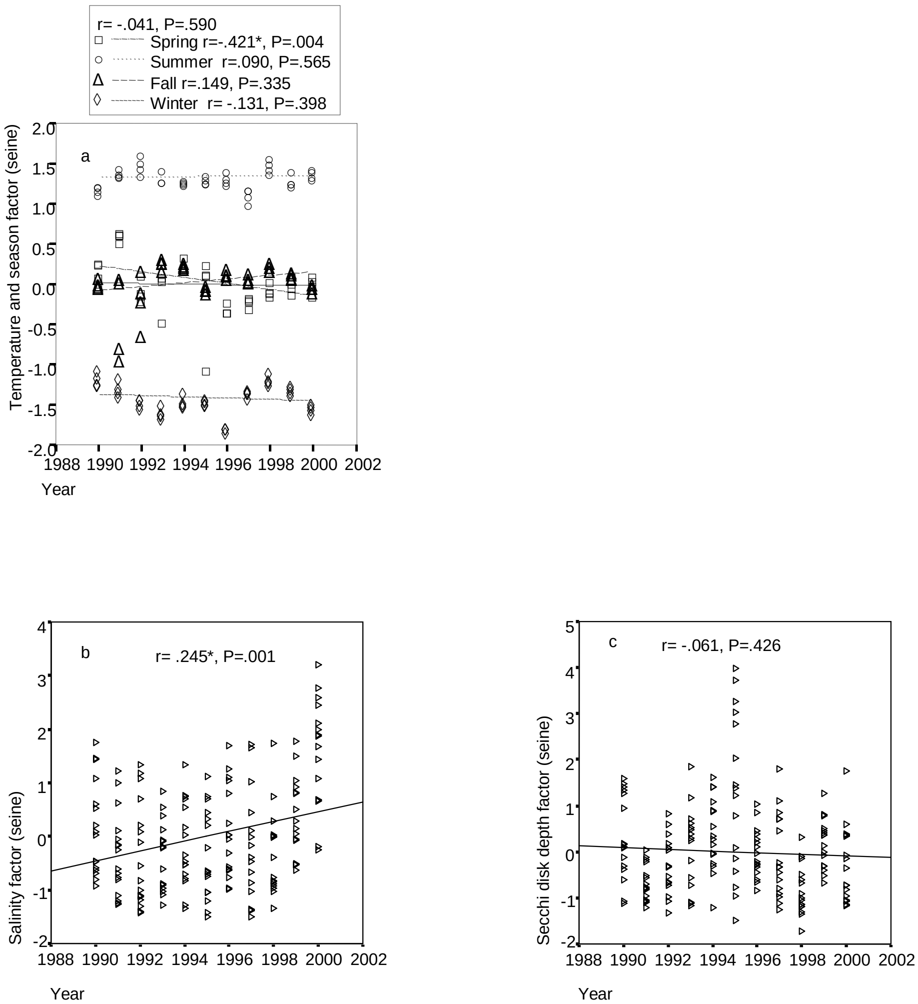


Figure B3. Scatterplots of temperature, salinity, and water secchi disk depth factors (uncorrelated to each other and season; from seine data) and year. * indicates significant correlation (Spearman's rho) at the 0.05 level.

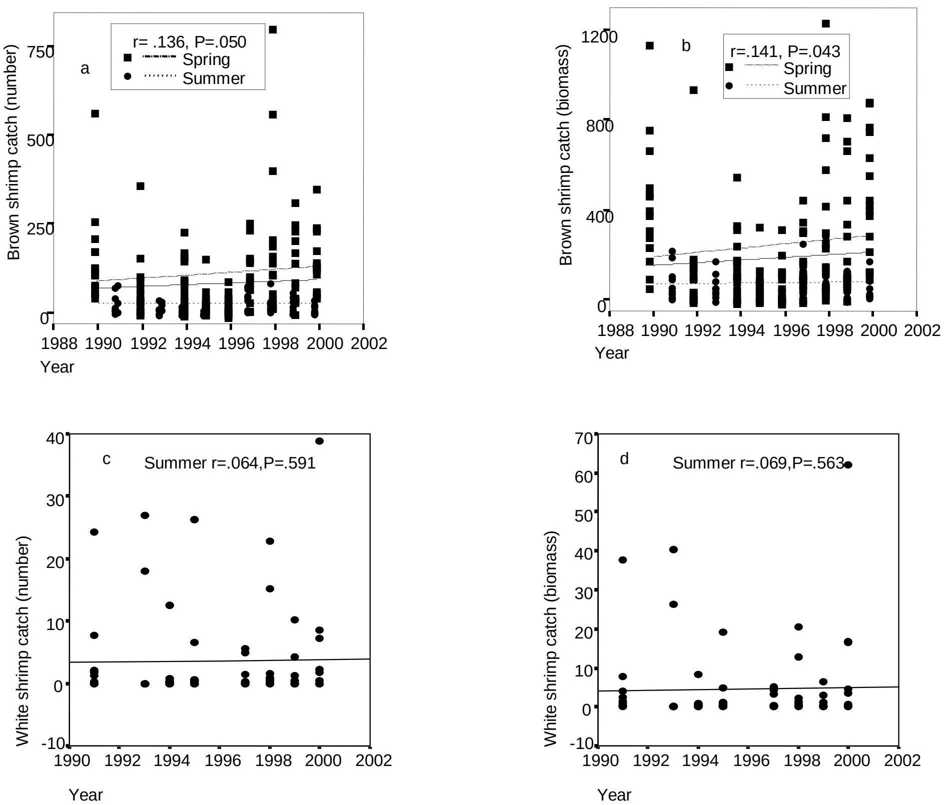


Figure B4. Scatterplots of species' catch (numbers and biomass (g); from the trawl; by season) and year. Solid lines, Spearman's rho, and P-values represent relationships between catch and year (without seasonal effects). * indicates significance at the 0.05 level (adjusted for multiple comparisons by the Dunn-Sidak method).

APPENDIX C – Task 3 Results

Table C1. Comparison of densities (mean m^{-2} + 1 S.E.) of decapod crustaceans and fishes collected among marsh (Saline, Brackish, Intermediate) and habitat (marsh vegetation, ponds) types in April-May 2002. Each mean is estimated from 16 marsh and 44 pond samples. The total number (TN) of species collected in each taxonomic category and the total number and relative abundance (RA) of each taxon also are given.

	SALINE				BRACKISH				INTERMEDIATE					
	Marsh		Pond		Marsh		Pond		Marsh		Pond			
Species	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	TN	RA (%)
Crustaceans (Total=14 species)														
Daggerblade grass shrimp	8.8	(1.91)	0.1	(0.05)	3.0	(1.11)	0.3	(0.13)	0.1	(0.06)	4.0	(1.51)	384	25.3%
Harris mud crab	0.0	(0.00)	1.8	(0.51)	0.0	(0.00)	2.5	(0.72)	0.0	(0.00)	0.5	(0.20)	220	14.5%
Unidentified fiddler crab	11.6	(2.21)	0.1	(0.04)	0.8	(0.23)	0.1	(0.04)	0.1	(0.13)	0.0	(0.00)	208	13.7%
Brown shrimp	0.8	(0.27)	1.6	(0.35)	0.4	(0.20)	1.0	(0.20)	0.0	(0.00)	0.7	(0.18)	180	11.9%
Blue crab	0.8	(0.23)	0.4	(0.11)	1.1	(0.37)	0.6	(0.14)	0.2	(0.10)	0.9	(0.20)	129	8.5%
Unidentified Xanthidae	0.0	(0.00)	2.0	(1.19)	0.0	(0.00)	0.1	(0.04)	0.0	(0.00)	0.0	(0.00)	93	6.1%
Brackish grass shrimp	0.0	(0.00)	0.0	(0.00)	0.8	(0.52)	0.0	(0.02)	0.0	(0.00)	1.5	(0.49)	82	5.4%
Gulf marsh fiddler crab	3.2	(2.04)	0.0	(0.00)	0.6	(0.41)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	61	4.0%
Heavy marsh crab	2.6	(0.60)	0.1	(0.09)	0.7	(0.22)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	57	3.8%
Flatback mud crab	0.0	(0.00)	0.8	(0.44)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	35	2.3%
Squareback marsh crab	1.7	(0.71)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	28	1.8%
Pink shrimp	0.0	(0.00)	0.2	(0.12)	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.02)	15	1.0%
Atlantic mud crab	0.1	(0.06)	0.2	(0.13)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	11	
Unidentified Callinectes	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	4	

Bigclaw snapping shrimp	0.0	(0.00)	0.1	(0.04)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	3	
Unidentified Portunidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	2	
White shrimp	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	2	
Thinstripe hermit crab	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1	
Total Crustaceans	29.6	(3.13)	7.4	(1.99)	7.4	(1.63)	4.5	(0.78)	0.4	(0.16)	7.7	(1.75)	1515	
Fishes (Total=32 species)														
Sheepshead minnow	1.3	(0.82)	6.4	(4.36)	9.6	(6.27)	0.2	(0.12)	1.1	(0.68)	3.9	(1.08)	670	26.5%
Rainwater killifish	2.4	(1.20)	4.4	(3.11)	2.3	(0.95)	0.6	(0.28)	0.6	(0.35)	6.2	(1.55)	578	22.8%
Naked goby	0.0	(0.00)	1.9	(1.12)	0.0	(0.00)	1.1	(0.75)	0.1	(0.06)	0.7	(0.22)	207	8.2%
Gulf menhaden	0.0	(0.00)	0.2	(0.18)	0.0	(0.00)	0.3	(0.27)	0.0	(0.00)	2.5	(2.50)	150	5.9%
Unidentified Gobiidae	0.1	(0.09)	2.7	(2.11)	0.0	(0.00)	0.3	(0.23)	0.0	(0.00)	0.3	(0.32)	147	5.8%
Gulf pipefish	0.0	(0.00)	0.1	(0.04)	0.0	(0.00)	0.2	(0.08)	0.0	(0.00)	2.0	(0.51)	119	4.7%
Bay anchovy	0.0	(0.00)	1.2	(0.41)	0.0	(0.00)	0.7	(0.37)	0.0	(0.00)	0.0	(0.03)	113	4.5%
Inland silverside	0.8	(0.44)	1.2	(0.96)	0.6	(0.29)	0.1	(0.07)	0.0	(0.00)	0.5	(0.16)	109	4.3%
Speckled worm eel	0.0	(0.00)	0.5	(0.16)	0.0	(0.00)	0.5	(0.13)	0.0	(0.00)	0.3	(0.15)	73	2.9%
Bayou killifish	0.9	(0.62)	0.0	(0.00)	0.6	(0.45)	0.0	(0.00)	1.6	(0.75)	0.1	(0.06)	55	2.2%
Gulf killifish	0.9	(0.46)	0.0	(0.00)	1.6	(1.02)	0.0	(0.00)	0.1	(0.06)	0.0	(0.03)	42	1.7%
Clown goby	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.07)	0.0	(0.00)	0.6	(0.46)	39	1.5%
Unidentified Fundulidae	0.0	(0.00)	0.0	(0.02)	0.2	(0.14)	0.0	(0.05)	0.1	(0.06)	0.4	(0.26)	28	1.1%
Atlantic croaker	0.0	(0.00)	0.1	(0.05)	0.0	(0.00)	0.1	(0.05)	0.0	(0.00)	0.1	(0.06)	20	
Unidentified fish	0.1	(0.06)	0.0	(0.02)	0.1	(0.06)	0.0	(0.00)	0.1	(0.06)	0.2	(0.21)	14	

Diamond killifish	0.2	(0.10)	0.0	(0.00)	0.4	(0.22)	0.0	(0.00)	0.2	(0.14)	0.0	(0.00)	13
Bay whiff	0.1	(0.06)	0.1	(0.08)	0.0	(0.00)	0.1	(0.04)	0.0	(0.00)	0.0	(0.02)	12
Code goby	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.1	(0.04)	11
Unidentified Clupeidae	0.0	(0.00)	0.2	(0.21)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	10
Sailfin molly	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.2	(0.21)	9
Atlantic needlefish	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.05)	9
Spot	0.0	(0.00)	0.1	(0.05)	0.0	(0.00)	0.1	(0.05)	0.0	(0.00)	0.0	(0.00)	8
Skilletfish	0.0	(0.00)	0.1	(0.07)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	6
Darter goby	0.1	(0.09)	0.0	(0.02)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	6
Ladyfish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.07)	4
Alligator gar	0.0	(0.00)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.1	(0.13)	0.0	(0.00)	4
Unidentified Engraulidae	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	3
Spanish sardine	0.0	(0.00)	0.1	(0.05)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	3
Unidentified Bothidae	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	2
Unidentified Eleotridae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.05)	0.0	(0.00)	0.0	(0.00)	2
Striped mullet	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	2
Unidentified Sciaenidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.02)	2
Unidentified Atherinidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	1
Striped blenny	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Sand seatrout	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Western mosquitofish	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Bigmouth sleeper	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Unidentified Gobiosoma	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Pinfish	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1

Gulf toadfish	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Southern flounder	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	1
Red drum	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	1
Least puffer	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Total Fishes	7.2	(2.90)	19.6	(8.47)	15.4	(8.05)	4.3	(0.81)	3.8	(1.30)	19.2	(3.86)	2481

Table C2. Comparison of biomasses (mean m^{-2} + 1 S.E.) of decapod crustaceans and fishes collected among marsh (Saline, Brackish, Intermediate) and habitat (marsh vegetation, ponds) types in April-May 2002. Each mean is estimated from 16 marsh and 44 pond samples. The total biomass (TB; g) and relative biomass (RB) of each taxon within the major taxonomic groups (crustaceans and fishes) also are given.

	SALINE				BRACKISH				INTERMEDIATE					
	Marsh		Pond		Marsh		Pond		Marsh		Pond		TB (g)	RB (%)
Species	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.		
Crustaceans														
Blue crab	5.2	(2.05)	1.1	(0.53)	6.6	(2.93)	0.4	(0.24)	2.4	(1.43)	1.8	(0.88)	376.11	43.4%
Brown shrimp	0.3	(0.15)	0.7	(0.18)	0.6	(0.48)	0.5	(0.18)	0.0	(0.00)	1.4	(0.47)	133.31	15.4%
Unidentified fiddler crab	3.1	(0.81)	0.0	(0.01)	1.5	(0.63)	0.0	(0.01)	0.8	(0.77)	0.0	(0.00)	86.56	10.0%
Heavy marsh crab	2.1	(0.71)	0.0	(0.01)	2.9	(1.20)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	80.38	9.3%
Daggerblade grass shrimp	1.3	(0.23)	0.0	(0.01)	0.8	(0.31)	0.0	(0.02)	0.0	(0.01)	0.5	(0.28)	57.48	6.6%
Harris mud crab	0.0	(0.00)	0.3	(0.07)	0.0	(0.00)	0.5	(0.15)	0.0	(0.00)	0.3	(0.14)	45.75	5.3%
Gulf marsh fiddler crab	1.8	(0.82)	0.0	(0.00)	0.7	(0.38)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	39.88	4.6%
Unidentified Xanthidae	0.0	(0.00)	0.5	(0.35)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	21.49	2.5%
Atlantic mud crab	0.2	(0.18)	0.4	(0.28)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	19.43	2.2%
Squareback marsh crab	1.2	(0.62)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	19.33	2.2%
Flatback mud crab	0.0	(0.00)	0.4	(0.22)	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	18.53	2.1%
Brackish grass shrimp	0.0	(0.00)	0.0	(0.00)	0.2	(0.11)	0.0	(0.01)	0.0	(0.00)	0.3	(0.10)	16.20	1.9%
Pink shrimp	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.04)	0.0	(0.00)	0.0	(0.02)	3.88	
Bigclaw snapping shrimp	0.0	(0.00)	0.1	(0.03)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	2.31	
Unidentified Callinectes	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.72	

Thinstripe hermit crab	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.51	
Unidentified Portunidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.07	
White shrimp	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.07	
Total Crustaceans	15.2	(2.68)	3.5	(1.24)	13.3	(4.34)	1.6	(0.36)	3.2	(1.54)	4.3	(1.12)	922.01	
Fishes														
Gulf menhaden	0.0	(0.00)	0.1	(0.09)	0.0	(0.00)	0.4	(0.35)	0.0	(0.00)	1.6	(1.61)	89.91	15.0%
Sheepshead minnow	0.0	(0.03)	0.1	(0.10)	1.9	(1.44)	0.1	(0.10)	0.1	(0.09)	0.5	(0.21)	66.59	11.1%
Spot	0.0	(0.00)	0.3	(0.23)	0.0	(0.00)	0.8	(0.41)	0.0	(0.00)	0.0	(0.00)	47.96	8.0%
Rainwater killifish	0.1	(0.03)	0.0	(0.03)	0.0	(0.02)	0.0	(0.01)	0.1	(0.05)	0.8	(0.16)	42.53	7.1%
Atlantic croaker	0.0	(0.00)	0.5	(0.22)	0.0	(0.00)	0.3	(0.15)	0.0	(0.00)	0.2	(0.10)	41.38	6.9%
Striped mullet	0.1	(0.12)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.9	(0.89)	40.89	6.8%
Naked goby	0.0	(0.00)	0.5	(0.19)	0.0	(0.04)	0.2	(0.07)	0.0	(0.00)	0.2	(0.10)	38.04	6.4%
Bay anchovy	0.0	(0.00)	0.6	(0.21)	0.0	(0.00)	0.3	(0.17)	0.0	(0.00)	0.0	(0.01)	37.89	6.3%
Red drum	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.8	(0.83)	0.0	(0.00)	0.0	(0.00)	36.58	6.1%
Gulf killifish	1.2	(0.74)	0.0	(0.00)	1.0	(0.61)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	34.75	5.8%
Speckled worm eel	0.0	(0.00)	0.1	(0.02)	0.0	(0.00)	0.1	(0.04)	0.0	(0.00)	0.2	(0.14)	17.08	2.9%
Bay whiff	0.0	(0.02)	0.1	(0.09)	0.0	(0.00)	0.2	(0.09)	0.0	(0.00)	0.0	(0.03)	14.91	2.5%
Bayou killifish	0.5	(0.27)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.1	(0.06)	0.0	(0.02)	12.49	2.1%
Clown goby	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.07)	0.0	(0.00)	0.2	(0.09)	11.87	2.0%
Inland silverside	0.0	(0.01)	0.1	(0.04)	0.0	(0.01)	0.1	(0.08)	0.0	(0.00)	0.1	(0.04)	10.36	1.7%
Southern flounder	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.2	(0.22)	0.0	(0.00)	0.0	(0.00)	9.56	1.6%
Gulf pipefish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.2	(0.05)	8.28	1.4%
Gulf toadfish	0.0	(0.00)	0.2	(0.18)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	7.84	1.3%
Pinfish	0.0	(0.00)	0.1	(0.11)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	4.77	
Diamond killifish	0.1	(0.04)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.1	(0.07)	0.0	(0.00)	4.37	

Striped blenny	0.0	(0.00)	0.1	(0.09)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	3.79
Code goby	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.04)	0.0	(0.00)	0.0	(0.02)	3.38
Unidentified Bothidae	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	2.13
Darter goby	0.1	(0.06)	0.0	(0.01)	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	2.10
Sand seatrout	0.0	(0.00)	0.0	(0.04)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1.57
Unidentified Sciaenidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	1.25
Unidentified Engraulidae	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.82
Bigmouth sleeper	0.0	(0.05)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.76
Least puffer	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.75
Sailfin molly	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.60
Unidentified Gobiidae	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.57
Unidentified Clupeidae	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.57
Unidentified fish	0.0	(0.01)	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.53
Unidentified Fundulidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.51
Atlantic needlefish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.50
Skilletfish	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.37
Spanish sardine	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.29
Ladyfish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.28
Alligator gar	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.13
Western mosquitofish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.04
Unidentified Eleotridae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.01
Unidentified Atherinidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.00
Unidentified Gobiosoma	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.00
Total Fishes	2.1	(0.81)	2.9	(0.52)	3.2	(1.67)	3.6	(1.18)	0.4	(0.17)	5.1	(1.84)	599.00

Table C3. Comparison of densities (mean m^{-2} + 1 S.E.) of decapod crustaceans and fishes collected among marsh (Saline, Brackish, Intermediate) and habitat (marsh vegetation, ponds) types in September 2002. Each mean is estimated from 16 marsh and 44 pond samples. The total number of species collected in each taxonomic category and the total number (TN) and relative abundance (RA) of each taxon also are given.

