Urban Land-Use Effects on Resident Saltmarsh Fish in the Gulf of Mexico

by

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Abstract

Salt marshes are valuable ecosystems and provide a number of important services, including providing habitat for fish. Urban land-use has been shown to alter salt marshes through changes in the hydrology, sedimentation, and vegetation, but little is known about how urban land-use near salt marshes impacts fish. In this study I compared resident fish in urban and reference salt marshes in tidal creeks of Alabama and west-Florida. Reference creeks had very little surrounding development (<3.0 houses km shoreline^{-1}) while urban creeks had ≥30.0 houses km shoreline^{-1}. Fish were sampled seasonally for one year along salt marsh edges using baited minnow traps and results were used to characterize fish communities. In addition two common salt marsh resident fish, *Fundulus grandis* and *Poecilia latipinna,* were evaluated to determine the impacts of urban land-use on fish condition through Liver Somatic Index (LSI), caloric density, and tissue concentration of metal contaminants. To help interpret fish data, marshes also had various habitat attributes assessed including: plant species composition and biomass, sediment contaminants, slope, salinity, and temperature. Fish abundance and length-weight regressions were compared for common species in addition to characterizing fish communities at both urban and reference marshes. Fish communities varied with season, but reference creek communities were consistently dominated by *Fundulus grandis*. Urban creeks had higher abundance of other species including *Poecilia latipinna, Fundulus confluentus, Gambusia holbrooki,* and *Adinia xenica*. Length-weight relationships showed that *F. confluentus, A. xenica, C. variegatus*, and *F. confluentus* were larger at urban marshes, while *G. holbrooki* was smaller.

Based on the results of a nonmetric multidimensional scaling (NMDS) ordination and a Poisson generalized linear model, urban and reference fish assemblages were significantly correlated with salinity, slope, and sediment contaminants. Condition measures showed *F. grandis* had lower LSI and caloric density at urban salt marshes compared to reference. However, *P. latipinna* did not have significantly different condition measures at urban salt marshes compared to reference. Both species showed seasonal patterns related to conditional measures that were likely related to reproduction and annual fattening cycles. Except for zinc, no significant differences were detected in metal concentration between urban and reference *F. grandis* and many metals associated with urban runoff (Cd, Cr, Pb) were below detection levels for fish from both creek types. Differences in fish condition, fish size and fish community at urban marshes are likely a result of an altered salinity regime and other habitat alterations.

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Chapter 1: Overview of Urban Land-use Impacts on Salt Marshes and Fish

Salt marshes are intertidal wetlands dominated by herbaceous vegetation. They are found along sheltered coastlines, lagoons, river mouths, and bays throughout the world (Mitsch et al. 2009). Salt marshes are important ecosystems that provide a number of ecological services. These services include being a source of nutrients and organic matter to nearby coastal habitats, protecting coastlines from wave erosion, being a sink for certain nutrients/pollutants, and providing critical habitat for a variety of organisms, including fish (Kennish 2001). Fish have been shown to greatly benefit from salt marsh habitat with some species requiring salt marshes for their entire life while others require it just for certain life stages (Rozas and Minello 1998). These fish are often important food sources for marine mammals, picivorous birds, and other fish, including a number of economically important species (Raposa et al. 2003). The fish caught in the United States Gulf of Mexico are a significant part of both the commercial and recreational fisheries in the whole United States (Chesney et al. 2000). Therefore, alterations to salt marshes in the Gulf of Mexico could impact these fisheries, and thus have a significant effect on the livelihoods of people dependent on these resources.

Coastal areas in the U.S. are experiencing large population growth, particularly in parts of the Gulf of Mexico (Wilson and Fischetti 2010), and this growth coupled with rapid development puts pressure on salt marshes (Beach 2002). Urban land-use has been shown to have a number of effects on salt marshes, including direct loss of marshes and alterations to marsh hydrology, sedimentation, and vegetation (Currin et al. 2010). These alterations can lead to degradation and indirect loss of salt marshes (Peterson and Lowe 2009). All of these alterations can result in changes to the salt marsh habitat, which consequently can impact the organisms dependent on them. Because salt marshes provide valuable habitat for fish, Knowing how land-use affects them is important.

Man-made structures often accompany urbanization, and these structures can impair salt marsh functioning. Canals and spoil banks can have serious hydrological impacts on salt marshes (Kennish 2001). Knott et al. (1997) found that canal construction in South Carolina caused a shift in fish community composition and a decrease in salt marsh resident *Fundulus heteroclitus* within the affected salt marsh. The authors hypothesized these results were due to the reduced *Spartina alterniflora* coverage caused by the construction (Knott et al. 1997). Similarly, a recently dredged channel had a similar fish community compared to a channel that was not dredged (Bilkovic 2011). However, fish and decapod crustaceans communities were similar in the shallow water and marsh surface of canals and natural channels in Louisiana salt marshes, which the authors thought was due to the similar structure of both canals and natural channels (Rozas 1992). In addition, dredge material levees were found to restrict fish and decapod crustacean access to high marsh in Louisiana (Reed et al. 2006). Also, Reed and Foote (1997) found salt marshes in Louisiana that were behind levees had significantly decreased sedimentation rates. Shoreline treatments, such as bulkheads and riprap, are often associated with urban land-use in estuarine systems. These shoreline alterations have been associated with declines in fish diversity and abundance (Bilkovic and Roggero 2008, Bradley 2011) and salt marsh loss (Kennish 2001).