	SALINE				BRACKISH				INTERMEDIATE					
	Marsh		Pond		marsh		Pond		marsh		Pond		TN	RA (%)
Taxa	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.		
Crustaceans (Total=13 species)														
Blue crab	6.8	(1.73)	4.5	(0.83)	7.3	(1.92)	7.8	(2.39)	0.1	(0.06)	1.0	(0.44)	809	26.2%
Unidentified Palaemonetes	6.6	(2.18)	0.2	(0.08)	7.9	(4.72)	0.2	(0.14)	0.3	(0.25)	7.6	(2.02)	587	19.0%
Daggerblade grass shrimp	13.1	(4.03)	0.1	(0.07)	11.7	(7.34)	0.1	(0.07)	0.4	(0.20)	3.9	(0.87)	582	18.9%
Harris mud crab	0.4	(0.22)	2.9	(0.92)	0.8	(0.56)	7.9	(3.00)	0.0	(0.00)	0.3	(0.10)	506	16.4%
White shrimp	5.0	(2.55)	0.9	(0.71)	1.6	(1.50)	0.4	(0.15)	0.0	(0.00)	0.0	(0.02)	161	5.2%
Brackish grass shrimp	0.0	(0.00)	0.0	(0.00)	0.3	(0.31)	0.0	(0.00)	0.1	(0.06)	2.1	(0.64)	98	3.2%
Unidentified Xanthidae	0.1	(0.06)	0.5	(0.31)	0.1	(0.06)	1.2	(0.77)	0.0	(0.00)	0.0	(0.00)	79	2.6%
Gulf marsh fiddler crab	2.5	(1.27)	0.0	(0.00)	0.4	(0.26)	0.0	(0.00)	0.3	(0.19)	0.0	(0.00)	51	1.7%
Brown shrimp	1.0	(0.52)	0.3	(0.10)	0.0	(0.00)	0.4	(0.10)	0.0	(0.00)	0.1	(0.06)	50	1.6%
Unidentified fiddler crab	2.3	(0.64)	0.0	(0.00)	0.5	(0.18)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	47	1.5%
Heavy marsh crab	1.3	(0.57)	0.0	(0.00)	1.6	(0.98)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	45	1.5%
marsh grass shrimp	0.5	(0.50)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.4	(0.31)	28	
Pink shrimp	0.0	(0.00)	0.2	(0.10)	0.0	(0.00)	0.2	(0.14)	0.0	(0.00)	0.0	(0.00)	16	
Riverine grass shrimp	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.2	(0.21)	9	

Unidentified Macrobrachium	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.1	(0.11)	6	
Unidentified Portunidae	0.1	(0.06)	0.0	(0.03)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.02)	5	
Squareback marsh crab	0.3	(0.20)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	5	
Thinstripe hermit crab	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1	
Total Crustaceans	39.8	(7.85)	9.6	(1.88)	32.3	15.11	18.2	(5.90)	1.0	(0.51)	15.8	(2.94)	3085	
Fishes (Total=24 species)														
Rainwater killifish	2.0	(1.48)	0.0	(0.00)	10.8	(5.78)	0.0	(0.00)	1.9	(0.84)	49.3	(5.77)	2407	37.7%
Naked goby	4.9	(2.65)	6.3	(1.78)	2.9	(2.10)	10.5	(2.51)	0.0	(0.00)	2.8	(1.31)	985	15.4%
Sheepshead minnow	4.0	(1.80)	0.0	(0.00)	7.3	(2.45)	0.2	(0.11)	4.0	(2.00)	15.4	(2.81)	932	14.6%
Sailfin molly	3.9	(3.04)	0.0	(0.00)	5.0	(2.00)	0.0	(0.00)	2.2	(1.18)	11.2	(3.04)	669	10.5%
Bay anchovy	0.0	(0.00)	1.5	(0.66)	0.0	(0.00)	4.8	(2.66)	0.0	(0.00)	2.1	(1.25)	365	5.7%
Bayou killifish	1.8	(0.46)	0.0	(0.00)	7.5	(2.08)	0.0	(0.00)	6.1	(1.62)	0.3	(0.11)	259	4.1%
Diamond killifish	6.8	(1.85)	0.0	(0.00)	3.3	(1.18)	0.0	(0.00)	0.9	(0.45)	0.0	(0.00)	176	2.8%
Clown goby	0.0	(0.00)	0.3	(0.10)	0.1	(0.13)	0.5	(0.17)	0.0	(0.00)	2.3	(0.50)	140	2.2%
Unidentified Gobiosoma	0.1	(0.06)	0.6	(0.55)	0.0	(0.00)	2.1	(2.09)	0.0	(0.00)	0.0	(0.00)	119	1.9%
Unidentified Gobiidae	0.0	(0.00)	0.8	(0.56)	0.1	(0.06)	0.6	(0.50)	0.0	(0.00)	0.1	(0.07)	71	1.1%
Speckled worm eel	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.9	(0.53)	0.0	(0.00)	0.4	(0.15)	61	1.0%
Gulf killifish	1.0	(0.52)	0.0	(0.00)	1.4	(0.52)	0.0	(0.00)	0.8	(0.57)	0.0	(0.00)	50	
Unidentified Fundulidae	0.1	(0.06)	0.0	(0.00)	0.1	(0.13)	0.0	(0.00)	1.3	(0.77)	0.2	(0.10)	32	
Darter goby	1.4	(1.37)	0.2	(0.10)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	31	
Inland silverside	0.1	(0.06)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.5	(0.25)	23	
Gulf pipefish	0.0	(0.00)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.4	(0.13)	18	

Spotted seatrout	0.1	(0.09)	0.0	(0.03)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	9
Unidentified Fundulus	0.0	(0.00)	0.0	(0.00)	0.4	(0.26)	0.0	(0.00)	0.2	(0.19)	0.0	(0.00)	9
Unidentified fish	0.0	(0.00)	0.0	(0.00)	0.2	(0.10)	0.1	(0.04)	0.0	(0.00)	0.0	(0.02)	8
Western mosquitofish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.3	(0.22)	0.0	(0.00)	5
Green goby	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.07)	0.0	(0.00)	0.0	(0.00)	5
Code goby	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.05)	0.1	(0.06)	0.0	(0.00)	3
Unidentified Anchoa	0.0	(0.00)	0.0	(0.05)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	2
Striped mullet	0.0	(0.00)	0.0	(0.00)	0.1	(0.06)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	2
Unidentified Atherinidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	1
Sand seatrout	0.0	(0.00)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Fat sleeper	0.0	(0.00)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Unidentified Engraulidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	1
Longnose killifish	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Spot	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Atlantic croaker	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Gulf toadfish	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	1
Total Fishes	26.2	(6.26)	9.9	(2.59)	39.4	(9.71)	20.0	(4.61)	17.8	(5.16)	84.9	(7.38)	6389

Table C4. Comparison of biomasses (mean m^{-2} + 1 S.E.) of decapod crustaceans and fishes collected among marsh (Saline, Brackish, Intermediate) and habitat (marsh vegetation, ponds) types in September 2002. Each mean was estimated from 16 marsh and 44 pond samples. The total biomass (TB; g) and relative biomass (RB) of each taxon within the major taxonomic categories (crustaceans and fishes) also were given.

	SALINE				BRACKISH				INTERMEDIATE					
	Marsh		Pond		marsh		Pond		marsh		Pond			RB
Taxa	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	MEAN	S. E.	TB (g)	(%)
Crustaceans														
Blue crab	2.3	(0.76)	0.1	(0.01)	8.9	(3.11)	0.3	(0.09)	0.2	(0.24)	0.2	(0.10)	211.26	31.9%
Heavy marsh crab	1.1	(0.55)	0.0	(0.00)	5.5	(2.26)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	105.92	16.0%
Gulf marsh fiddler crab	2.9	(1.39)	0.0	(0.00)	1.2	(0.76)	0.0	(0.00)	1.6	(1.22)	0.0	(0.00)	91.67	13.9%
Unidentified Palaemonetes	0.2	(0.08)	0.0	(0.00)	1.0	(0.89)	0.0	(0.01)	0.0	(0.01)	0.7	(0.17)	52.46	7.9%
White shrimp	1.4	(0.98)	0.0	(0.01)	1.5	(1.33)	0.0	(0.02)	0.0	(0.00)	0.1	(0.06)	49.93	7.5%
Brown shrimp	0.3	(0.20)	0.1	(0.06)	0.0	(0.00)	0.8	(0.35)	0.0	(0.00)	0.1	(0.05)	45.38	6.9%
Daggerblade grass shrimp	1.0	(0.35)	0.0	(0.00)	0.5	(0.34)	0.0	(0.00)	0.0	(0.01)	0.4	(0.12)	44.77	6.8%
Unidentified fiddler crab	1.4	(0.50)	0.0	(0.00)	0.5	(0.23)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	30.49	4.6%
Brackish grass shrimp	0.0	(0.00)	0.0	(0.00)	0.0	(0.04)	0.0	(0.00)	0.0	(0.01)	0.3	(0.07)	11.74	1.8%
Harris mud crab	0.0	(0.01)	0.0	(0.01)	0.0	(0.03)	0.1	(0.05)	0.0	(0.00)	0.0	(0.01)	9.41	1.4%
Squareback marsh crab	0.3	(0.19)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	4.22	
marsh grass shrimp	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.03)	1.86	
Riverine grass shrimp	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.03)	1.14	
Thinstripe hermit crab	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.63	
Unidentified Portunidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.21	

Unidentified Xanthidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.19	
Pink shrimp	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.16	
Unidentified Macrobrachium	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.02	
Total Crustaceans	10.9	(1.90)	0.2	(0.06)	19.3	(5.32)	1.3	(0.39)	1.9	(1.22)	1.8	(0.34)	661.46	
Fishes														
Rainwater killifish	0.9	(0.85)	0.0	(0.00)	1.7	(1.15)	0.0	(0.00)	0.3	(0.15)	8.3	(1.14)	413.15	29.4%
Sheepshead minnow	2.0	(0.96)	0.0	(0.00)	4.8	(2.12)	0.0	(0.00)	1.6	(0.72)	4.6	(0.80)	336.02	23.9%
Sailfin molly	1.2	(1.00)	0.0	(0.00)	0.4	(0.13)	0.0	(0.00)	0.3	(0.14)	2.4	(0.75)	132.53	9.4%
Striped mullet	0.0	(0.00)	0.0	(0.00)	0.9	(0.94)	1.7	(1.68)	0.0	(0.00)	0.0	(0.00)	89.00	6.3%
Gulf killifish	2.2	(1.45)	0.0	(0.00)	1.2	(0.46)	0.0	(0.00)	1.1	(0.76)	0.0	(0.00)	72.28	5.1%
Bayou killifish	0.7	(0.31)	0.0	(0.00)	2.3	(1.01)	0.0	(0.00)	1.3	(0.51)	0.1	(0.04)	72.26	5.1%
Atlantic croaker	0.0	(0.00)	1.1	(1.12)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	49.07	3.5%
Naked goby	0.5	(0.22)	0.1	(0.04)	0.4	(0.30)	0.4	(0.14)	0.0	(0.00)	0.1	(0.05)	42.64	3.0%
Diamond killifish	1.7	(0.52)	0.0	(0.00)	0.5	(0.18)	0.0	(0.00)	0.3	(0.14)	0.0	(0.00)	41.10	2.9%
Clown goby	0.0	(0.00)	0.0	(0.01)	0.0	(0.03)	0.1	(0.03)	0.0	(0.00)	0.8	(0.20)	40.55	2.9%
Speckled worm eel	0.0	(0.00)	0.2	(0.20)	0.0	(0.00)	0.3	(0.17)	0.0	(0.00)	0.3	(0.10)	33.47	2.4%
Bay anchovy	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.3	(0.16)	0.0	(0.00)	0.2	(0.10)	27.42	2.0%
Spot	0.0	(0.00)	0.4	(0.38)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	16.73	1.2%
Spotted seatrout	0.4	(0.24)	0.0	(0.00)	0.0	(0.00)	0.2	(0.15)	0.0	(0.00)	0.0	(0.00)	13.54	1.0%
Fat sleeper	0.0	(0.00)	0.0	(0.00)	0.7	(0.66)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	10.53	
Inland silverside	0.0	(0.03)	0.0	(0.00)	0.1	(0.06)	0.0	(0.00)	0.0	(0.00)	0.1	(0.03)	4.04	
Gulf pipefish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.02)	3.11	
Darter goby	0.2	(0.15)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	2.65	
Unidentified Fundulidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.0	(0.01)	1.04	
Unidentified fish	0.0	(0.00)	0.0	(0.00)	0.1	(0.05)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.97	
Sand seatrout	0.0	(0.00)	0.0	(0.00)	0.0	(0.04)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.66	

Unidentified Gobiosoma	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.51
Unidentified Gobiidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.51
Green goby	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.39
Unidentified Atherinidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.38
Western mosquitofish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.00)	0.35
Longnose killifish	0.0	(0.01)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.08
Unidentified Fundulus	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.07
Gulf toadfish	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.06
Unidentified Anchoa	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.04
Code goby	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.00
Unidentified Engraulidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.00
Total Fishes	9.8	(3.41)	2.0	(1.18)	13.0	(3.87)	2.9	(1.72)	4.9	(1.72)	16.9	(1.85)	1405.15

Table C5. ANOVA results (p values) comparing mean densities of decapod crustaceans and fishes among marsh types (S=saline, B=brackish, I=intermediate), between pond sizes (S=small, M=medium), and between habitat types (M=marsh, P=pond) in April-May and September 2002. Results are given for the three main effects (MARTYPE=marsh type, PSIZE=pond size, and HABTYPE=habitat type), for the three 2-way interactions of the main effects, and for the 3-way interaction in the ANOVA model. The total and residual degrees of freedom in the model were 131 and 120, respectively. Data from Large Ponds were not included in this analysis. Only taxa with a mean density of >0.5 m^{-2} in at least one marsh- or habitat-type category were included in the analysis. Differences in means (DIFF) also are given when the probability value was significant based on the Games-Howell post hoc test for the comparison among marsh types or when the main effect of pond size or habitat type was significant in the ANOVA model.

	MAIN EFFECTS						INTERACTIONS			
	MARTYPE		PSIZE		HABTYPE		MARTYPE * PSIZE	MARTYPE * HABTYPE	PSIZE * HABTYPE	MARTYPE * PSIZE * HABTYPE
Species	P VALUE	DIFF	P VALUE	DIFF	P VALUE	DIFF	P VALUE	P VALUE	P VALUE	P VALUE
April-May 2002										
Crustaceans										
Daggerblade grass shrimp	0.0001		0.8630		0.0001	M>P	0.1113	0.0001	0.0830	0.2819
Brown shrimp	0.0202	S>I	0.0004	M>S	0.0884		0.0202	0.3948	0.1865	0.8656
Blue crab	0.1552		0.1653		0.2009		0.4953	0.1100	0.0158	0.5708
Gulf marsh fiddler crab	0.0078		1.0000		0.0004	M>P	0.2267	0.0078	1.0000	0.2267
Heavy marsh crab	0.0001	S=B>I	0.0180	M>S	0.0001	M>P	0.2157	0.0001	0.0180	0.2157
Brackish grass shrimp	0.0467	I>S	0.0071	M>S	0.5703		0.1566	0.0003	0.9223	0.0046
Squareback marsh crab	0.0001	S>B=I	0.1034		0.0001	M>P	0.0718	0.0001	0.1034	0.0718
Total Crustaceans	0.0001	S>B=I	0.0019	M>S	0.0001	M>P	0.2850	0.0001	0.1604	0.3357
Fishes										
Sheepshead minnow	0.3202		0.0059	S>M	0.8688		0.6388	0.0016	0.6461	0.5893
Rainwater killifish	0.5223		0.8422		0.6792		0.0001	0.0009	0.0043	0.0300
Gulf menhaden	0.6177		0.6079		0.2876		0.4006	0.6177	0.6079	0.4006

Inland silverside	0.1267		0.1642		0.8219		0.2099	0.2216	0.8587	0.1680
Bayou killifish	0.1015		0.0300	S>M	0.0001	M>P	0.7079	0.5551	0.0829	0.5193
Gulf killifish	0.1390		0.4008		0.0004	M>P	0.5605	0.0320	0.4395	0.5097
Gulf pipefish	0.0235	I>S=B	0.0195	M>S	0.0046	P>M	0.1278	0.0235	0.0195	0.1278
Total Fishes	0.3239	I>B	0.4823		0.6488		0.2657	0.0003	0.0010	0.2673

Table C6. ANOVA results (p values) comparing mean densities of decapod crustaceans and fishes among marsh types (S=saline, B=brackish, I=intermediate) and pond sizes (S=small, M=medium, L=large) in April-May and September 2002. Results are given for the two main effects (MARTYPE=marsh type, PSIZE=pond size) and the 2-way interaction of the main effects. The ANOVA model had total and residual degrees of freedom of 131 and 123, respectively. Data from marsh sites were not included in these analyses. Only taxa with a mean density of >0.5 m^{-2} in at least one marsh type or pond size category are included. Differences in means (DIFF) among marsh types and pond sizes also are given when the probability value was significant based on the Games-Howell post hoc test.

	MAIN EFFECTS				INTERACTION
	MARTYPE		PSIZE		MARTYPE * PSIZE
Species	P VALUE	DIFF	P VALUE	DIFF	P VALUE
April-May 2002					
Crustaceans					
Daggerblade grass shrimp	0.0001	I>S=B	0.0779		0.0753
Brown shrimp	0.1856		0.0004	L=M>S	0.2052
Blue crab	0.2299		0.0007	L=M>S	0.3468
Brackish grass shrimp	0.0001	I>S=B	0.1408		0.1368
Flatback mud crab	0.1052		0.3601		0.6007
Harris mud crab	0.0016	B=S>I	0.0001	L>M>S	0.0421
Total Crustaceans	0.3160		0.0001	L>M>S	0.7205
Fishes					
Sheepshead minnow	0.0004	I>B	0.0001	S=M>L	0.0259
Rainwater killifish	0.0001	I>B=S	0.0243		0.0001
Gulf menhaden	0.6853		0.7088		0.1761
Inland silverside	0.1856		0.3451		0.0425
Gulf pipefish	0.0001	I>B=S	0.0001	L=M>S	0.0002
Bay anchovy	0.0017	S>I	0.0580		0.0569
Naked goby	0.8021		0.0001	L>M>S	0.6489
Clown goby	0.0891		0.2437		0.3332
Speckled worm eel	0.3942		0.0192	L=M>S	0.7117
Total Fishes	0.0001	I>B=S	0.0048	S>L	0.0129

September 2002					
Crustaceans					
Daggerblade grass shrimp	0.0001	I>S=B	0.7509		0.9435
Blue crab	0.0001	S=B>I	0.0001	M=L>S	0.4948
White shrimp	0.2310		0.5012		0.6469
Harris mud crab	0.0004	S=B>I	0.0001	L>M>S	0.0008
Brackish grass shrimp	0.0001	I>S=B	0.9619		0.9971
marsh grass shrimp	0.0287		0.0390		0.0052
Total Crustaceans	0.1396		0.0001	M=L>S	0.1183
Fishes					
Rainwater killifish	0.0001	I>S=B	0.2777		0.2758
Sheepshead minnow	0.0001	I>S=B	0.0001	S>L	0.0001
Naked goby	0.0053	S=B>I	0.0001	M=L>S	0.1860
Sailfin molly	0.0001	I>S=B	0.8181		0.9373
Bay anchovy	0.3847		0.0383	M=L>S	0.9851
Clown goby	0.0001	I>S=B	0.8313		0.0863
Speckled worm eel	0.1199		0.0915		0.4192
Inland silverside	0.0123		0.7015		0.8397
Total Fishes	0.0001	I>S=B	0.0001	M=L>S	0.0113

Table C7. ANOVA results (p values) comparing means of environmental variables among marsh types (S=saline, B=brackish, I=intermediate), between pond sizes (S=small, M=medium), and between habitat types (M=marsh, P=pond) in April-May and September 2002. Results are given for the three main effects (MARTYPE=marsh type, PSIZE=pond size, and HABTYPE=habitat type), for the three 2-way interactions of the main effects, and for the 3-way interaction in the ANOVA model. Data from Large Ponds were not included in this analysis. Differences in means (DIFF) also are given when the probability value was significant based on the Games-Howell post hoc test for the comparison among marsh types or when the main effect of pond size or habitat type was significant in the ANOVA model.

	MAIN EFFECTS						INTERACTIONS			
	MARTYPE		PSIZE		HABTYPE		MARTYPE * PSIZE	MARTYPE * HABTYPE	PSIZE * HABTYPE	MARTYPE * PSIZE * HABTYPE
Species	P VALUE	DIFF	P VALUE	DIFF	P VALUE	DIFF	P VALUE	P VALUE	P VALUE	P VALUE
April-May 2002										
Water depth	0.0004		0.0045	M>S	0.0001	P>M	0.1133	0.1627	0.0001	0.4864
Distance to shoreline	0.9893		0.0049	M>S	0.0001	P>M	0.9658	0.9874	0.0051	0.9661
Dissolved oxygen	0.1918		0.0001	M>S	0.0001	P>M	0.0400	0.0237	0.6315	0.7278
Water temperature	0.0007		0.1847		0.2737		0.0401	0.7820	0.6646	0.5794
Salinity	0.0001	S>B=I	0.8088		0.4220		0.8147	0.6805	0.8419	0.7161
Turbidity	0.0263	B>I	0.1646		0.0344	M>P	0.7131	0.8744	0.2674	0.2875
SAV coverage	0.0001	I>S=B	0.0001	M>S			0.0001			
Stem density	0.0008	B=I>S	0.5567				0.3027			
September 2002										
Water depth	0.0092		0.0001	M>S	0.0001	P>M	0.3324	0.7306	0.0001	0.3698
Distance to shoreline	0.9687		0.0032	M>S	0.0001	P>M	0.9924	0.9366	0.0041	0.9911
Dissolved oxygen	0.0281	I>S	0.0098	M>S	0.0001	P>M	0.5940	0.0001	0.1533	0.0279
Water temperature	0.0798		0.1753		0.0192	P>M	0.0644	0.0260	0.8859	0.5497
Salinity	0.0001	S>B>I	0.9195		0.2344		0.8395	0.6167	0.8875	0.7954
Turbidity	0.6215		0.0445		0.3290		0.4906	0.3780	0.4088	0.7728
SAV coverage	0.0001	I>S=B	0.5183				0.6578			
Stem density	0.0281	B=I>S	0.2257				0.7042			

Table C8. Comparison of sizes (mean + 1 S.E.) in mm of brown shrimp, white shrimp, and blue crab among marsh types (saline, brackish, intermediate) and between habitat types (marsh vegetation, ponds). For each species, size data were analyzed for the month in which it was most abundant. Each mean (total length of shrimps or carapace width of crabs) was estimated from the mean sizes of n samples that contained that species. Results (p values) are given for ANOVA analyses comparing means among marsh types and between habitat types. Differences in means (DIFF) also are given when the probability value was significant based on the Games-Howell post hoc test for the comparison among marsh types or when the main effect of habitat type was significant in the ANOVA model.

	MARSH TYPE									ANOVA RESULTS		HABITAT TYPE						ANOVA RESULTS	
	Saline			Brackish			Intermediate					Marsh			Pond				
Species	n	Mean	SE	n	Mean	SE	n	Mean	SE	P VALUE	DIFF	n	Mean	SE	n	Mean	S. E.	P VALUE	DIFF
<u>April-May 2002</u>																			
Brown shrimp	26	39.3	(3.12)	23	42.6	(3.66)	15	67.2	(3.09)	0.0001	I>S=B	10	42.8	(4.35)	54	47.8	(2.73)	0.2561	
<u>September 2002</u>																			
White shrimp	9	20.3	(3.95)	9	27.6	(5.72)	1	74.0	(0.00)	0.0001		8	31.7	(6.58)	11	22.9	(5.49)	0.0005	M>P
Blue crab	48	10.2	(0.79)	43	13.8	(1.82)	14	15.5	(2.17)	0.0022		34	19.1	(2.13)	71	9.2	(0.52)	0.0001	M>P

Table C9. ANOVA results for log transformed blue crab densities in marsh vegetation from Fall 2002 samples. The main effects are marsh type (MARTYPE), pond size (PSIZE), and distance from the marsh edge (DISTCAT).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	2	28.653	14.326	46.684	.0001
PSIZE	1	1.521	1.521	4.956	.0324
DISTCAT	1	8.434	8.434	27.482	.0001
MARTYPE * DISTCAT	2	4.106	2.053	6.691	.0034
PSIZE * DISTCAT	1	.916	.916	2.986	.0926
MARTYPE * PSIZE	2	1.893	.946	3.084	.0581
MARTYPE * PSIZE * DISTCAT	2	.720	.360	1.173	.3211
Residual	36	11.048	.307		

Dependent: LnCsapidus

Table C10. ANOVA results for log transformed blue crab densities in marsh ponds from Fall 2002 samples. The main effects are marsh type (MARTYPE), pond size (PSIZE), and distance from the marsh edge (DISTCAT).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	2	21.620	10.810	16.698	.0001
PSIZE	2	25.750	12.875	19.888	.0001
DISTCAT	3	17.175	5.725	8.844	.0001
MARTYPE * DISTCAT	6	12.469	2.078	3.210	.0064
PSIZE * DISTCAT	5	2.858	.572	.883	.4956
MARTYPE * PSIZE	4	4.186	1.046	1.616	.1761
MARTYPE * PSIZE * DISTCAT	10	4.242	.424	.655	.7629
Residual	99	64.089	.647		

Dependent: LnCsapidus

Table C11. ANOVA results for log transformed blue crab densities in marsh ponds from Fall 2002 samples (intermediate marsh data excluded). The main effects are marsh type (MARTYPE), pond size (PSIZE), and distance from the marsh edge (DISTCAT).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	1	1.827E-4	1.827E-4	2.520E-4	.9874
PSIZE	2	28.233	14.116	19.476	.0001
DISTCAT	3	25.019	8.340	11.506	.0001
MARTYPE * DISTCAT	3	4.259	1.420	1.959	.1287
PSIZE * DISTCAT	5	3.128	.626	.863	.5107
MARTYPE * PSIZE	2	.073	.037	.050	.9509
MARTYPE * PSIZE * DISTCAT	5	3.469	.694	.957	.4505
Residual	66	47.836	.725		

Dependent: LnCsapidus

Table C12. ANOVA results for log transformed brown shrimp densities in marsh vegetation from Fall and Spring 2002 samples (intermediate marsh excluded). The main effects are marsh type (MARTYPE), pond size (PSIZE), distance from the marsh edge (DISTCAT), and Season.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	1	1.378	1.378	9.940	.0028
PSIZE	1	1.815	1.815	13.090	.0007
DISTCAT	1	1.378	1.378	9.940	.0028
SEASON	1	.294	.294	2.124	.1515
SEASON * DISTCAT	1	.001	.001	.004	.9513
MARTYPE * DISTCAT	1	.428	.428	3.086	.0853
PSIZE * DISTCAT	1	1.378	1.378	9.940	.0028
SEASON * MARTYPE	1	.105	.105	.755	.3891
SEASON * PSIZE	1	.023	.023	.163	.6881
MARTYPE * PSIZE	1	1.378	1.378	9.940	.0028
SEASON * MARTYPE * DISTCAT	1	.247	.247	1.781	.1883
MARTYPE * PSIZE * DISTCAT	1	.428	.428	3.086	.0853
SEASON * PSIZE * DISTCAT	1	.001	.001	.004	.9513
SEASON * MARTYPE * PSIZE	1	.105	.105	.755	.3891
SEASON * MARTYPE * PSIZE * DISTCAT	1	.247	.247	1.781	.1883
Residual	48	6.654	.139		

Dependent: LnFaztecus

Table C13. ANOVA results for log transformed brown shrimp densities in marsh ponds from Fall and Spring 2002 samples. The main effects are marsh type (MARTYPE), pond size (PSIZE), distance from the marsh edge (DISTCAT), and Season.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	2	1.193	.596	2.551	.0805
PSIZE	2	5.410	2.705	11.572	.0001
DISTCAT	3	.468	.156	.667	.5732
SEASON	1	7.219	7.219	30.886	.0001
SEASON * DISTCAT	3	.859	.286	1.225	.3017
MARTYPE * DISTCAT	6	.446	.074	.318	.9273
PSIZE * DISTCAT	5	.394	.079	.337	.8901
SEASON * MARTYPE	2	.491	.245	1.050	.3518
SEASON * PSIZE	2	.649	.325	1.389	.2518
MARTYPE * PSIZE	4	2.118	.530	2.266	.0635
SEASON * MARTYPE * DISTCAT	6	1.451	.242	1.035	.4038
MARTYPE * PSIZE * DISTCAT	10	.997	.100	.427	.9324
SEASON * PSIZE * DISTCAT	5	2.407	.481	2.059	.0721
SEASON * MARTYPE * PSIZE	4	.850	.212	.909	.4596
SEASON * MARTYPE * PSIZE * DISTCAT	10	3.807	.381	1.629	.1006
Residual	198	46.278	.234		

Dependent: LnFaztecus

Table C14. ANOVA results for log transformed white shrimp densities in marsh vegetation from Fall 2002 samples (intermediate marsh data excluded). The main effects are marsh type (MARTYPE), pond size (PSIZE), and distance from the marsh edge (DISTCAT).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	1	2.367	2.367	2.421	.1328
PSIZE	1	3.661	3.661	3.744	.0649
DISTCAT	1	5.430	5.430	5.553	.0269
MARTYPE * DISTCAT	1	.646	.646	.660	.4244
PSIZE * DISTCAT	1	1.389	1.389	1.420	.2450
MARTYPE * PSIZE	1	.150	.150	.153	.6991
MARTYPE * PSIZE * DISTCAT	1	.121	.121	.124	.7278
Residual	24	23.468	.978		

Dependent: LnLsetiferus

Table C15. ANOVA results for log transformed white shrimp densities in marsh ponds from Fall 2002 samples. The main effects are marsh type (MARTYPE), pond size (PSIZE), and distance from the marsh edge (DISTCAT).

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	2	.484	.242	1.429	.2444
PSIZE	2	.489	.245	1.446	.2404
DISTCAT	3	1.965	.655	3.870	.0115
MARTYPE * DISTCAT	6	1.428	.238	1.407	.2196
PSIZE * DISTCAT	5	1.262	.252	1.492	.1994
MARTYPE * PSIZE	4	.602	.150	.889	.4734
MARTYPE * PSIZE * DISTCAT	10	2.224	.222	1.314	.2335
Residual	99	16.753	.169		

Dependent: LnLsetiferus

Table C16. ANOVA results for water depth in nekton samples from Fall and Spring 2002. The main effects are marsh type (MARTYPE), pond size (PSIZE), distance from the marsh edge (DISTCAT), and Season.

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	2	10458.814	5229.407	33.731	.0001
PSIZE	2	24042.967	12021.484	77.541	.0001
DISTCAT	5	142112.823	28422.565	183.331	.0001
SEASON	1	555.197	555.197	3.581	.0595
SEASON * DISTCAT	5	323.885	64.777	.418	.8362
MARTYPE * DISTCAT	10	5127.398	512.740	3.307	.0005
PSIZE * DISTCAT	7	12136.130	1733.733	11.183	.0001
SEASON * MARTYPE	2	399.939	199.969	1.290	.2770
SEASON * PSIZE	2	645.623	322.812	2.082	.1267
MARTYPE * PSIZE	4	1435.590	358.897	2.315	.0577
SEASON * MARTYPE * DISTCAT	10	579.133	57.913	.374	.9573
MARTYPE * PSIZE * DISTCAT	14	4265.105	304.650	1.965	.0206
SEASON * PSIZE * DISTCAT	7	626.002	89.429	.577	.7746
SEASON * MARTYPE * PSIZE	4	507.447	126.862	.818	.5144
SEASON * MARTYPE * PSIZE * DISTCAT	14	1158.887	82.778	.534	.9121
Residual	270	41859.250	155.034		

Dependent: WDEPTH

Table C17. ANOVA results for water depth in nekton samples taken on the vegetated marsh surface from Fall and Spring 2002. The main effects are marsh type (MARTYPE), pond size (PSIZE), distance from the marsh edge (DISTCAT), and Season.

Type III Sums of Squares

Source	df	Sum of Squares	Mean Square	F-Value	P-Value
MARTYPE	2	508.083	254.042	4.746	.0116
PSIZE	1	380.010	380.010	7.099	.0095
DISTCAT	1	333.760	333.760	6.235	.0148
SEASON	1	36.260	36.260	.677	.4132
SEASON * DISTCAT	1	58.594	58.594	1.095	.2990
MARTYPE * DISTCAT	2	50.083	25.042	.468	.6283
PSIZE * DISTCAT	1	3.760	3.760	.070	.7917
SEASON * MARTYPE	2	46.583	23.292	.435	.6489
SEASON * PSIZE	1	.844	.844	.016	.9004
MARTYPE * PSIZE	2	217.583	108.792	2.032	.1385
SEASON * MARTYPE * DISTCAT	2	3.000	1.500	.028	.9724
MARTYPE * PSIZE * DISTCAT	2	10.333	5.167	.097	.9081
SEASON * PSIZE * DISTCAT	1	15.844	15.844	.296	.5881
SEASON * MARTYPE * PSIZE	2	54.750	27.375	.511	.6018
SEASON * MARTYPE * PSIZE * DISTCAT	2	106.750	53.375	.997	.3740
Residual	72	3854.250	53.531		

Dependent: WDEPTH

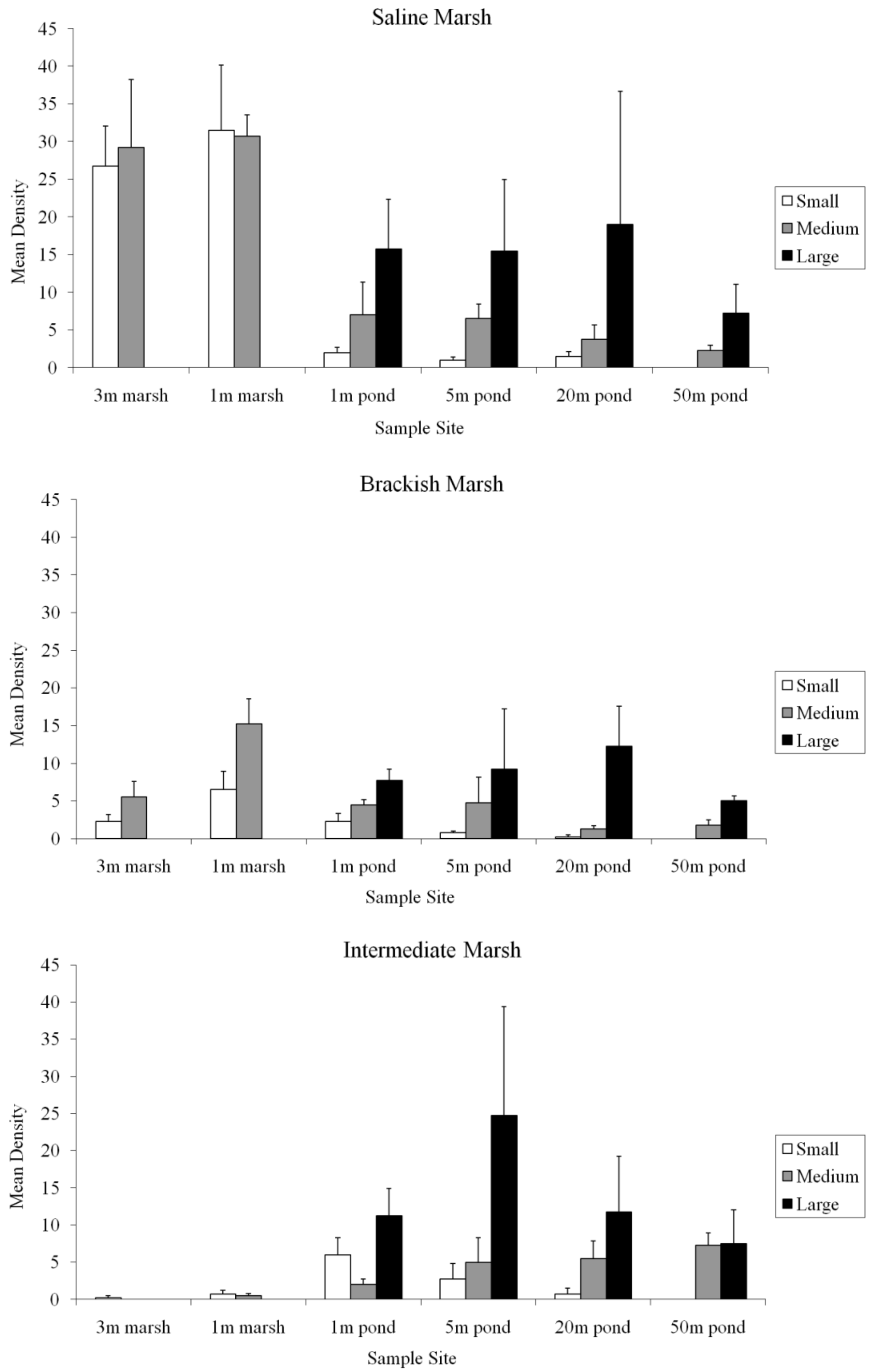


Figure C1. Mean density (individuals m^{-2}) of total crustaceans collected April-May 2002 between two habitat types (marsh, pond), among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

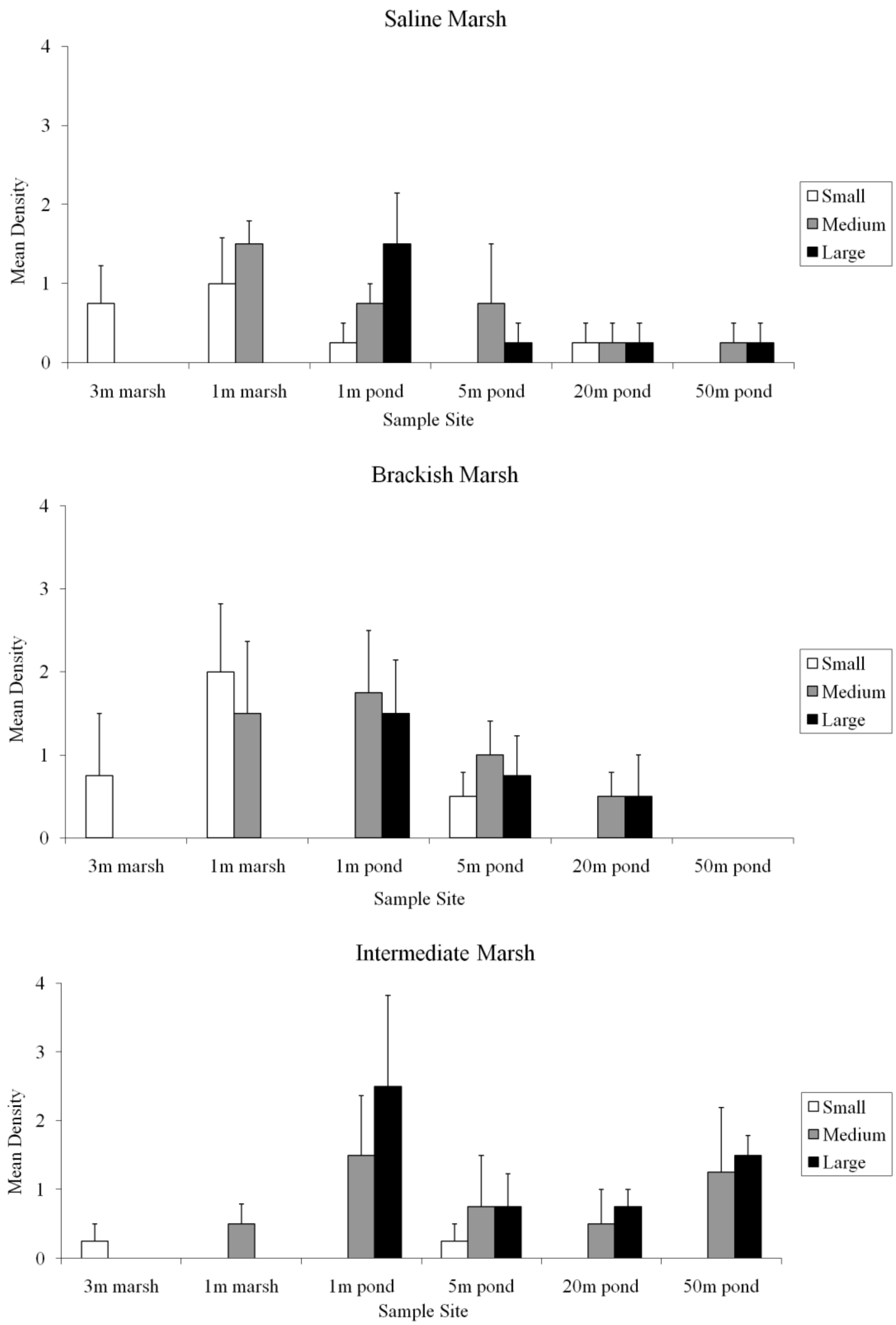


Figure C2. Mean density (individuals m^{-2}) of blue crab collected April-May 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

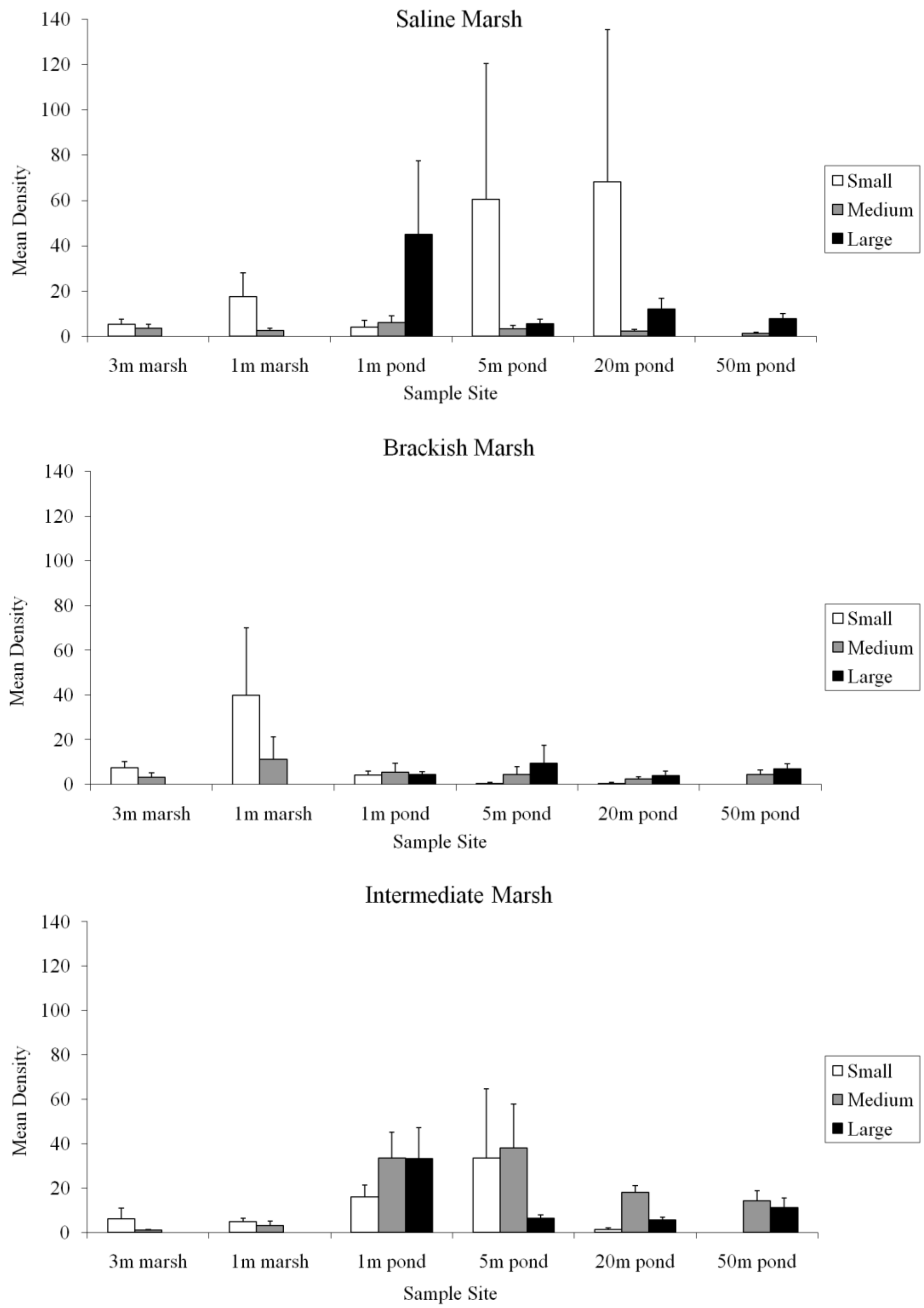


Figure C3. Mean density (individuals m^{-2}) of total fish collected April-May 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

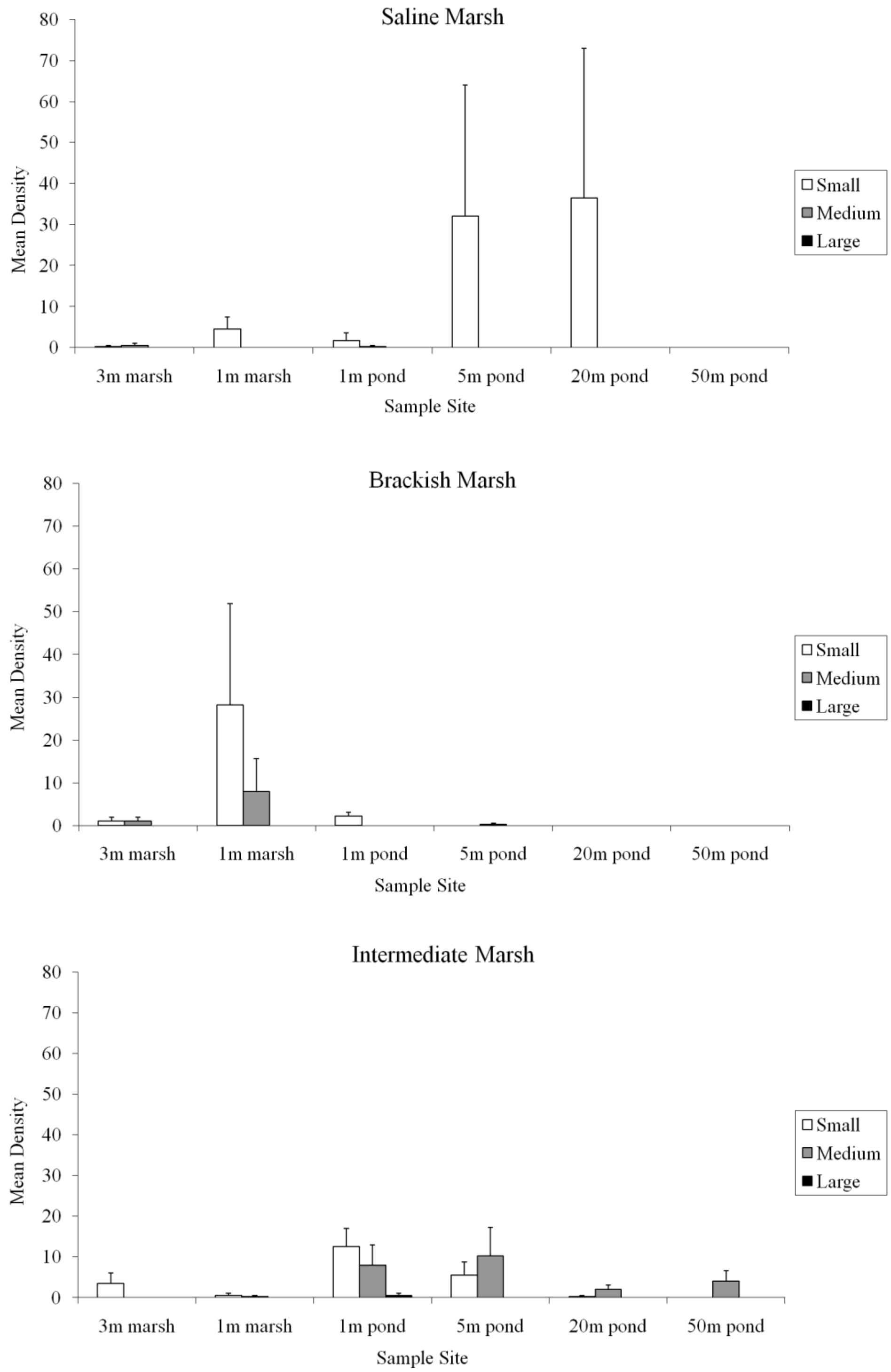


Figure C4. Mean density (individuals m^{-2}) of sheepshead minnow collected April-May 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