Hydrologic impacts can also prevent tidal inundation of salt marshes, which restricts access for fish and decapod crustaceans to the marsh (Harrington and Harrington 1982, Stolen et al. 2009). Urban land-use can also result in extreme salinity fluctuations in salt marshes (Shirley et al. 2005) and conversion from salt marsh to brackish marsh due to the increased freshwater runoff (Greer and Stow 2003). The effect of shoreline development on hydrology was found to decrease soil salinity, which facilitated invasion by non-native *Phragmites australis* in Rhode Island (Silliman and Bertness 2004). Holland et al. (2004) found that salinity range, volume, and magnitude of fluctuations increased in tidal creeks when watershed impervious surface exceeded 10% in the Charleston, South Carolina area. Therefore even low amounts of development in the watershed can have impacts on the hydrology of a tidal creek, which in turn can alter the salt marsh habitat. Salinity was found to be one of the major abiotic factors associated with fish assemblages along an estuarine gradient in Texas (Gelwick et al. 2001). Thus any changes to salinity could result in altered fish communities based on salinity tolerance. However, there has been little work on linking changes in salinity regimes to salt marsh fish communities. Changes in marsh plant composition take a longer time than changes in fish communities, so alterations to the salinity regimes are likely to be seen first in the fish community.

Urbanization near salt marshes can change sediment composition and sedimentation rates. Urban salt marshes tend to have coarser sediments due to increased runoff capable of transporting sandy, eroded soils into tidal creeks (Holland et al. 2004). Urbanization was correlated with increased sedimentation in California salt marshes (Mudie and Byrne 1980). Partyka and Peterson (2008) found higher percent total organic carbon and coarser sediments at urban salt marshes compared to reference marshes in Mississippi. Some benthic invertebrates avoid coarse sediments because they decrease sediment stability. Changes in the benthic invertebrate community could potentially reduce fish food sources (Partyka and Peterson 2008).

When sedimentation becomes too low, vegetation can become too deeply submerged in water to grow, and salt marsh is lost (Mattheus et al. 2010). This loss of marsh can isolate salt marshes as connectivity decreases and distance between remaining marshes increases, which can cause changes in species assemblages. Species richness and resident fish abundance was lower at small salt marshes disconnected from upland habitat compared to marshes connected to land (Meyer 2006). *F. heteroclitus* had limited occurrence in isolated marshes which suggested they are limited in their dispersal ability (Meyer and Posey 2009). Isolation can also cause changes in the benthic invertebrate communities and decreased species richness (Partyka and Peterson 2008). Thus isolation can ultimately change fish communities dependent on salt marshes.

Urban land-use is also often associated with an increase in pollutants such as polychlorinated biphenyls (PCBs), petroleum aromatic hydrocarbons (PAHs), metals such as mercury and lead, and pesticides. Van Dolah et al. (2008) found higher concentrations of pollutants in sediments from urban salt marshes in South Carolina. Pollution in a Florida estuarine system resulted in lower estuarine fish species richness, and most species avoided the polluted areas except for a few detritivore species (Felley and Felley 1986). In coastal habitats of the Mississippi Delta, oil contamination resulted in a higher proportion of more tolerant species making up the fish and decapod crustacean community and resulted in high accumulation of petroleum hydrocarbons in benthic organism tissues (Ko and Day 2004). Similarly, Roth (2009) found fish and decapod crustacean abundance decreased in Louisiana salt marshes exposed to oil, which the author thought was due to the more mobile, transient species leaving the salt marsh. In addition, salt marsh vegetation can change in composition (Bertness et al. 2009, Wigand et al. 2003) and density (Darby and Turner 2008) due to increased nutrients from nearby urban land-use. For instance, eutrophication gave *Spartina alterniflora* a competitive advantage over *Juncus roemerianus* in Georgia salt marshes (McFarlin et al. 2008). Invasive *P. australis* was also more common in marshes with increased nutrient availability and shoreline development (Silliman and Bertness 2004). In contrast, fish abundance and species richness were actually found to increase with higher nitrogen loadings (Wigand 2008). However, eutrophication can lead to hypoxia, which has been shown to have a number of negative effects on fish, including death, reduced growth, and reduced reproduction (Brouwer et al. 2005, Breitburg et al. 2009). Thus, fish responses to urban land-use are likely a complex interaction between habitat deterioration (e.g. increased pollutants and altered hydrology) and possible benefits (e.g. increased food availability due to high nutrient loads).