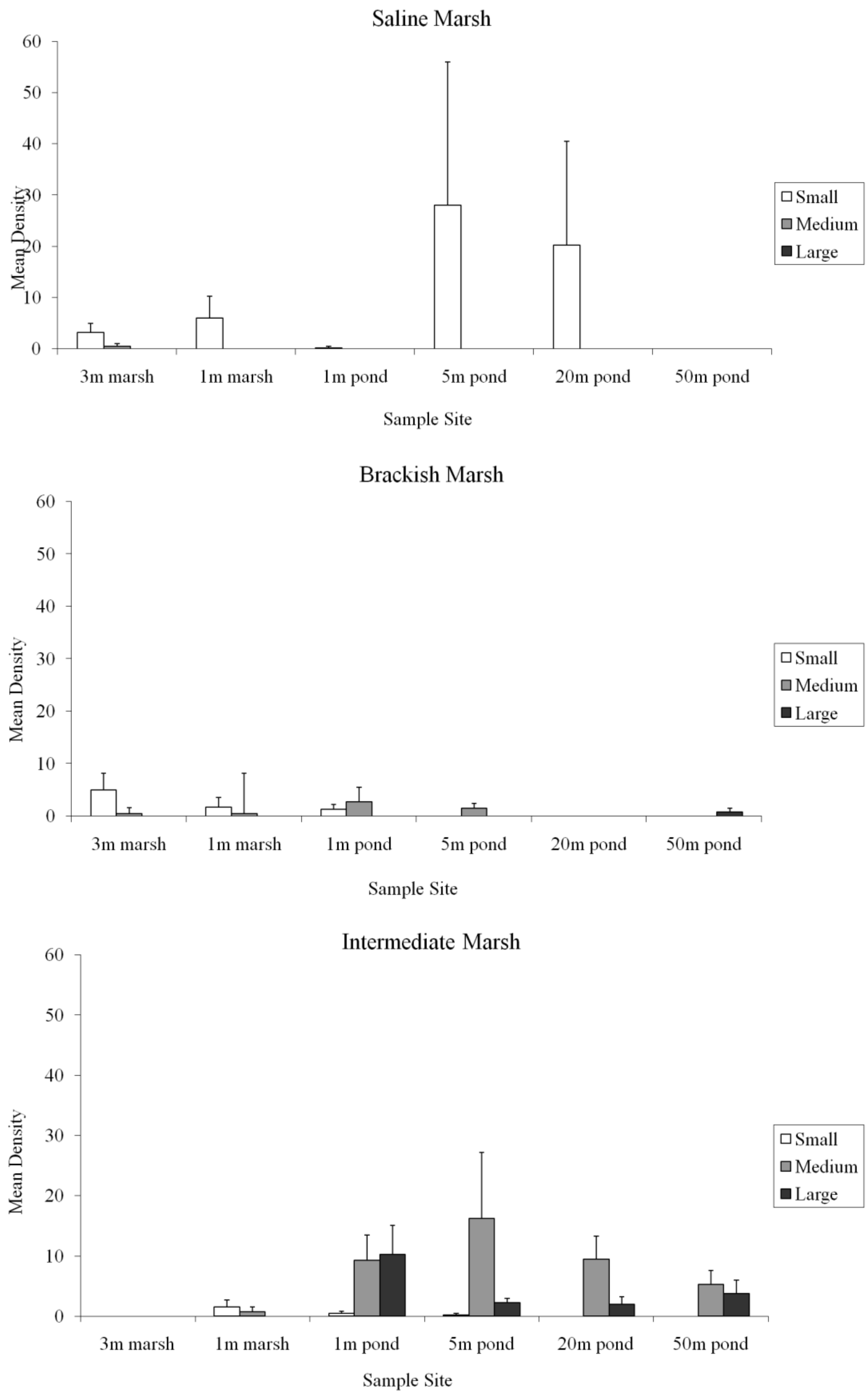


Figure C5. Mean density (individuals m^{-2}) of rainwater killifish collected April-May 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

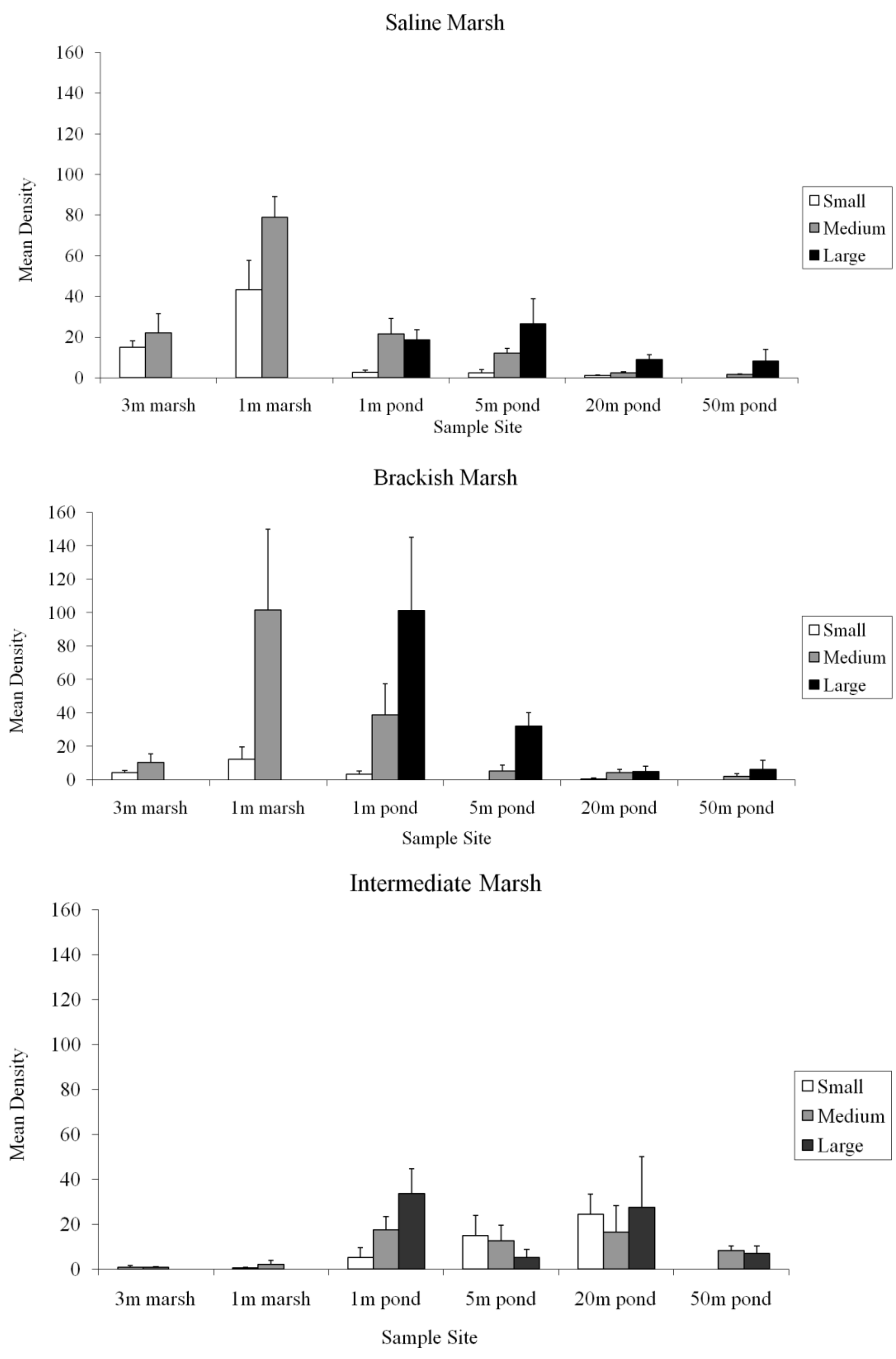


Figure C6. Mean density (individuals m^{-2}) of total crustaceans collected September 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

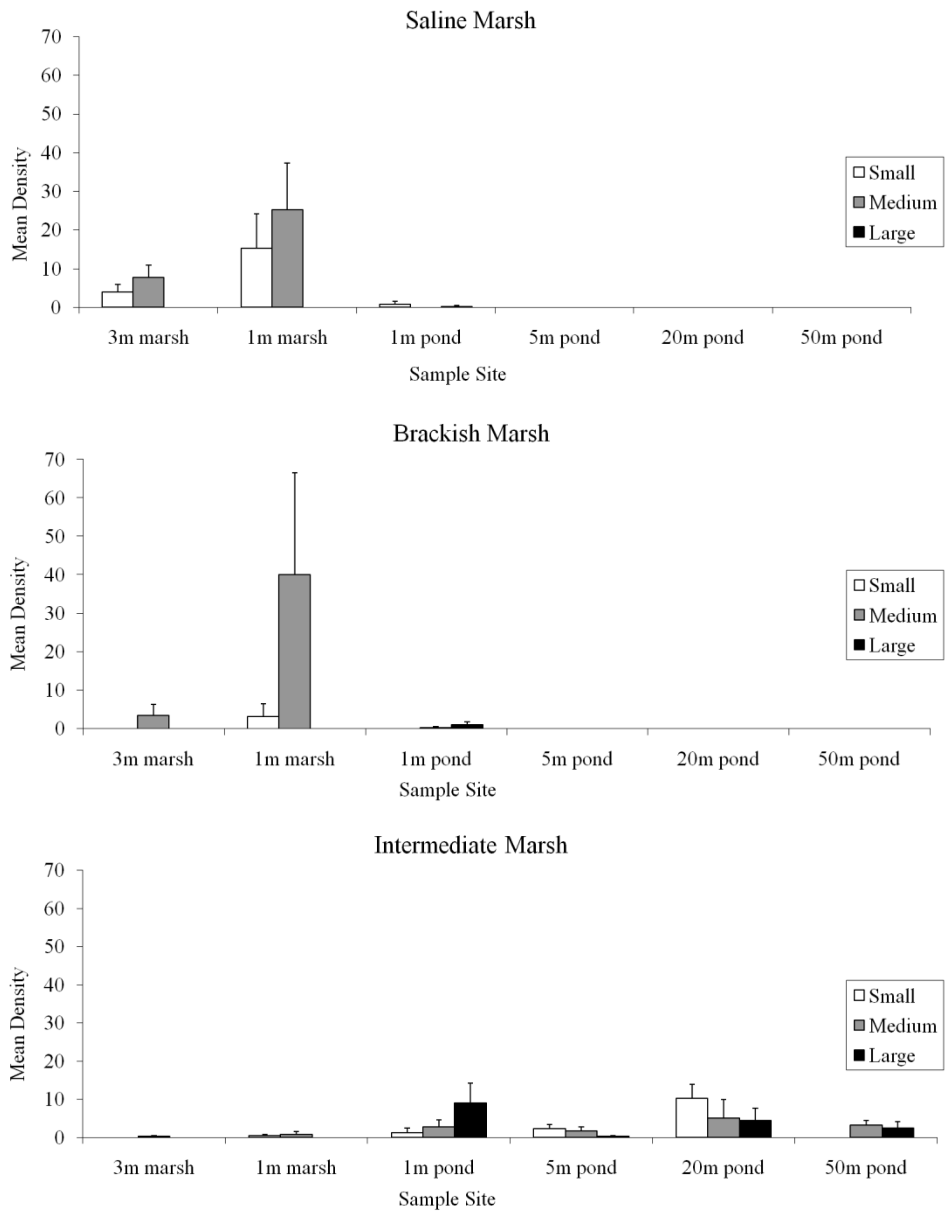


Figure C7. Mean density (individuals m^{-2}) of daggerblade grass shrimp collected September 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

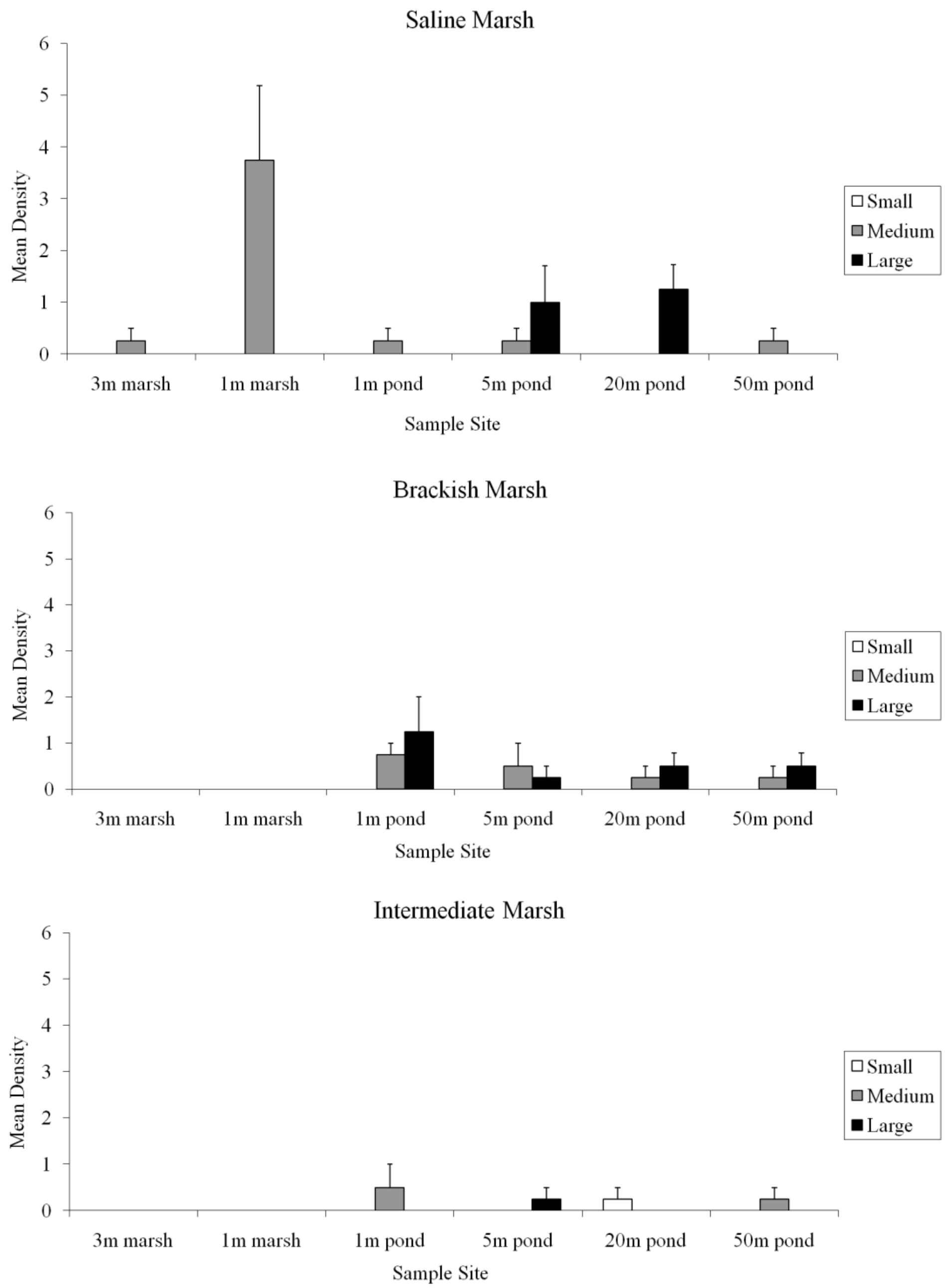


Figure C8. Mean density (individuals m^{-2}) of brown shrimp collected September 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

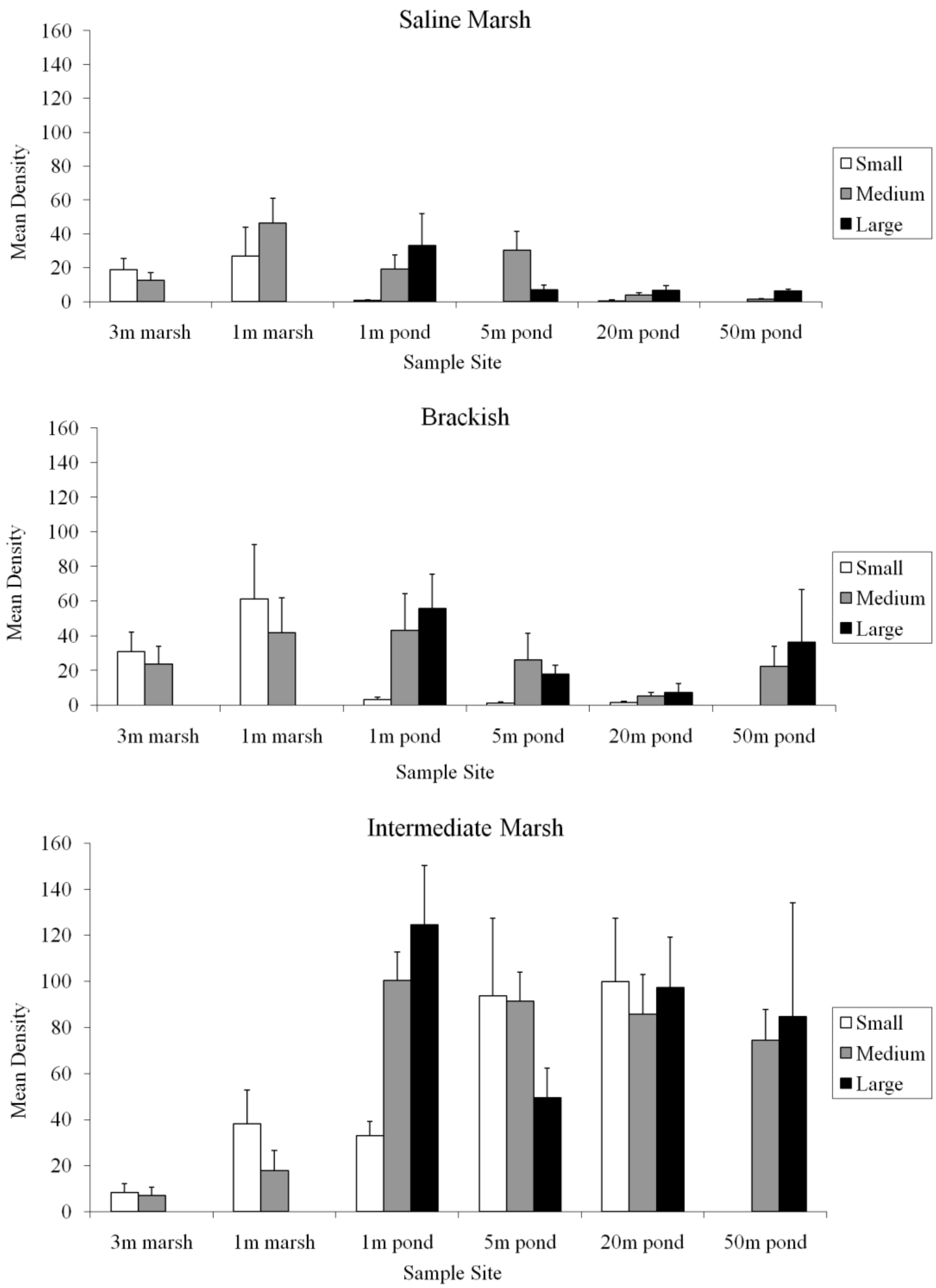


Figure C9. Mean density (individuals m^{-2}) of total fish collected September 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

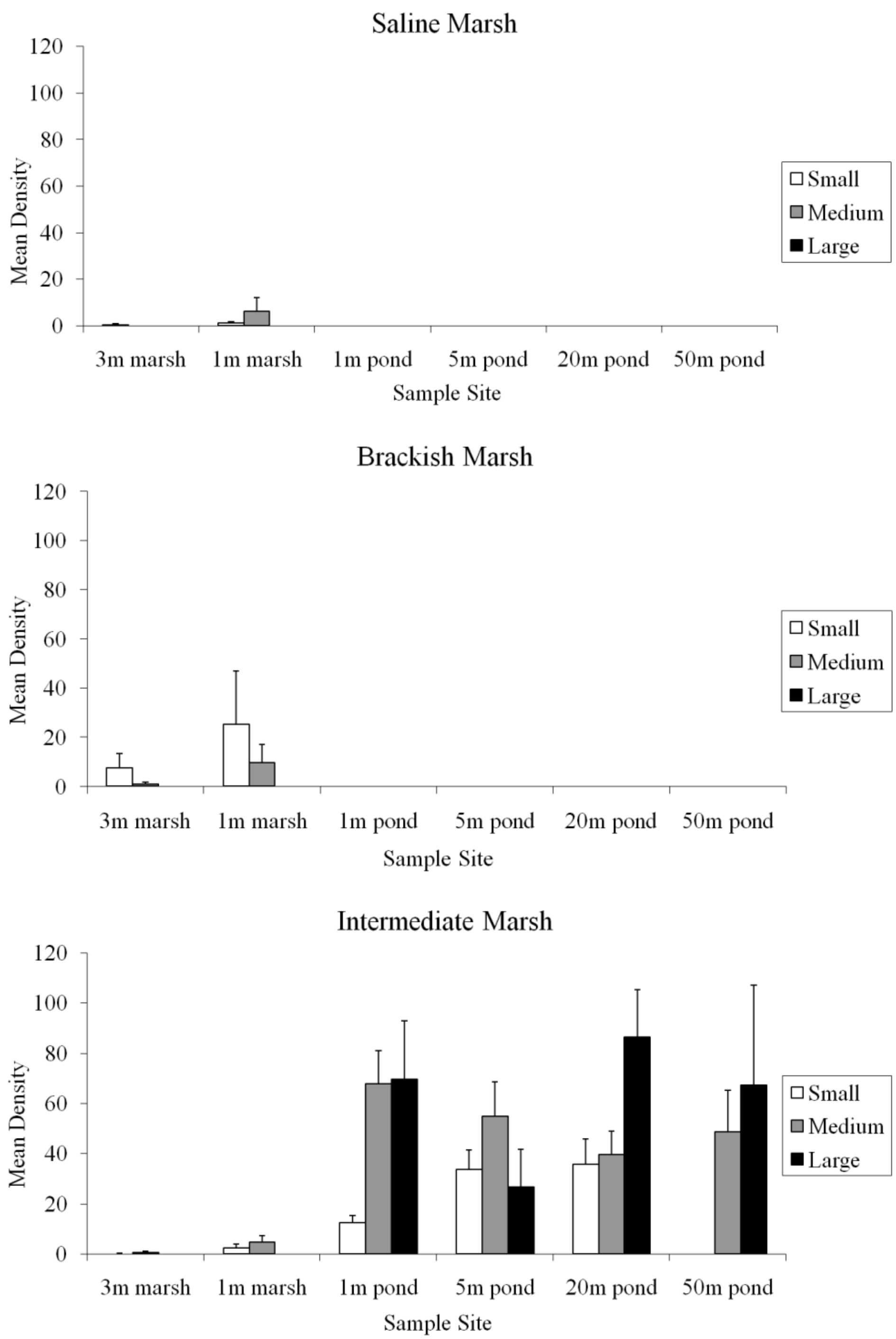


Figure C10. Mean density (individuals m^{-2}) of rainwater killifish collected September 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

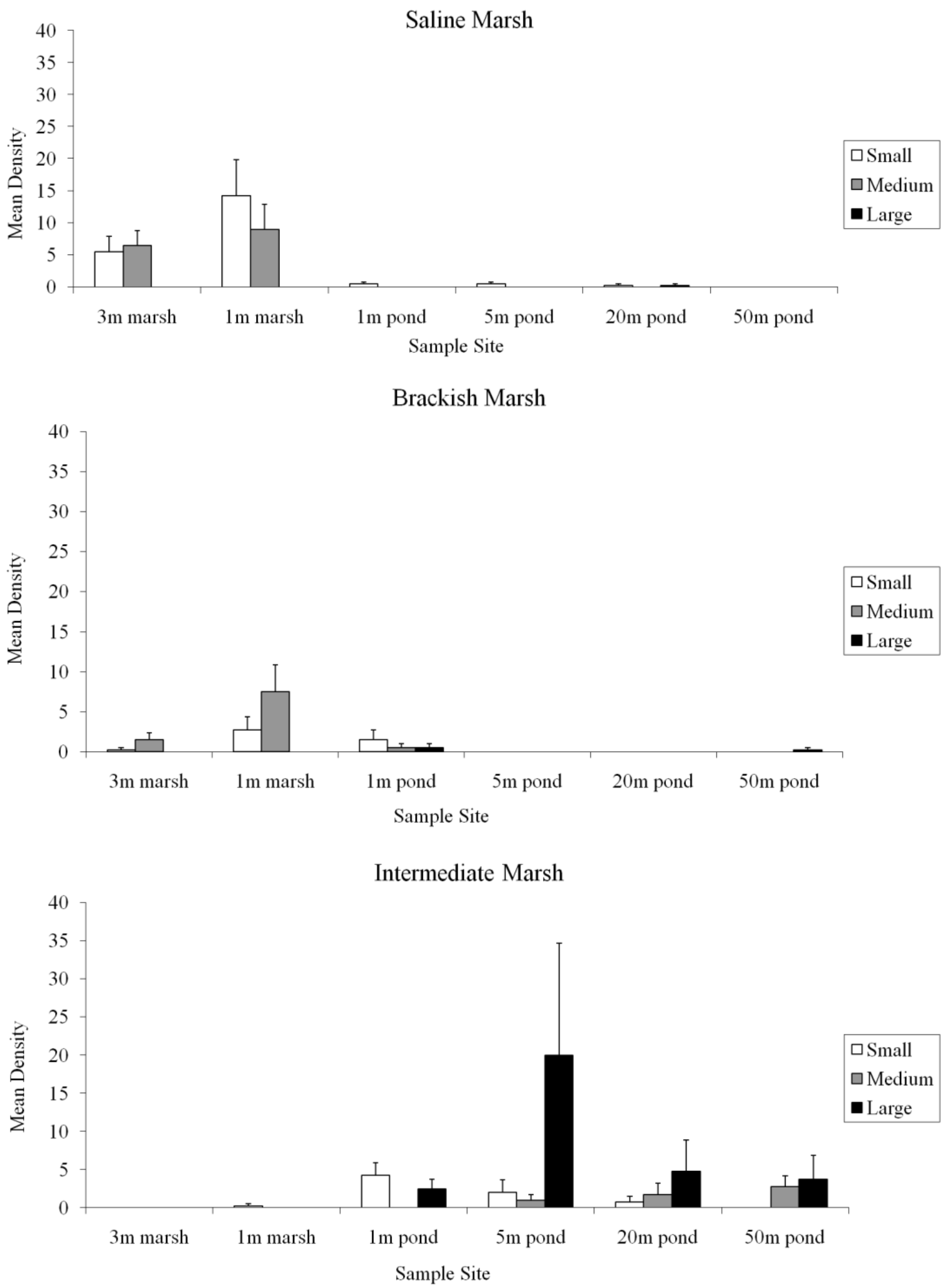


Figure C11. Mean density (individuals m^{-2}) of daggerblade grass shrimp collected April-May 2002 between two habitat types (marsh, pond), among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

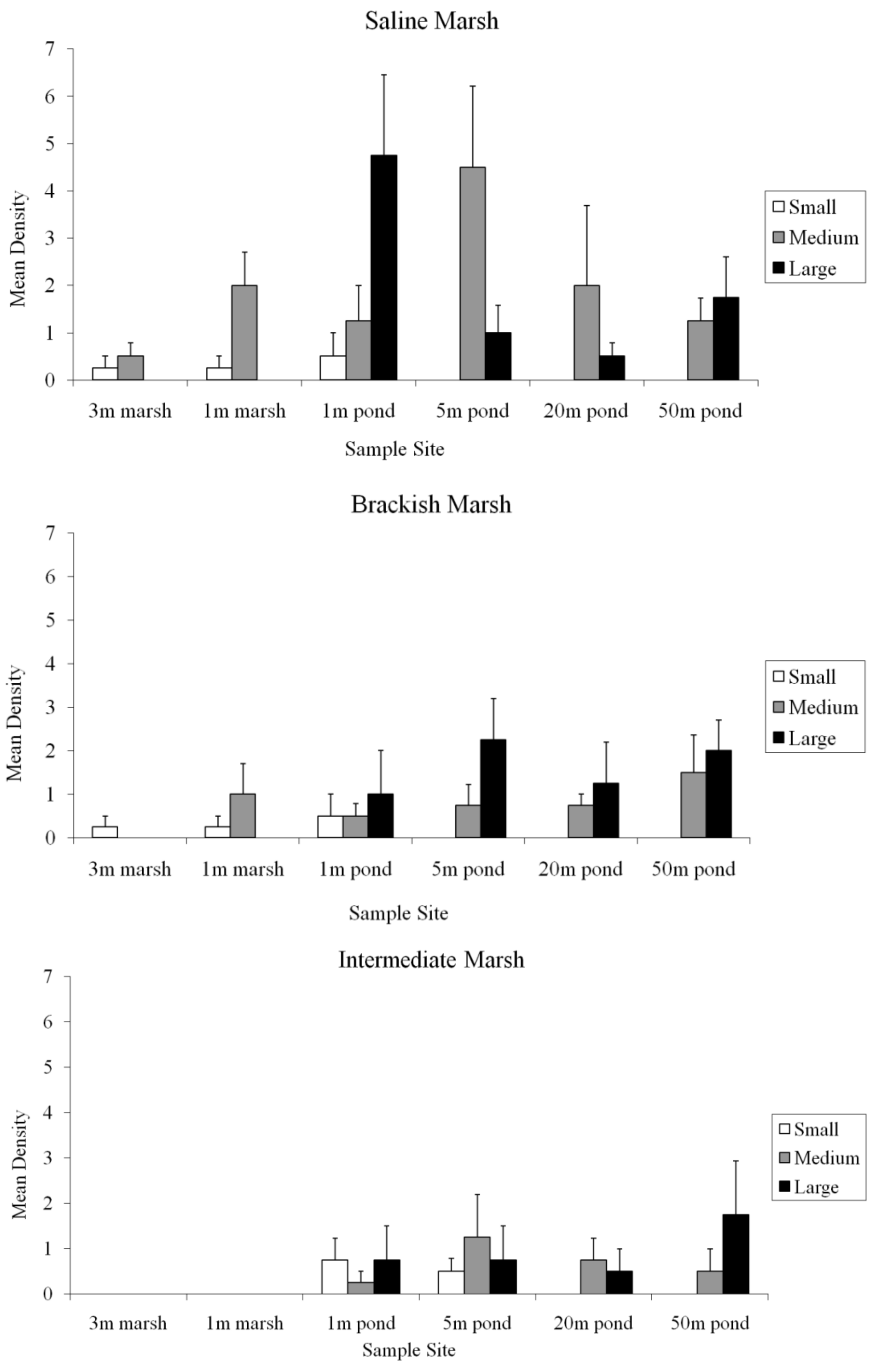


Figure C12. Mean density (individuals m^{-2}) of brown shrimp collected April-May 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

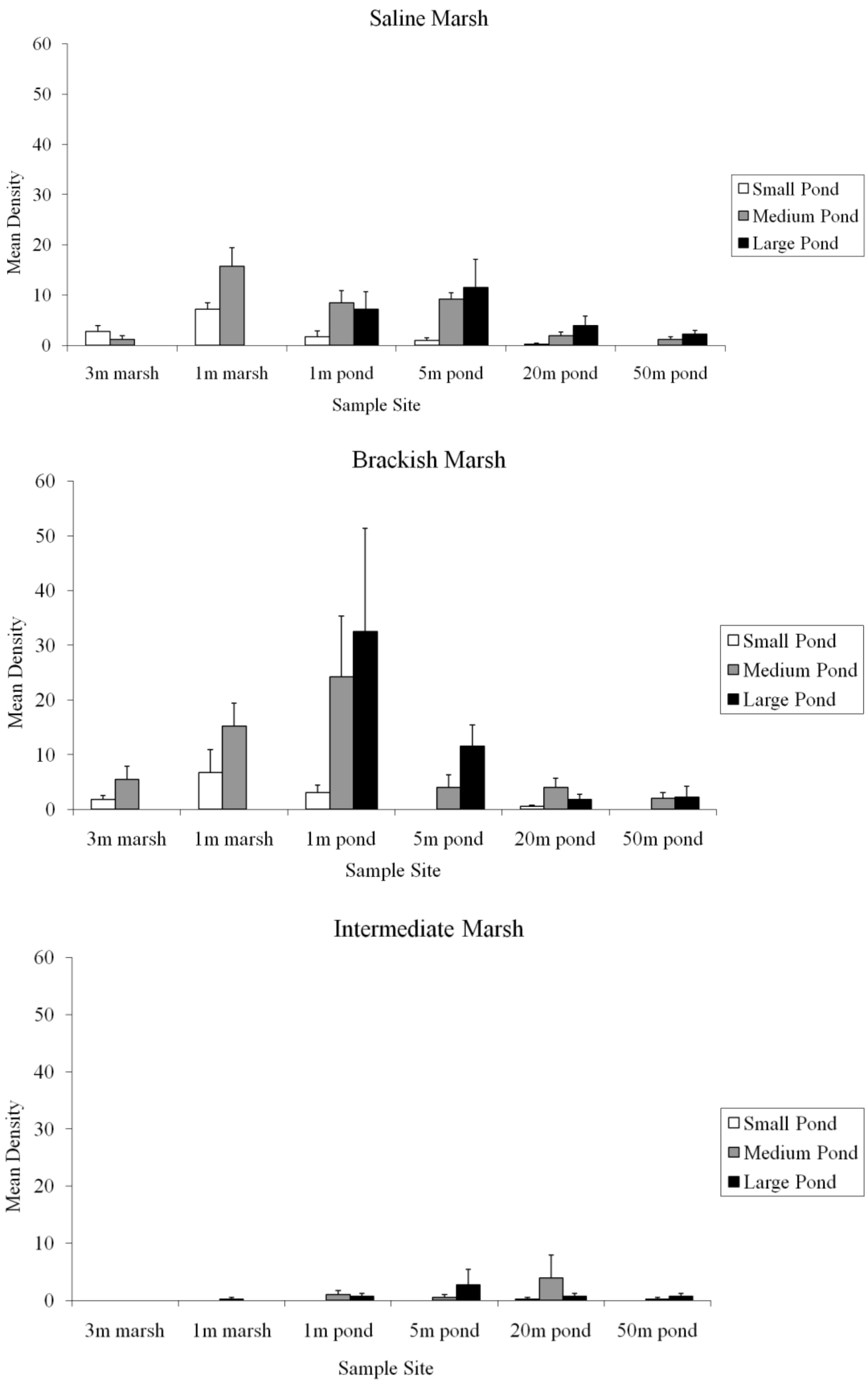


Figure C13. Mean density (individuals m^{-2}) of blue crab collected September 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

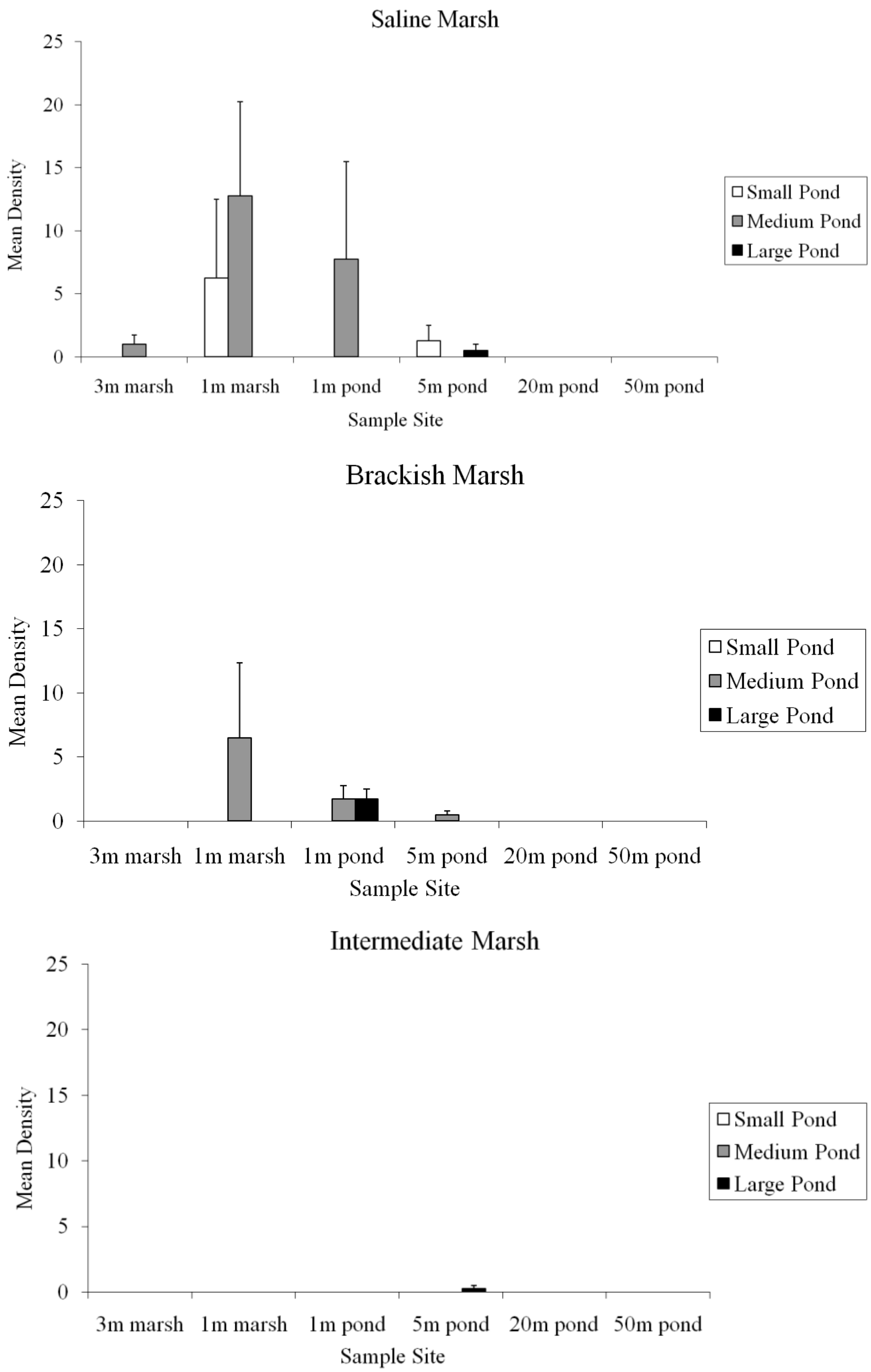


Figure C14. Mean density (individuals m^{-2}) of white shrimp collected September 2002 between two habitat types (marsh, pond) and among three pond sizes (small, medium, large) and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

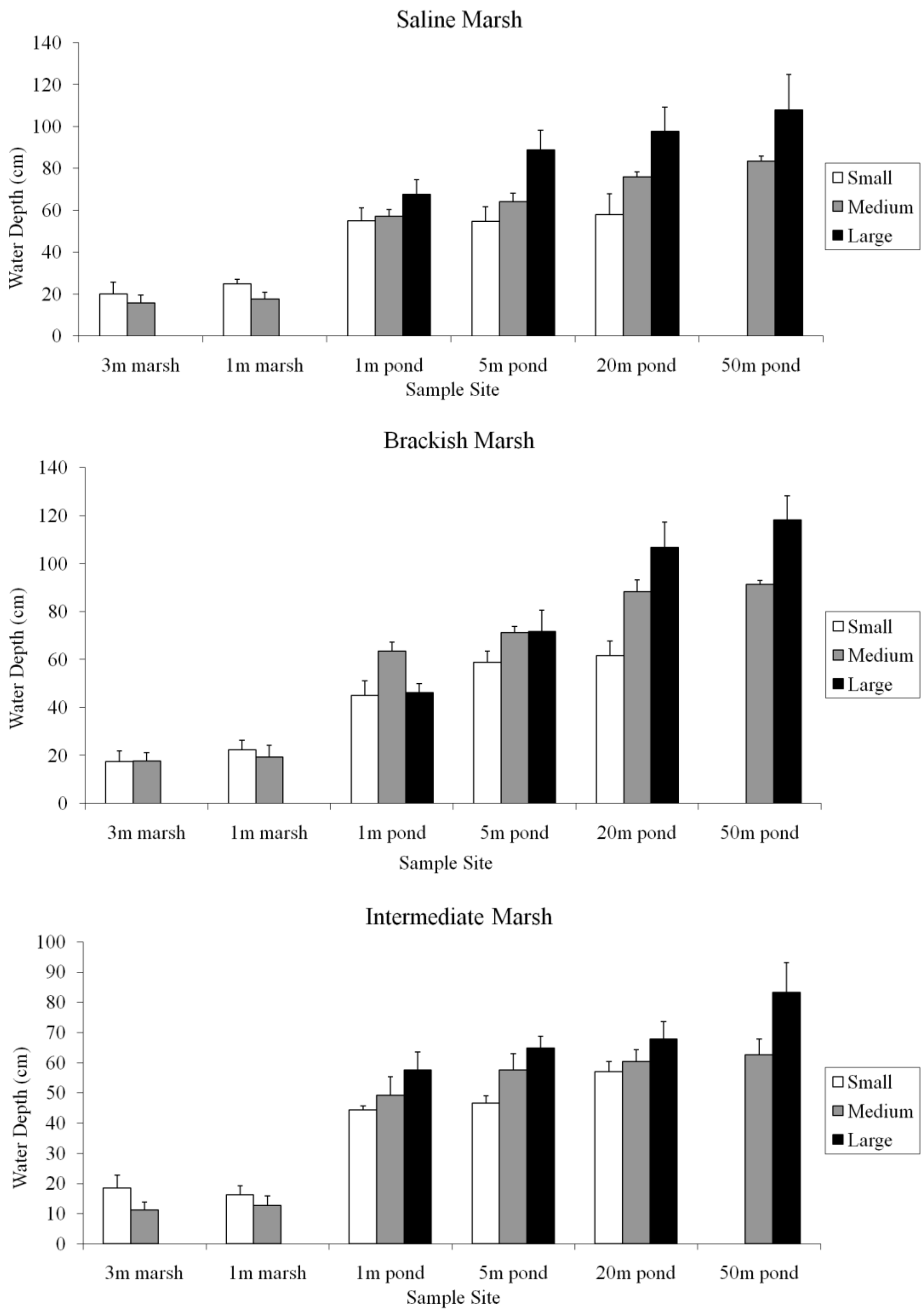


Figure C15. Mean water depth in April-May 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

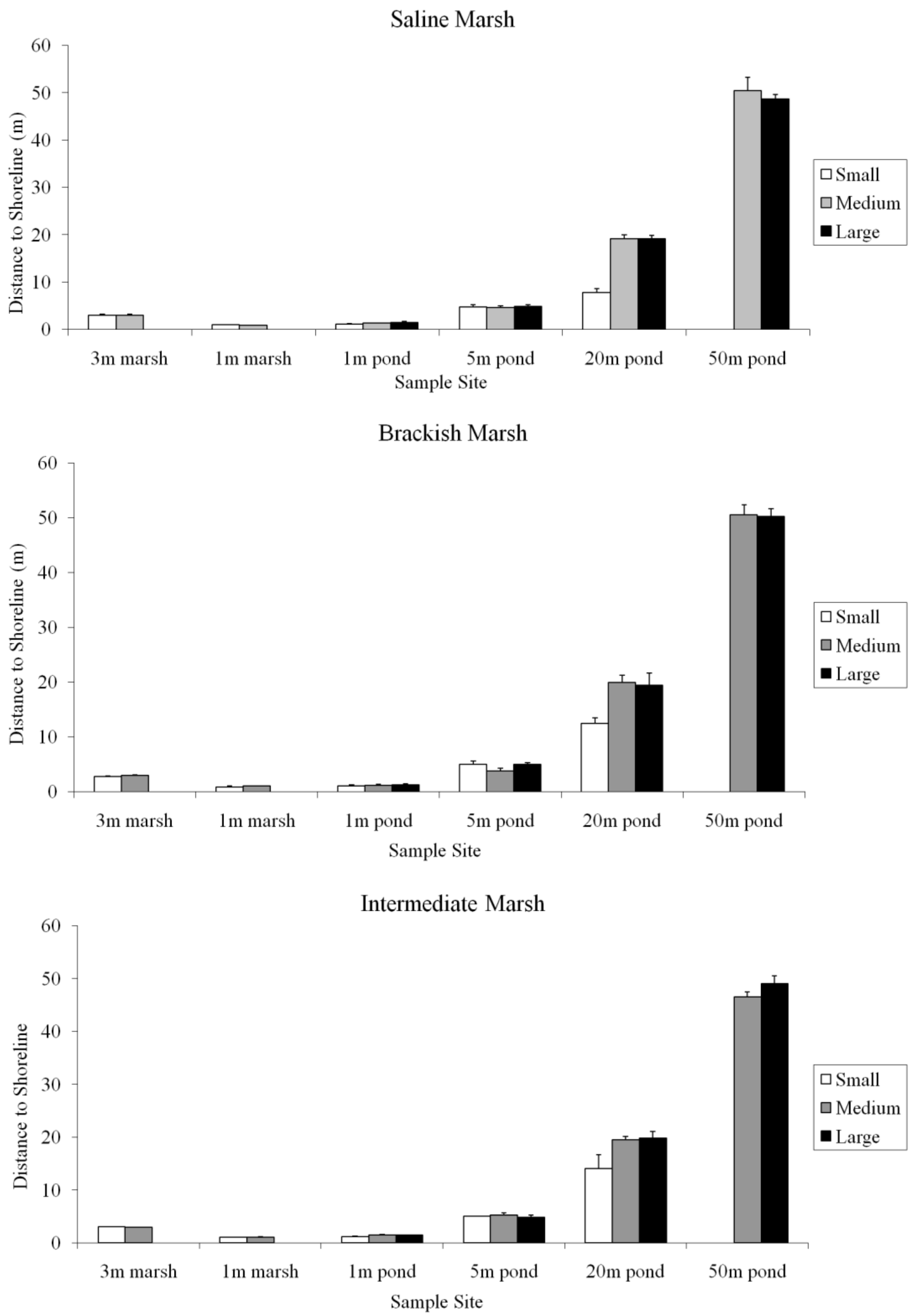


Figure C16. Mean distance to shoreline in April-May 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

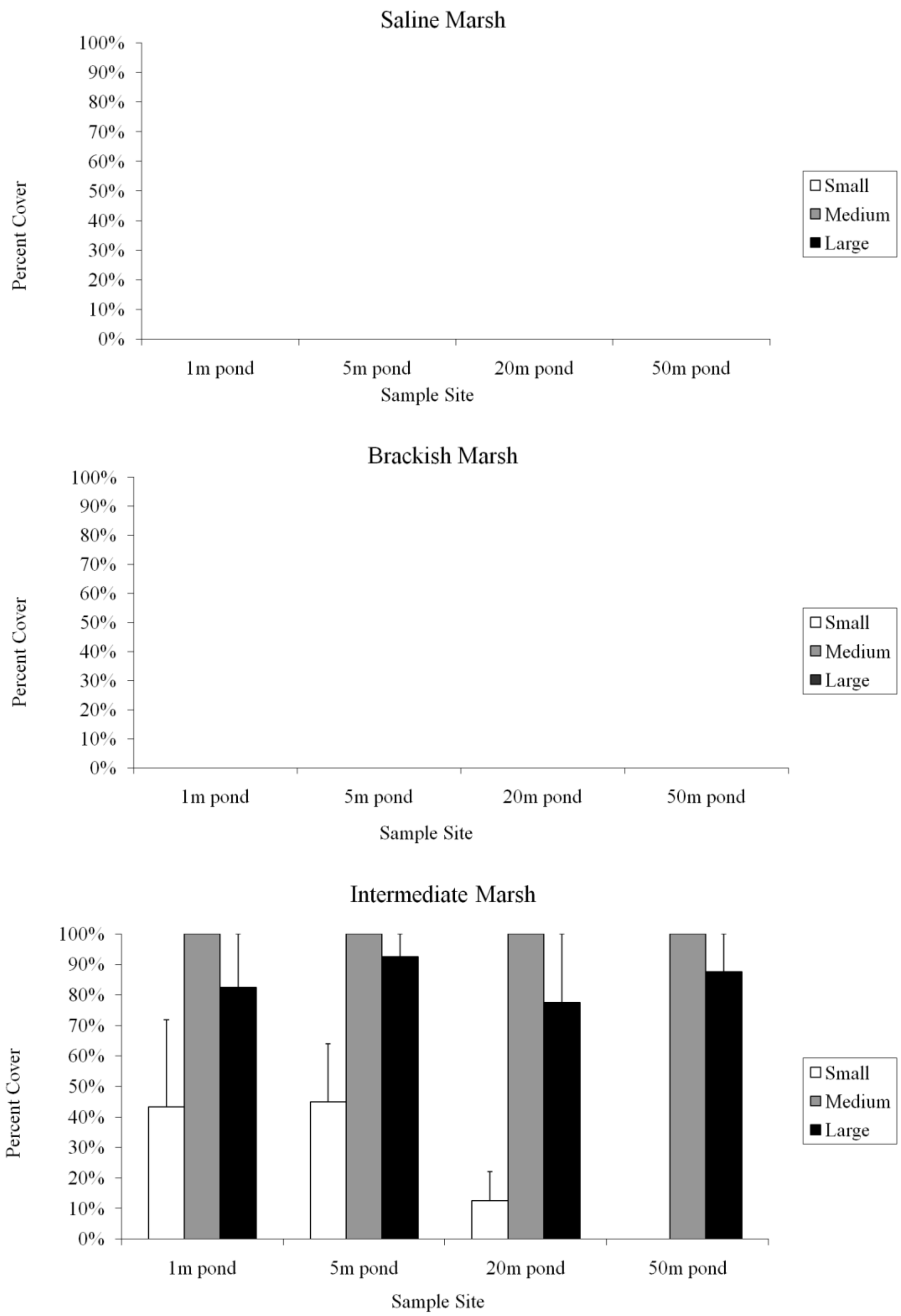


Figure C17. Mean SAV coverage in April-May 2002 in ponds of three sizes (small, medium, large) and four distance categories (1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

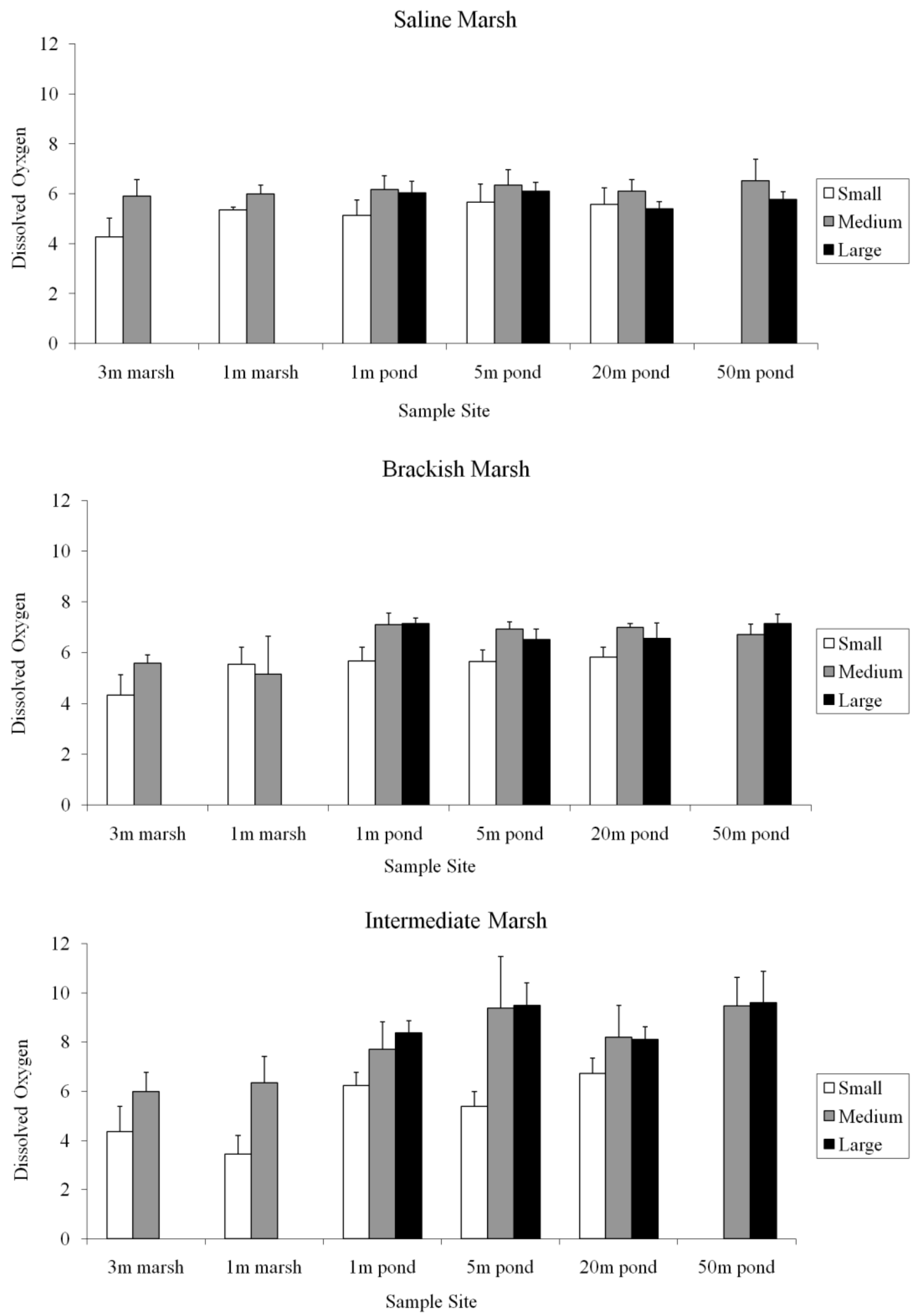
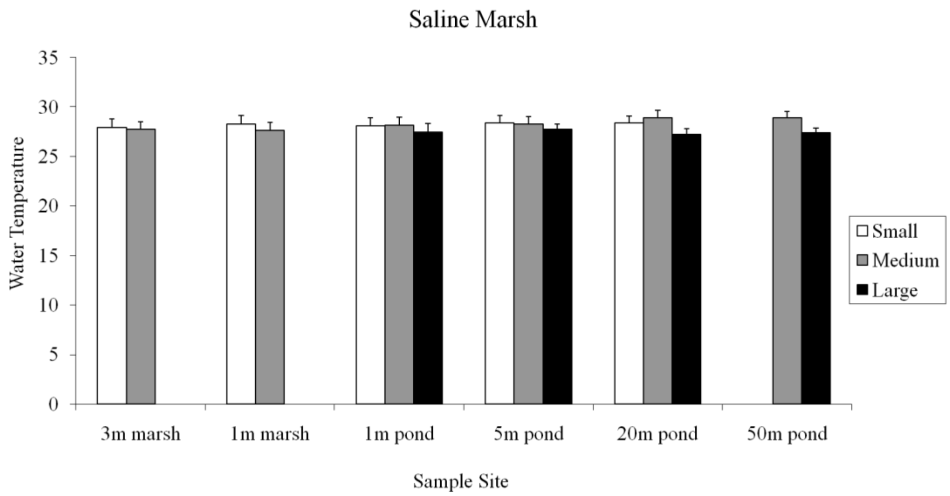
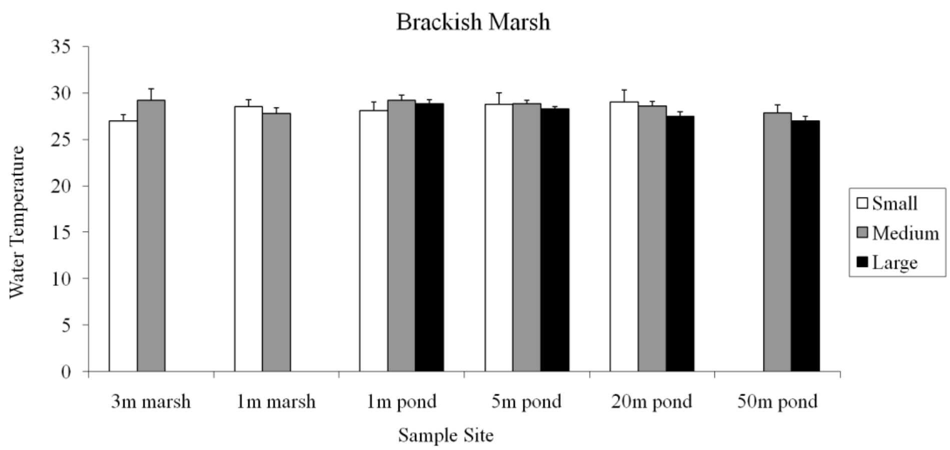


Figure C18. Mean dissolved oxygen concentration in April-May 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.





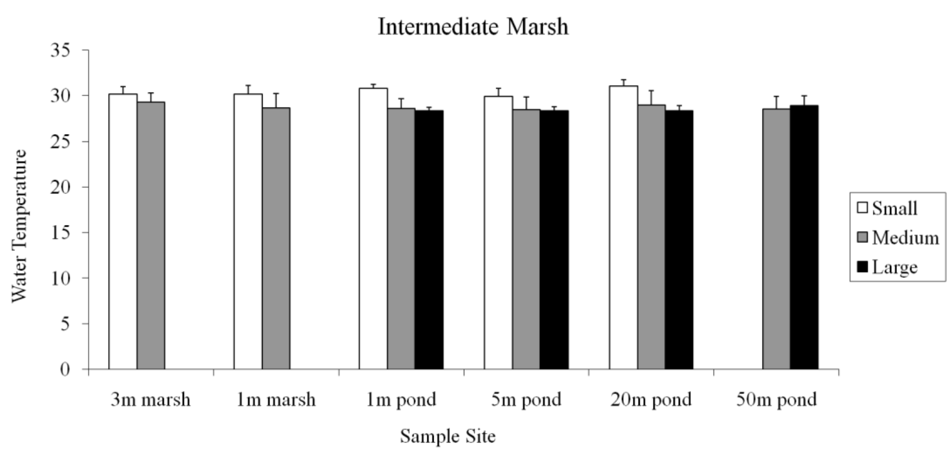


Figure C19. Mean water temperature in April-May 2002 in two habitat types (marsh, pond) and among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

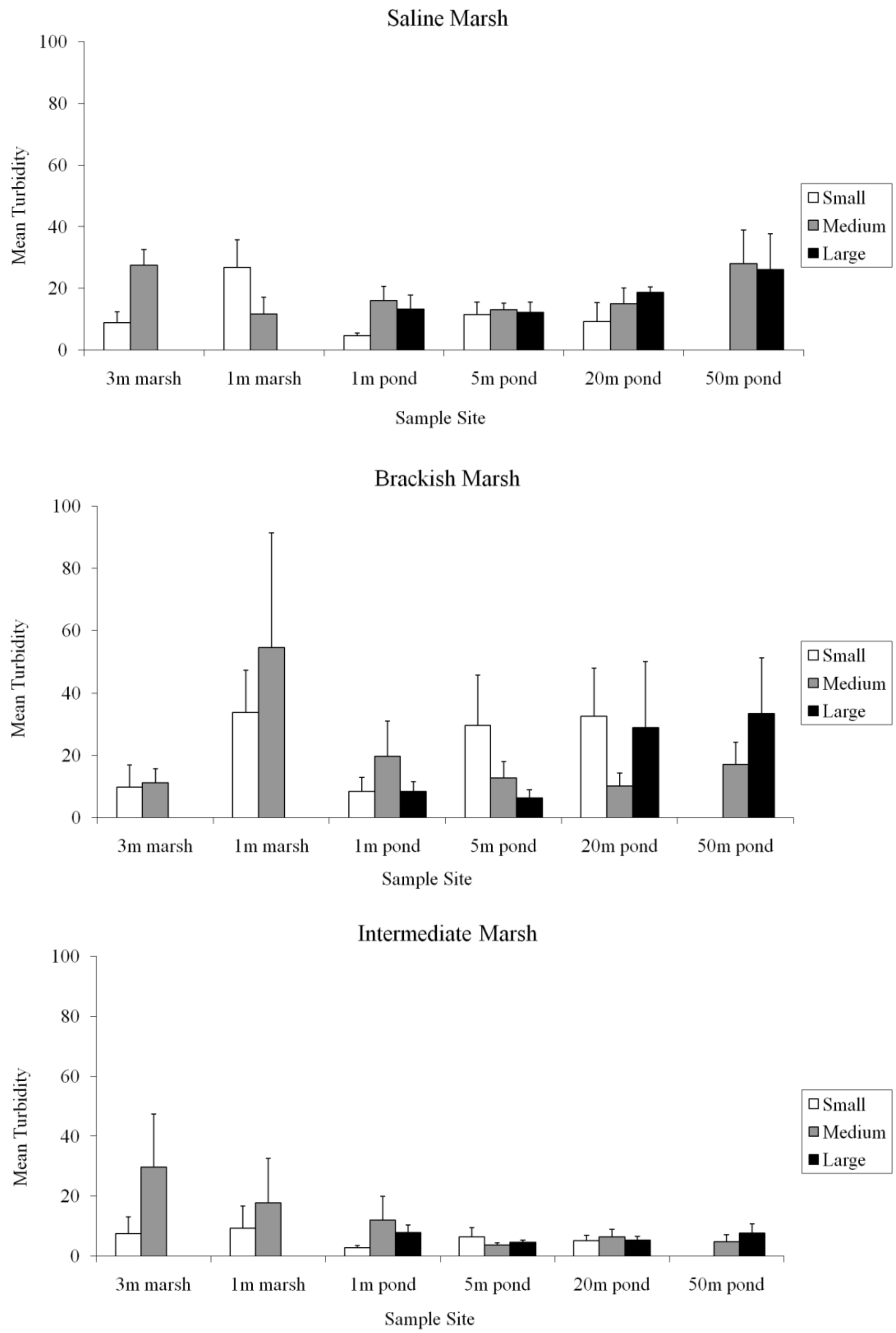


Figure C20. Mean turbidity in April-May 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

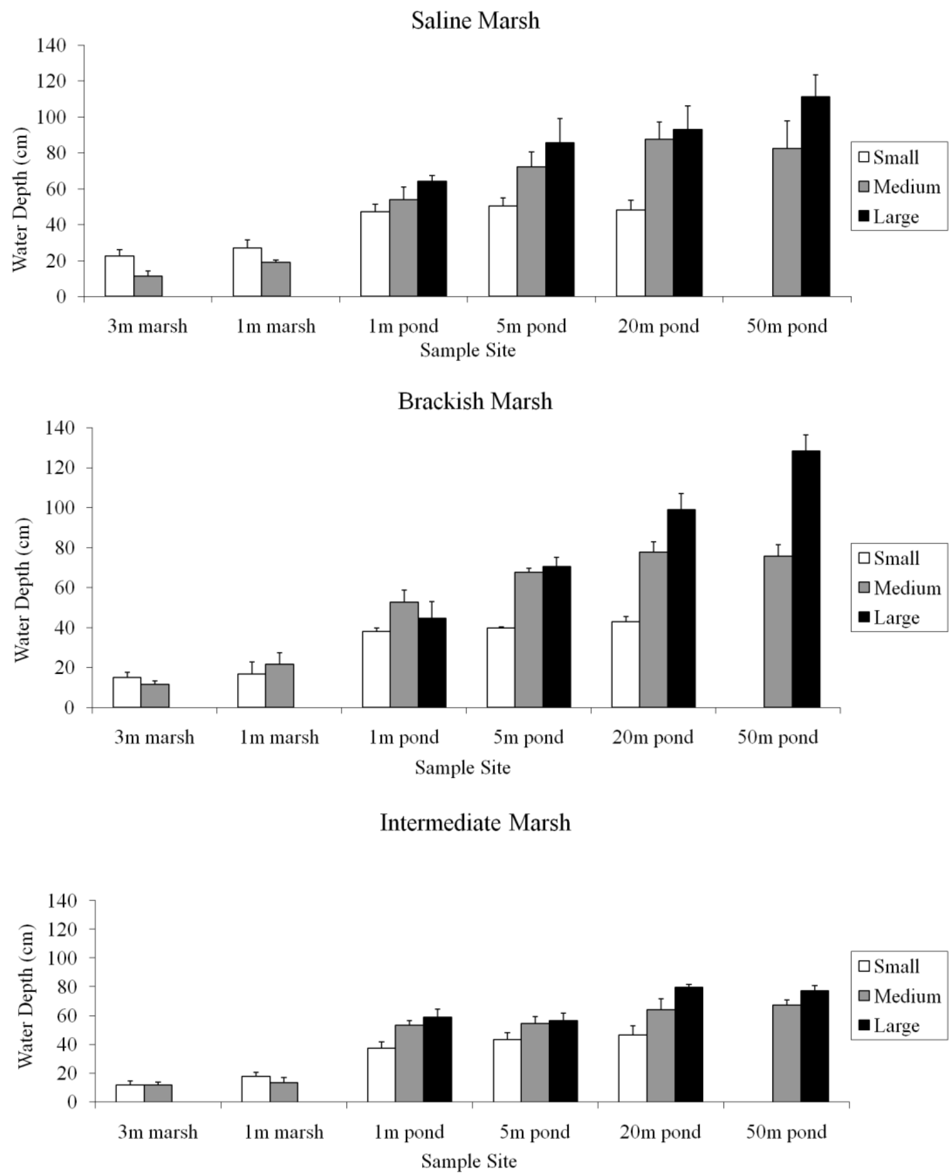


Figure C21. Mean water depth in September 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

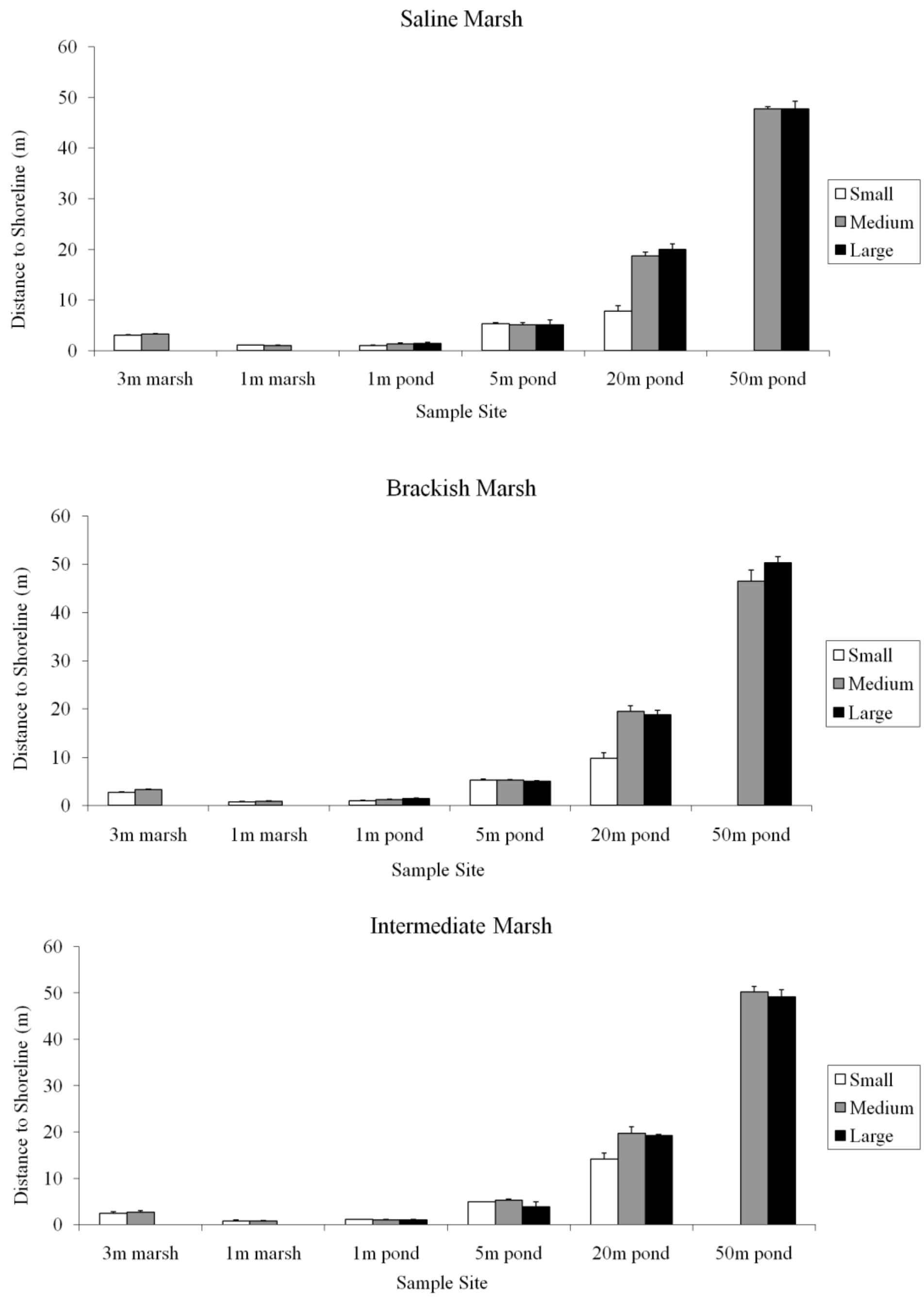


Figure C22. Mean distance to shoreline in September 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

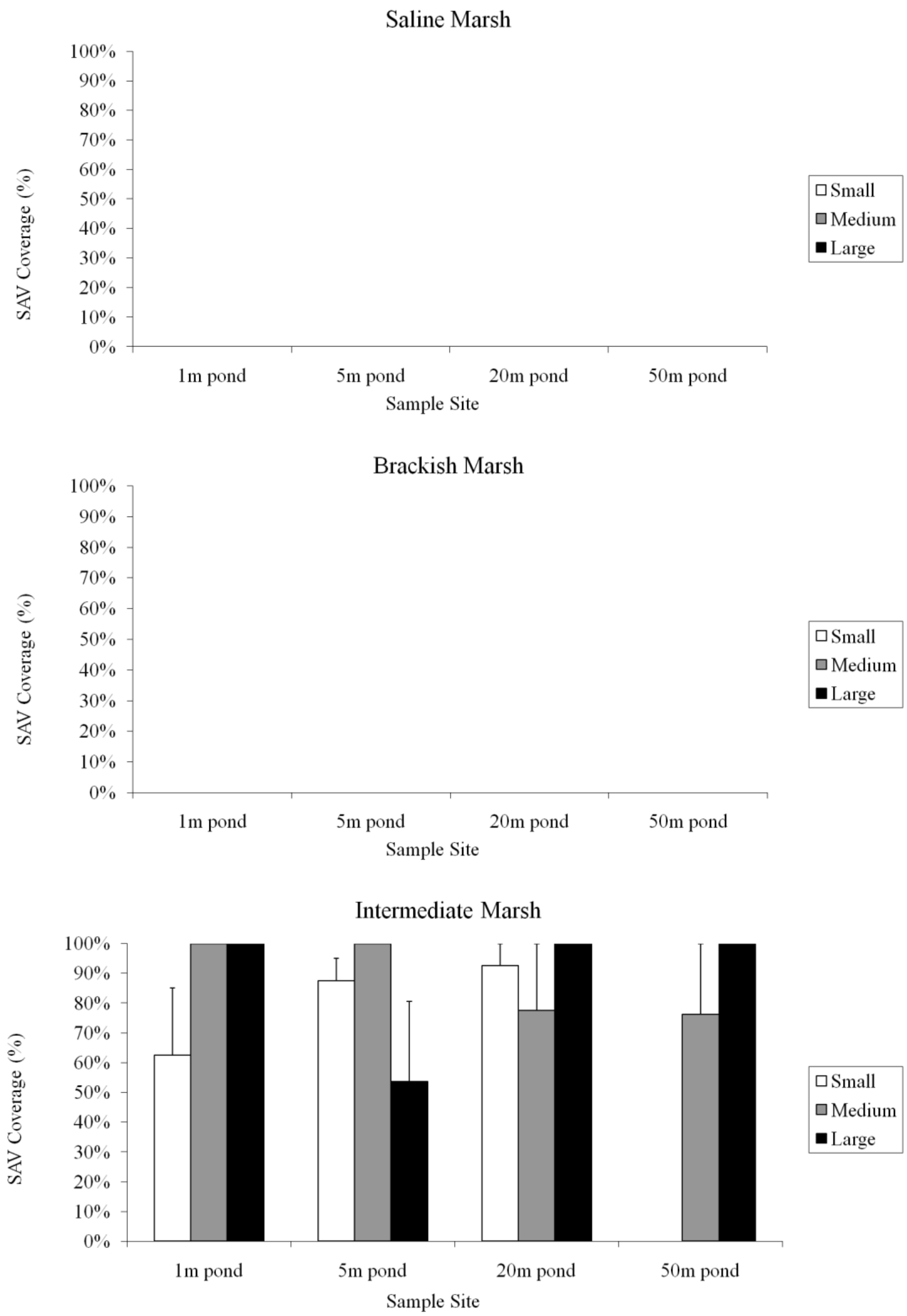


Figure C23. Mean SAV coverage in September 2002 in ponds of three sizes (small, medium, large) and four distance categories (1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

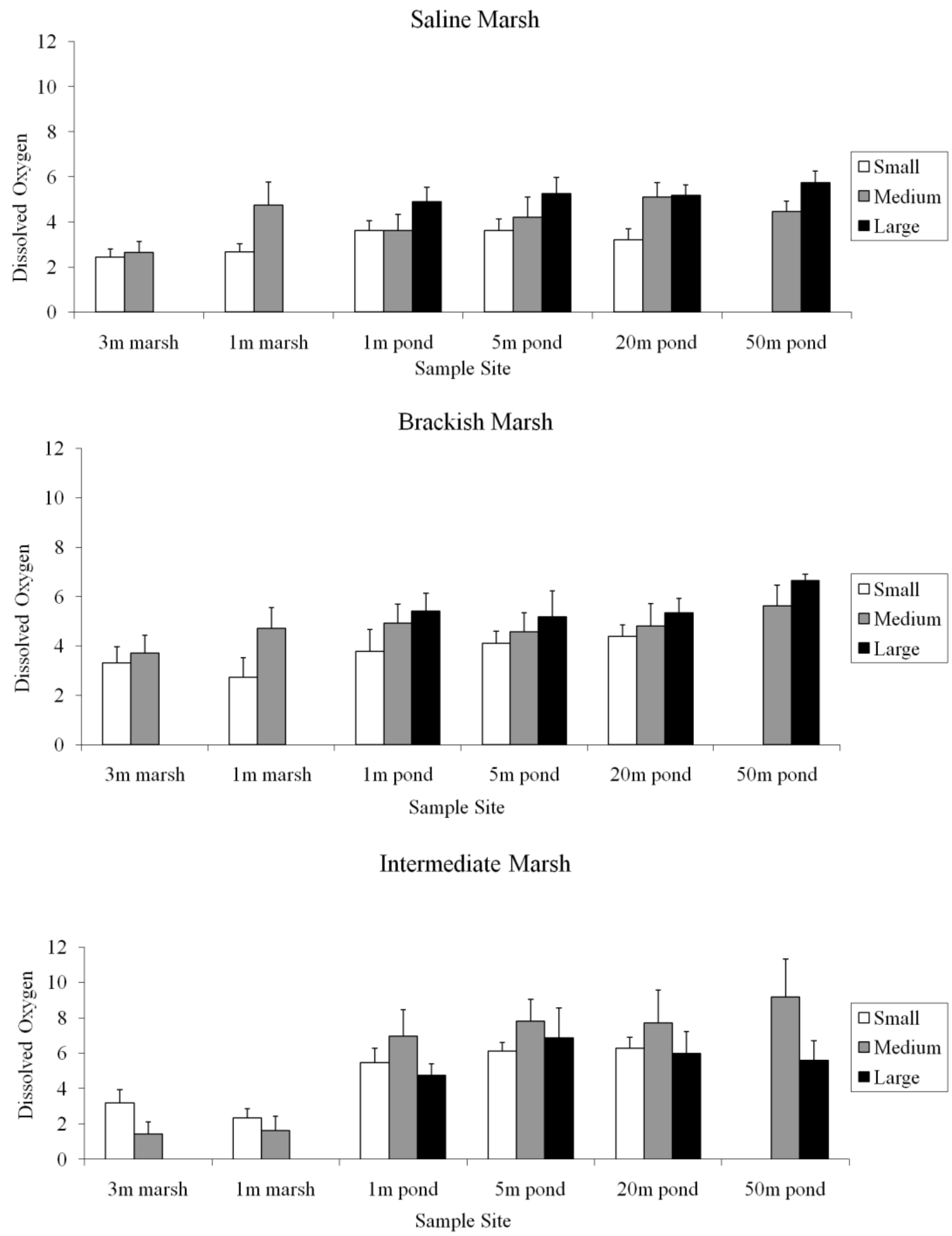


Figure C24. Mean dissolved oxygen concentration in September 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

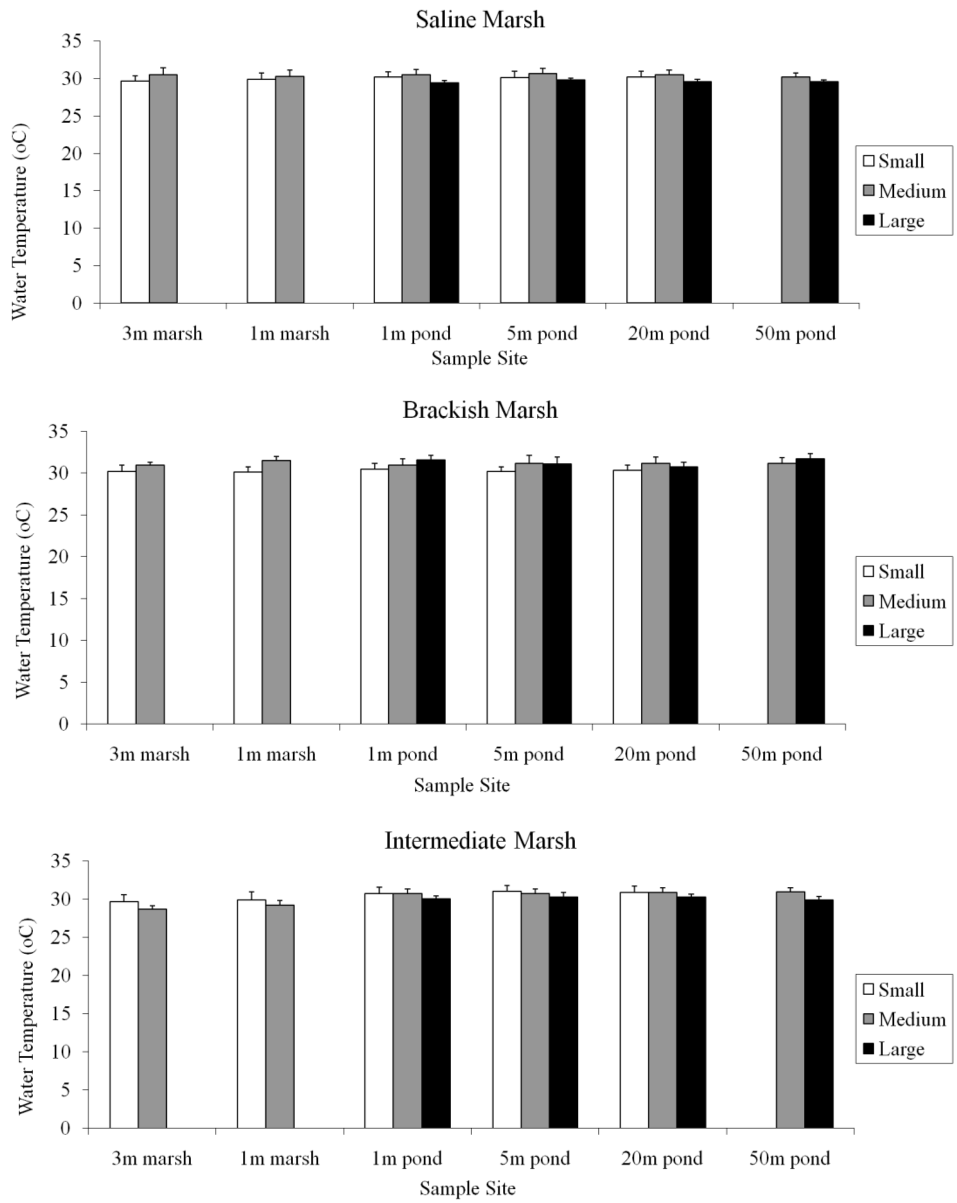


Figure C25. Mean water temperature in September 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

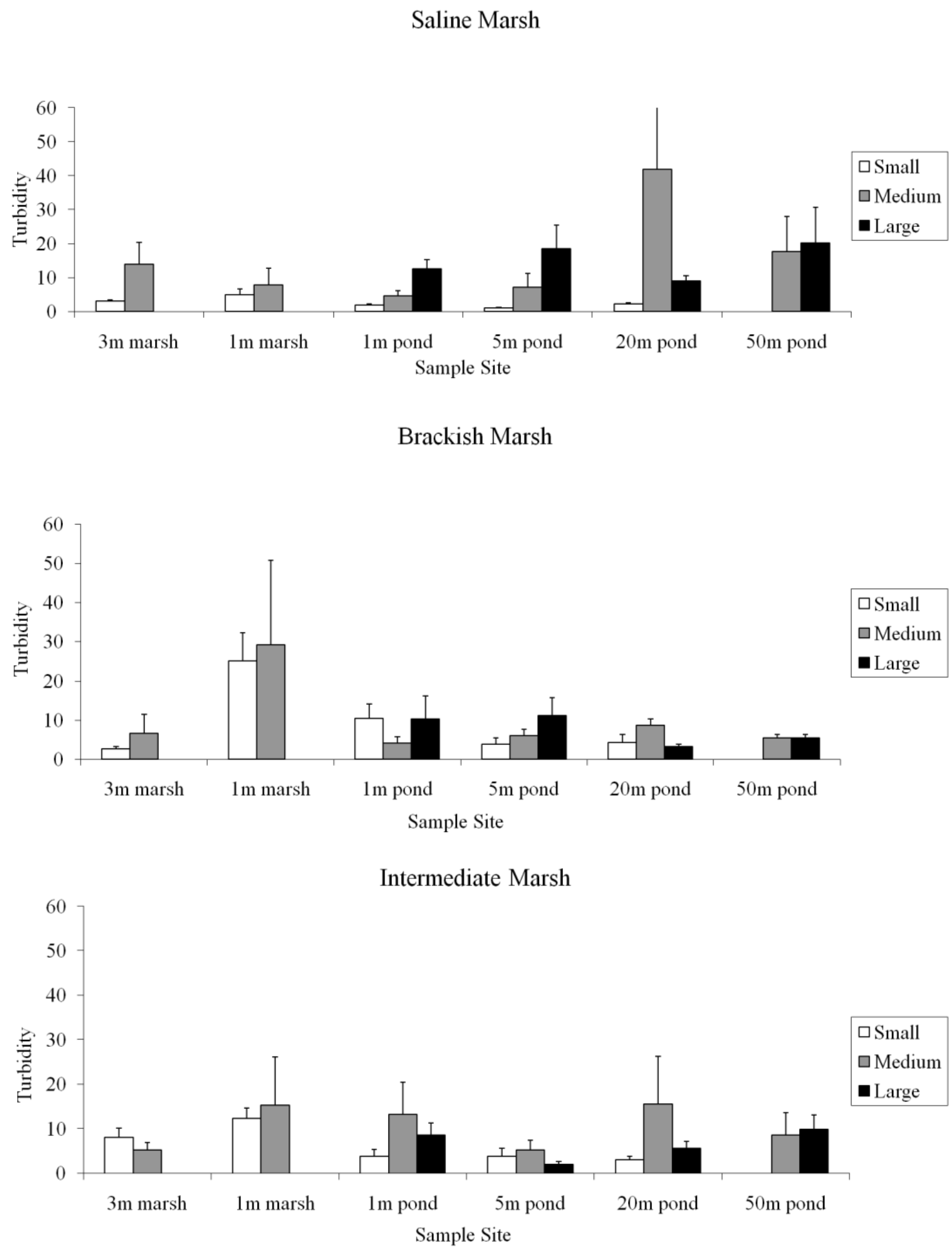


Figure C26. Mean turbidity in September 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

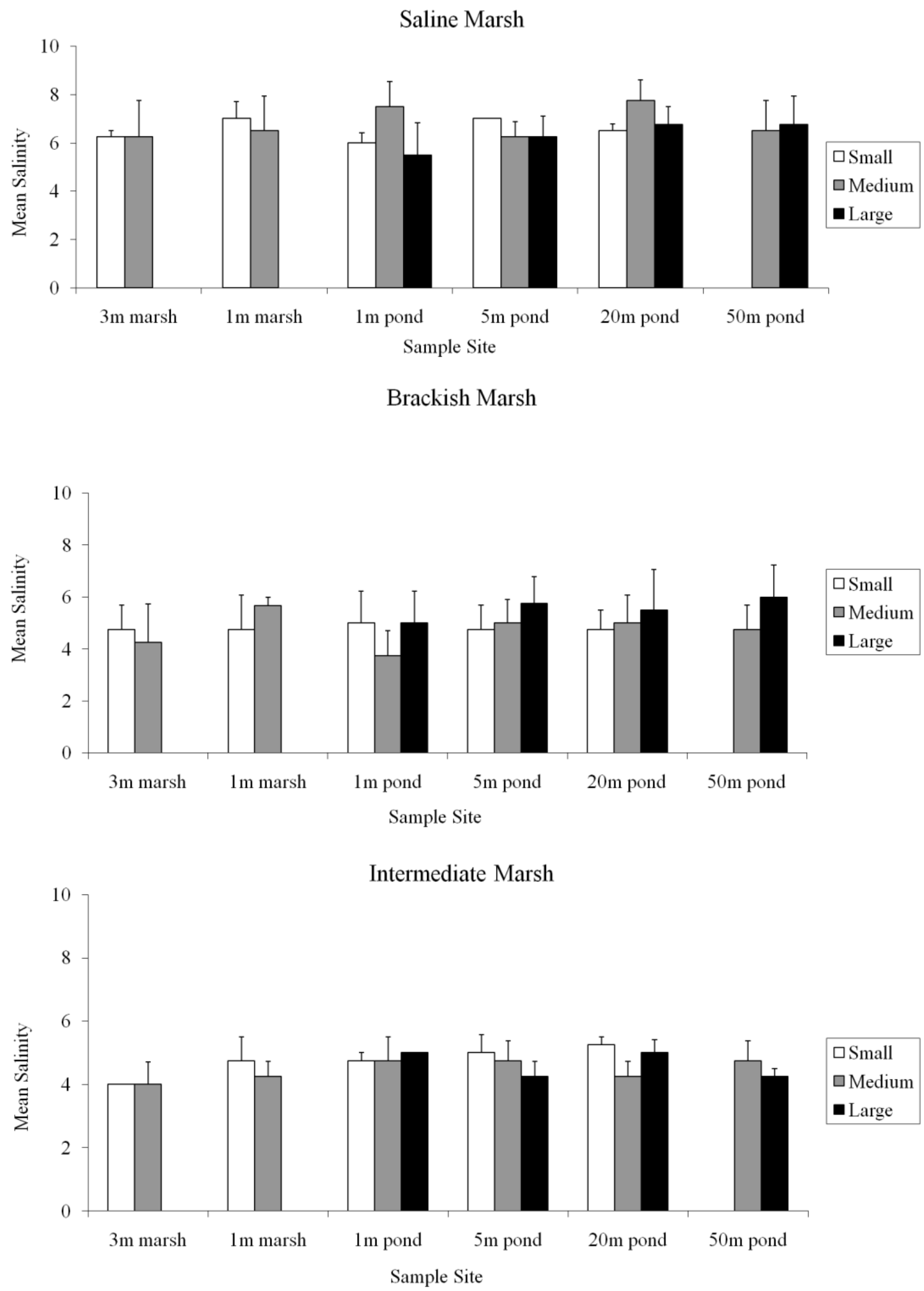


Figure C27. Mean salinity in April-May 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

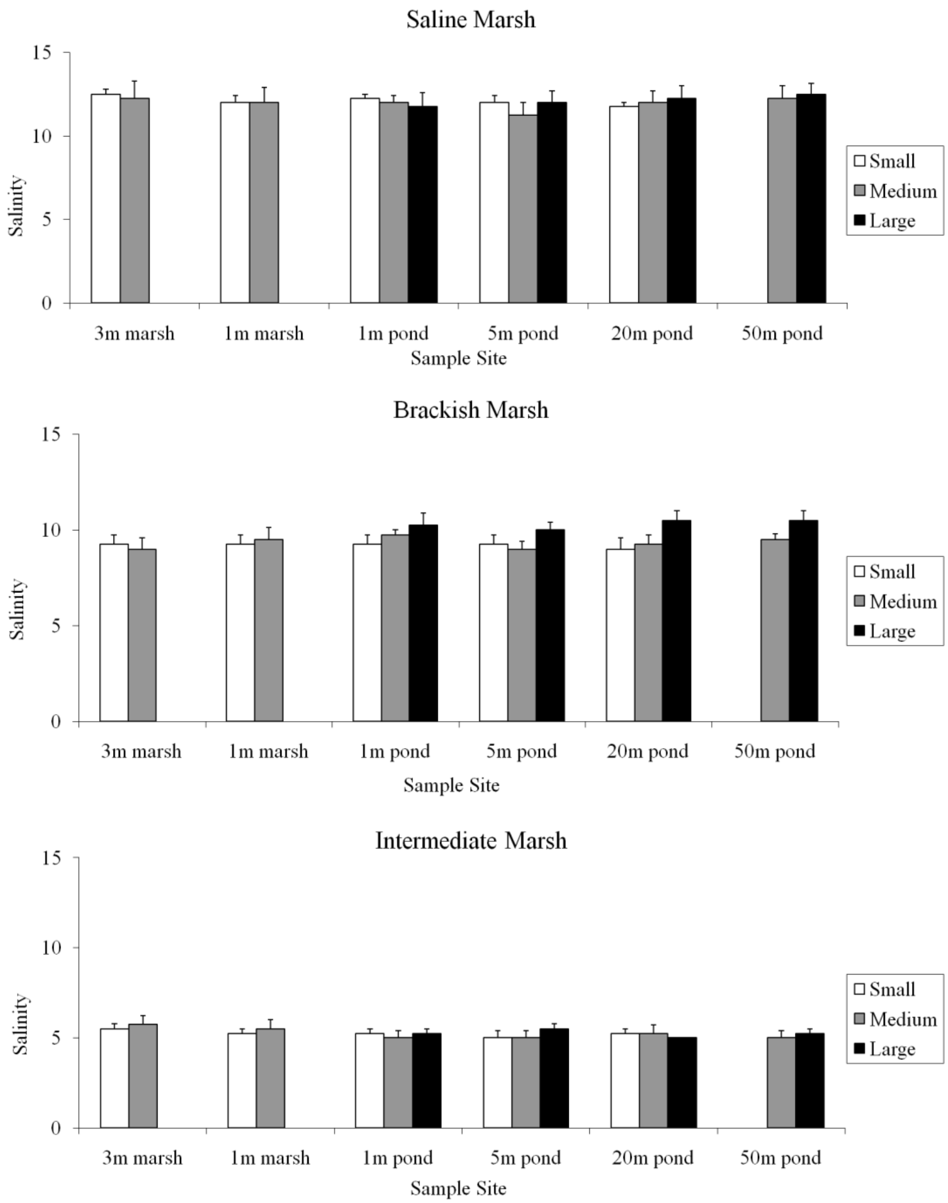


Figure C28. Mean salinity in September 2002 in two habitat types (marsh, pond), among three pond sizes (small, medium, large), and six distance categories (marsh=1 m and 3 m, pond=1 m, 5 m, 20 m, 50 m). Means were calculated from four samples. Error bars represent 1 S.E.

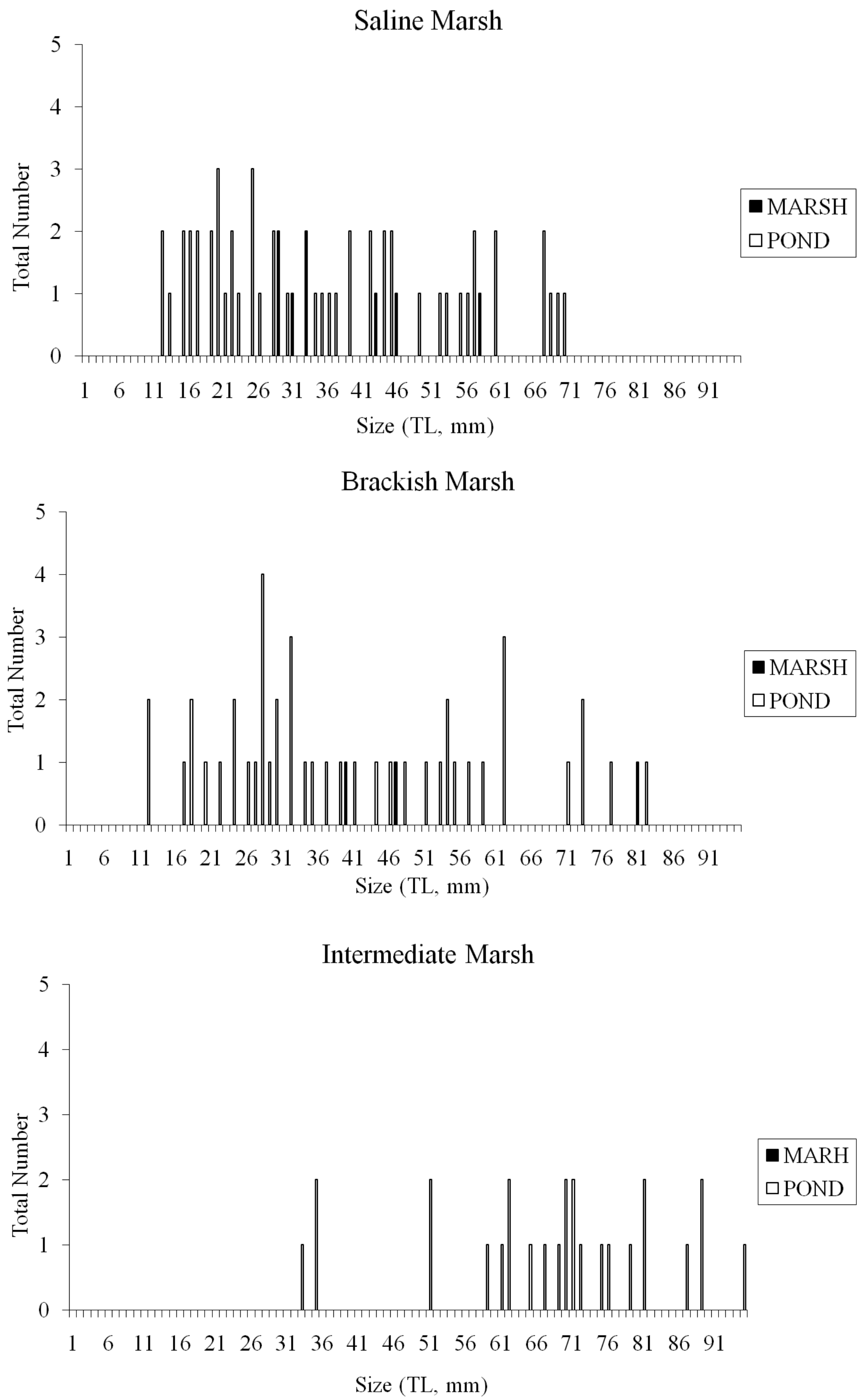


Figure C29. Size distribution of brown shrimp in marsh and ponds within saline, brackish, and intermediate marsh types in April-May 2002.

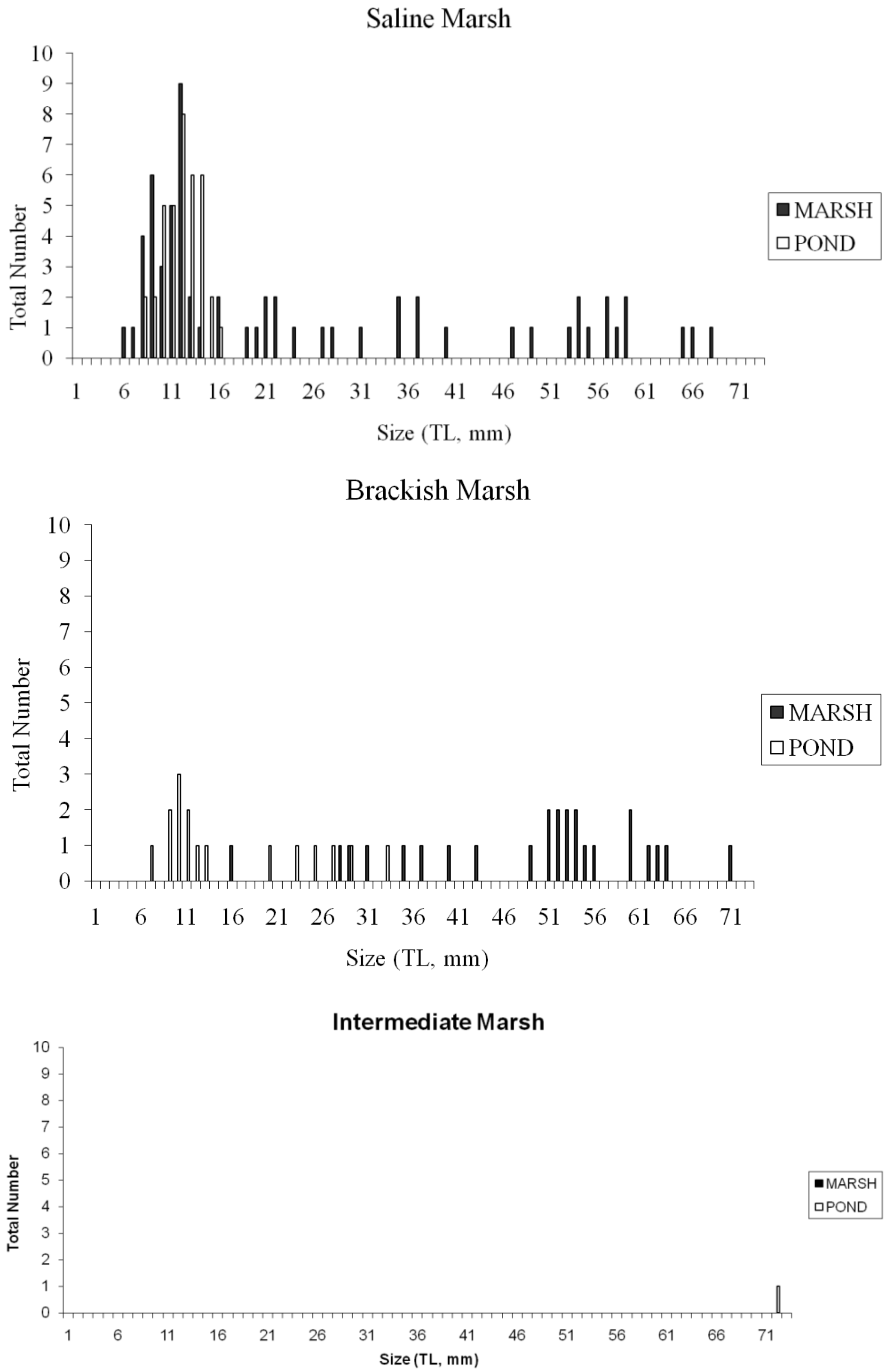


Figure C30. Size distribution of white shrimp in marsh and ponds within saline, brackish, and intermediate marsh types in September 2002.

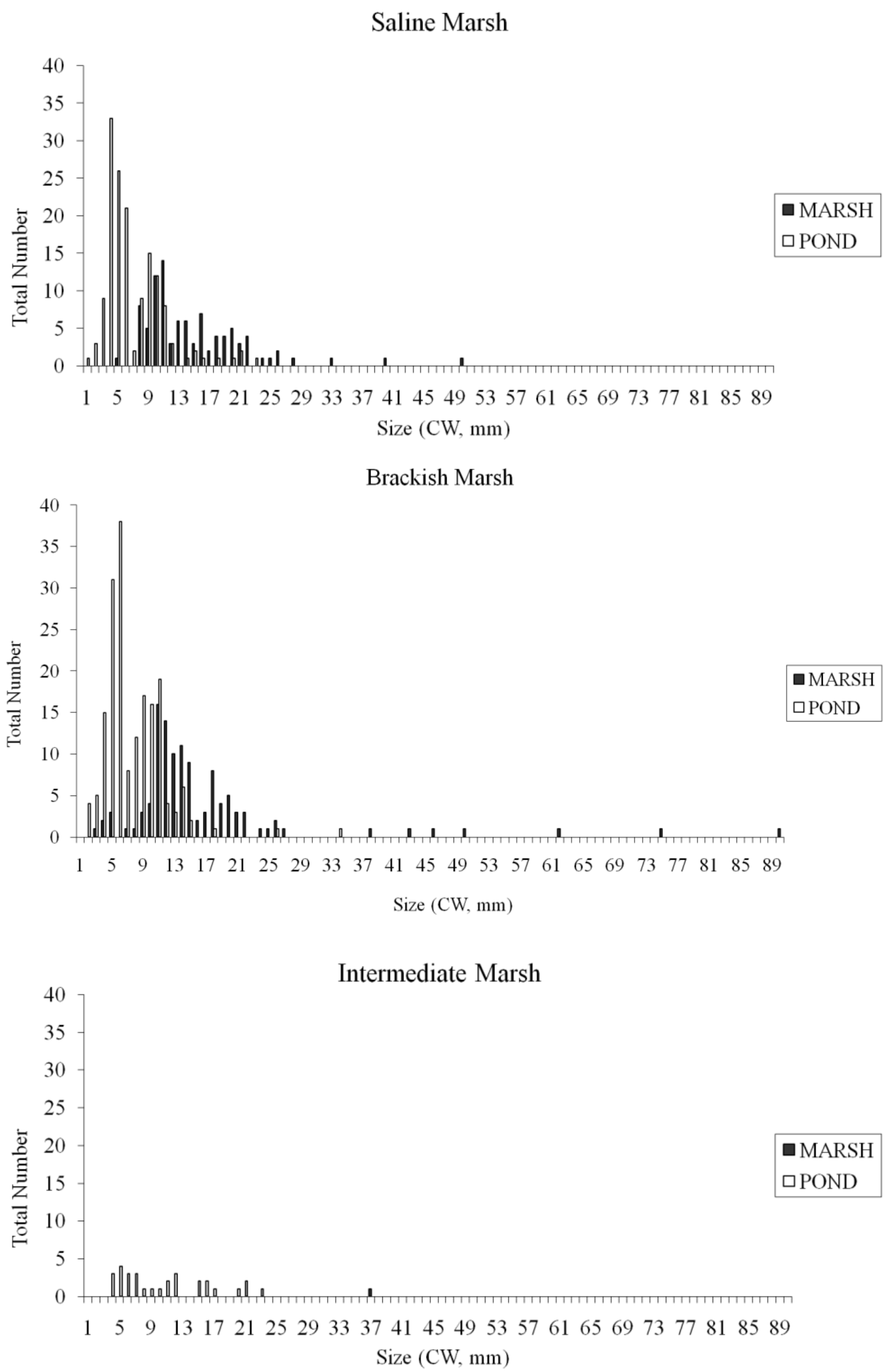


Figure C31. Size distribution of blue crab in marsh and ponds within saline, brackish, and intermediate marsh types in September 2002.

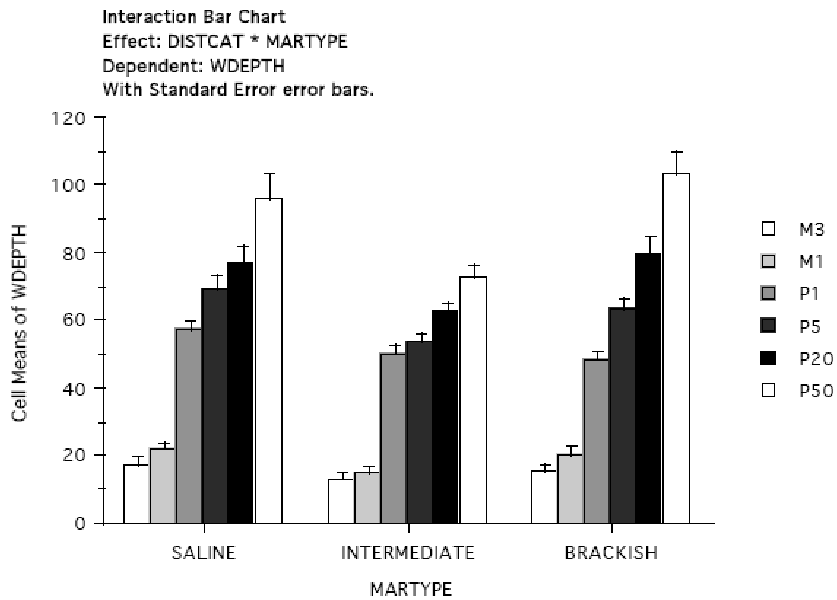


Figure C32. Mean water depth (cm) at different distances from the marsh edge in different marsh types.

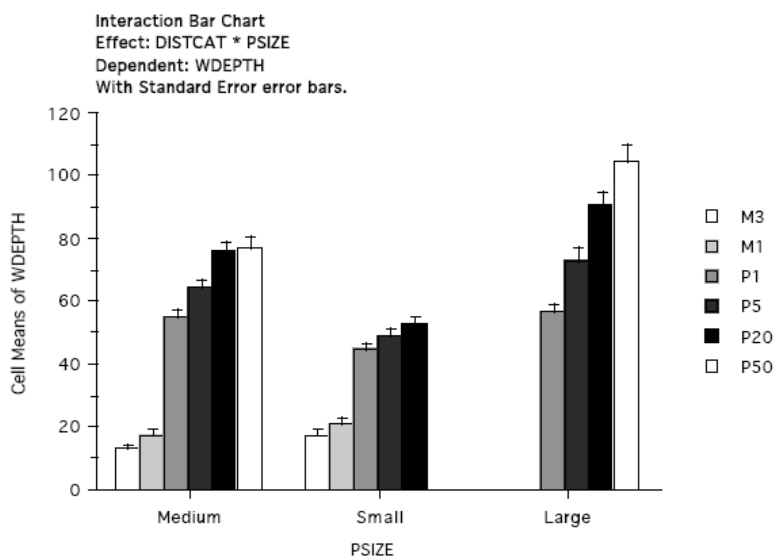


Figure C33. Mean water depth (cm) at different distances from the marsh edge in different pond sizes.

APPENDIX D – Task 4 Results

Table D1. Area of the individual microhabitat bands by marsh type for the study area. Large Water, Medium Water, and Small Ponds are designated LW, MW, and SP, respectively. Bands within the water are designated "*w*" and bands within the vegetation are designation "*m*."

Marsh Type	Band Length (m)	Area (Hectares)	Percent of Total Area
Fresh/Intermediate	LW > 10 *w*	27	< 1%
Fresh/Intermediate	LW 0-10 *w*	8	< 1%
Fresh/Intermediate	MW >10 *w*	4,939	23%
Fresh/Intermediate	MW 0-10 *w*	2,218	10%
Fresh/Intermediate	MW 0-2 *m*	590	3%
Fresh/Intermediate	MW 2-4 *m*	300	1%
Fresh/Intermediate	MW 4-6 *m*	229	1%
Fresh/Intermediate	MW 6-8 *m*	245	1%
Fresh/Intermediate	MW 8-10 *m*	137	< 1%
Fresh/Intermediate	SP > 10 *w*	0	
Fresh/Intermediate	SP 0-10 *w*	208	< 1%
Fresh/Intermediate	SP 0-2 *m*	223	1%
Fresh/Intermediate	SP 2-4 *m*	161	< 1%
Fresh/Intermediate	SP 4-6 *m*	143	< 1%
Fresh/Intermediate	SP 6-8 *m*	185	< 1%
Fresh/Intermediate	SP 8-10 *m*	112	< 1%
Brackish	LW > 10 *w*	475	2%
Brackish	LW 0-10 *w*	193	< 1%
Brackish	MW >10 *w*	2,094	10%
Brackish	MW 0-10 *w*	1,848	9%
Brackish	MW 0-2 *m*	555	3%
Brackish	MW 2-4 *m*	311	1%
Brackish	MW 4-6 *m*	262	1%
Brackish	MW 6-8 *m*	316	1%
Brackish	MW 8-10 *m*	200	< 1%
Brackish	SP > 10 *w*	0	
Brackish	SP 0-10 *w*	417	2%
Brackish	SP 0-2 *m*	513	2%
Brackish	SP 2-4 *m*	351	2%
Brackish	SP 4-6 *m*	313	1%
Brackish	SP 6-8 *m*	418	2%
Brackish	SP 8-10 *m*	262	1%
Saline	LW > 10 *w*	224	1%
Saline	LW 0-10 *w*	124	< 1%
Saline	MW >10 *w*	589	3%
Saline	MW 0-10 *w*	652	3%
Saline	MW 0-2 *m*	198	< 1%
Saline	MW 2-4 *m*	100	< 1%
Saline	MW 4-6 *m*	79	< 1%
Saline	MW 6-8 *m*	89	< 1%
Saline	MW 8-10 *m*	54	< 1%
Saline	SP > 10 *w*	0	
Saline	SP 0-10 *w*	253	1%
Saline	SP 0-2 *m*	342	2%
Saline	SP 2-4 *m*	216	< 1%
Saline	SP 4-6 *m*	180	< 1%

Saline	SP 6-8 *m*	225	1%
Saline	SP 8-10 *m*	131	< 1%
TOTAL		21,709	100%

Table D2. Nekton abundance in each of the microhabitat bands and marsh types. The distribution of a species across all marsh types is also included as a percent of the total abundance of that species. Large Water, Medium Water, and Small Ponds are designated LW, MW, and SP, respectively. Bands within the water are designated "*w*" and bands within the vegetation are designation "*m*."

		Blue crab		Brown shrimp		White shrimp	
Marsh Type	**Band Length (m)**	**Abundance**	**Percent**	**Abundance**	**Percent**	**Abundance**	**Percent**
Fresh/Intermediate	LW > 10 *w*	245,779	< 1%	245,779	< 1%	0	< 1%
Fresh/Intermediate	LW 0-10 *w*	73,480	< 1%	73,480	< 1%	65,315	< 1%
Fresh/Intermediate	MW >10 *w*	44,445,672	6%	44,445,672	34%	0	< 1%
Fresh/Intermediate	MW 0-10 *w*	19,965,258	3%	19,965,258	15%	17,746,896	12%
Fresh/Intermediate	MW 0-2 *m*	590,283	< 1%	0		0	
Fresh/Intermediate	MW 2-4 *m*	0		0		0	
Fresh/Intermediate	MW 4-6 *m*	0		0		0	
Fresh/Intermediate	MW 6-8 *m*	0		0		0	
Fresh/Intermediate	MW 8-10 *m*	0		0		0	
Fresh/Intermediate	SP > 10 *w*	209	< 1%	23	< 1%	0	
Fresh/Intermediate	SP 0-10 *w*	1,870,672	< 1%	207,852	< 1%	1,662,819	1%
Fresh/Intermediate	SP 0-2 *m*	222,625	< 1%	0		0	
Fresh/Intermediate	SP 2-4 *m*	0		0		0	
Fresh/Intermediate	SP 4-6 *m*	0		0		0	
Fresh/Intermediate	SP 6-8 *m*	0		0		0	
Fresh/Intermediate	SP 8-10 *m*	0		0		0	
Brackish	LW > 10 *w*	11,411,242	2%	4,279,216	3%	0	
Brackish	LW 0-10 *w*	26,234,237	3%	1,736,089	1%	1,543,190	1%
Brackish	MW >10 *w*	50,263,152	7%	18,848,682	14%	0	
Brackish	MW 0-10 *w*	251,339,370	33%	16,632,752	13%	14,784,669	10%
Brackish	MW 0-2 *m*	85,879,548	11%	2,770,308	2%	35,459,942	23%
Brackish	MW 2-4 *m*	13,045,402	2%	310,605	< 1%	931,814	1%
Brackish	MW 4-6 *m*	2,886,149	< 1%	0		0	
Brackish	MW 6-8 *m*	950,076	< 1%	0		0	
Brackish	MW 8-10 *m*	0		0		0	
Brackish	SP > 10 *w*	232	< 1%	46	< 1%	0	
Brackish	SP 0-10 *w*	5,837,395	1%	416,957	< 1%	3,335,654	2%
Brackish	SP 0-2 *m*	35,899,444	5%	512,849	< 1%	32,822,349	21%
Brackish	SP 2-4 *m*	6,673,172	1%	351,220	< 1%	1,053,659	1%
Brackish	SP 4-6 *m*	1,565,214	< 1%	0		0	

Brackish	SP 6-8 *m*	417,610	< 1%	0		0	
Brackish	SP 8-10 *m*	0		0		0	
Saline	LW > 10 *w*	5,368,032	1%	2,013,012	2%	0	
Saline	LW 0-10 *w*	16,860,192	2%	1,115,748	1%	991,776	1%
Saline	MW >10 *w*	14,119,402	2%	5,294,776	4%	0	
Saline	MW 0-10 *w*	88,668,029	12%	5,867,737	4%	5,215,766	3%
Saline	MW 0-2 *m*	30,734,516	4%	5,750,329	4%	12,690,381	8%
Saline	MW 2-4 *m*	4,162,990	1%	297,356	< 1%	297,356	< 1%
Saline	MW 4-6 *m*	866,593	< 1%	0		0	
Saline	MW 6-8 *m*	268,416	< 1%	0		0	
Saline	MW 8-10 *m*	0		0		0	
Saline	SP > 10 *w*	70	< 1%	14	< 1%	0	
Saline	SP 0-10 *w*	3,548,871	< 1%	253,491	< 1%	2,027,926	1%
Saline	SP 0-2 *m*	23,913,400	3%	341,620	< 1%	21,863,680	14%
Saline	SP 2-4 *m*	4,102,784	1%	215,936	< 1%	647,808	< 1%
Saline	SP 4-6 *m*	900,610	< 1%	0		0	
Saline	SP 6-8 *m*	224,634	< 1%	0		0	
Saline	SP 8-10 *m*	0		0		0	
TOTAL		753,554,758	100%	131,946,807	100%	153,141,002	100%

Table D3. Population estimates of juvenile fishery species from studies in Louisiana and Texas.

			Population estimates per ha			
Marsh Type	Location	Date	Brown shrimp	White shrimp	Blue crab	Citation
Brackish marsh	Triple Bayou, Barataria Basin, LA	May 1995	9,865		4,007	Rozas & Minello 1999
Intermediate marsh	Little Lake, Barataria Basin, LA	May 1995	2,169		2,444	Rozas & Minello 1999
Saline Marsh	Sabine National Wildlife Refuge, LA (Natural Control)	May 1999	16,000		5,000	Rozas & Minello 2001
Saline Marsh	Sabine National Wildlife Refuge, LA (Natural Control)	September 1999	5,500	78,000	20,000	Rozas & Minello 2001
Created Saline Marsh	Sabine National Wildlife Refuge, LA (Created Terraces)	May 1999	14,005		7,695	Rozas & Minello 2001
Created Saline Marsh	Sabine National Wildlife Refuge, LA (Created Terraces)	September 1999	2,840	284,855	30,410	Rozas & Minello 2001
Saline	Elmgrove Point, Galveston Bay, TX	Seasonal Average	37,748	38,606	26,680	Minello & Rozas 2002
Created Saline Marsh	Jumbile Cove, Galveston Bay, TX	Seasonal Average	22,246	21,773	17,240	Rozas et al. 2005a
Created Saline Marsh	Pierce Marsh, Galveston Bay, TX	Seasonal Average	27,296	25,698	17,978	Rozas et al. 2005a
Created Saline Marsh	I-45 East, Galveston Bay, TX	Seasonal Average	28,997	28,815	19,775	Rozas et al. 2005a
Created Saline Marsh	I-45 West, Galveston Bay, TX	Seasonal Average	30,863	33,139	24,927	Rozas et al. 2005a
Created Saline Marsh	GISP Terraces, Galveston Bay, TX	Seasonal Average	26,490	24,807	17,823	Rozas et al. 2005a

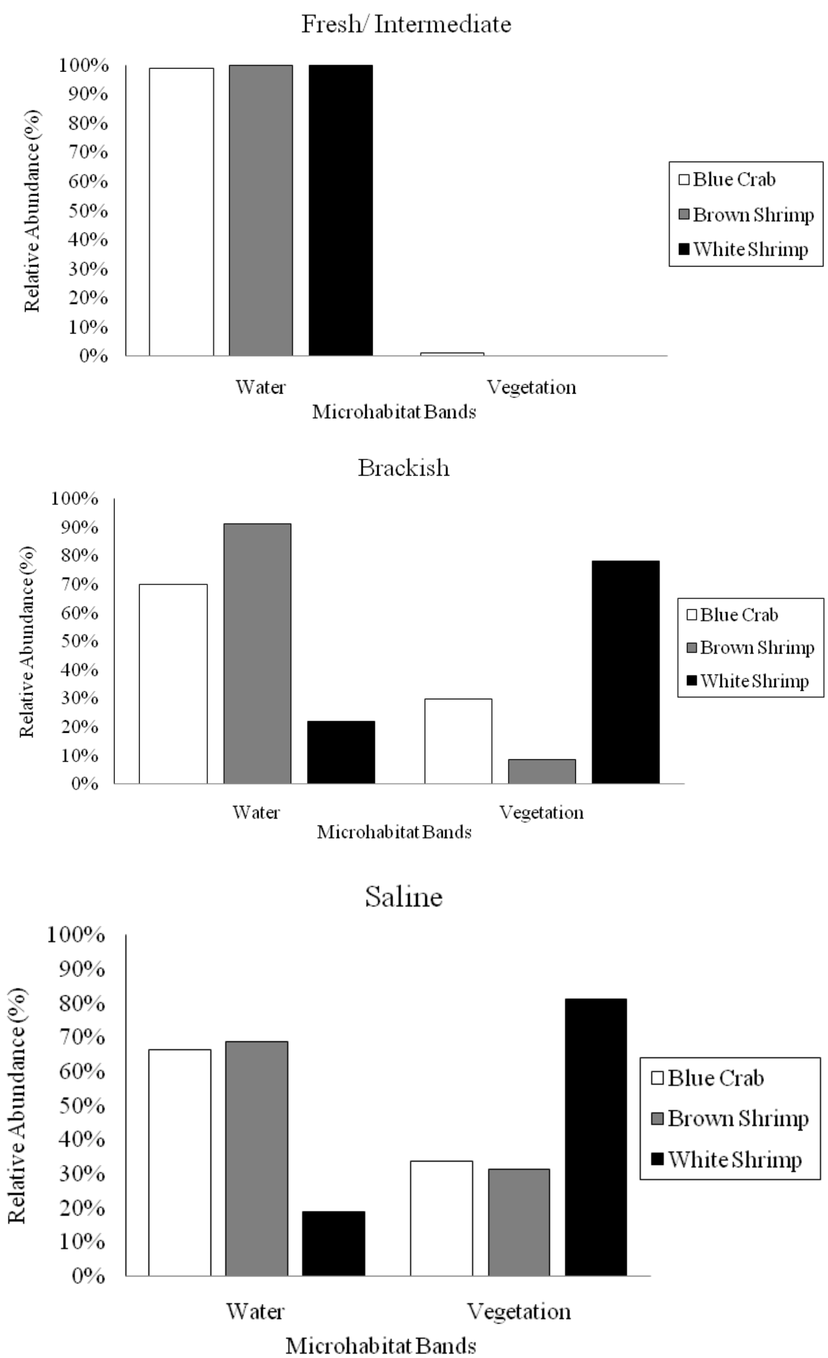


Figure D1. The relative abundance of individual species within the microhabitat bands for each marsh type. The microhabitat bands from Table D2 were combined into two categories: water and vegetation. All abundances within those categories were summed and the relative abundance in the water and vegetation was calculated as a percent of a species total abundance in a marsh type.