Extensive work in freshwater streams has shown that urban land-use within a watershed is linked with decreased fish diversity (Helms et al. 2005, Slawski et al. 2008, Weaver and Garman 1994, Meador et al. 2005, Fitzpatrick et al. 2004) and abundance (Zampella and Bunnell 1998, Weaver and Garman 1994) as well as shifts in fish community composition (Weaver and Garman 1994, Helms et al. 2005, Roy et al. 2005, Wang et al. 2007). However, studies in estuarine environments are not as numerous as their freshwater counterparts. The few studies that have been done in salt marshes have found similar trends to freshwater studies. Urbanization near salt marshes was associated with different fish communities (Felley and Felley 1986), lower abundance (Peterson et al. 2000), and lower prey diversity and abundance (Sanger et al. 2004, Lerberg et al. 2000, Washburn and Sanger 2011, Lawless 2008). Fish diversity was lower at bulkhead and rip-rap compared to unmodified shoreline (marshes) in Maryland (Seitz et al. 2006). Partyka and Peterson (2008) also found lower species richness of fish and decapod crustaceans at hardened shorelines compared to marsh in Mississippi. Larval fish were smaller in size at hardened shorelines in Mississippi (Peterson et al. 2000). Bilkovic and Roggero (2008) determined a threshold of 23% of developed land-use within 200 m and 1000 m of a shoreline before seeing a decline in diversity in the fish and decapod crustacean community. However, this study was also looking at hardened shorelines, so the threshold may not be the same for salt marshes that are in developed areas. Most of these studies have looked at comparing alternative habitats to salt marshes, not salt marshes within an urban landscape. How urban land-use potentially altesr the quality of salt marsh habitat for fish is unknown.

Fish using salt marshes can be divided into two general groups: transients and residents. These two groups tend to use salt marshes in different ways. Transients use the marsh intermittently and have less habitat specificity than residents, using a variety of estuary habitats (Rountree and Able 2007, Meyer and Posey 2009). Because they are habitat generalists, they are not as strongly influenced by environmental change in one habitat and often are not tied developmentally to salt marshes (Thom et al. 2004, Nordlie 2003). They typically require a subtidal refuge to escape low water levels and are usually not found in marshes at low tide as a result (Able et al. 2008, Kimball and Able 2007). Because of this refuge need, transients are not able to use the marsh for the full high tide given that they need time to travel to and from their low tide refuge to the marsh. The distance between the two can be critical in how much transients can use the marsh as well (Kneib and Wagner 1994). For this reason many transients only use the marsh edge or adjacent subtidal habitats (Peterson and Turner 1994). This restriction also explains the tendency for salt marshes to have higher diversity and abundance of fish at high tide (Kneib and Wagner 1994). Common transients in the Gulf of Mexico include red fish (*Sciaenops ocellatus*), pinfish (*Lagodon rhomboides*), spot (*Lieostomus xanthurus*), and speckled trout (*Cynoscion nebulosus*). In contrast, resident fish species, particularly species like *Fundulus grandis*, associate with the salt marsh their whole lives. Residents often rely on marsh pools and upper reaches of tidal creeks and regularly use the actual marsh surface for foraging (Raposa 2008, Peterson and Turner 1994). Residents also tend to have small home ranges, which can include just one marsh (Skinner et al. 2005). Residents are also prey for a number of the transient fish species, and are important in connecting the productivity of salt marshes to the larger estuarine system (Valiela et al. 1977, Stout 1984). Despite these differences, both types of species will use salt marshes for food and shelter (Rountree and Able 2007, Able et al. 2008).

However, when assessing changes in salt marsh habitat, residents can be more informative because they rely on the marsh their entire lives and thus better reflect changes in the habitat through changes in abundance, size, and condition. *F. heteroclitus*, a salt marsh resident found along the Atlantic Coast, has been used as a bioindicator species for human impacts on salt marshes and other estuarine environments in a number of studies (Finley et al. 2009, Nacci et al. 2010, LeBlanc et al. 1997, Pait and Nelson 2009, Goto and Wallace 2010). Linking transient fish health and abundance to salt marshes is more difficult, and often studies are limited to stating the presence or absence of these fish as an indicator of salt marsh habitat quality (Rozas 1992, Bilkovic 2011, Seitz et al. 2006). Thus, for this study cyprinodontiform salt marsh residents will be used to assess the difference in habitat quality between urban and reference salt marshes.

In this study I focused on the impacts of urban land-use on Cyprinodontiformes in salt marshes dominated by *Juncus roemerianus* (black-needle rush, henceforth *Juncus*) in the Gulf of Mexico. These marshes are common along the coasts of Mississippi, Alabama, and western Florida (Stout 1984). While there have been a few studies on how urban land-use affects fish and salt marshes in the Gulf of Mexico (Partyka and Peterson 2008, Hendon et al. 2000, Peterson et al. 2000), none have looked at *Juncus* marshes. Cyprinodontiformes make up the majority of the resident species in *Juncus* marshes (Stout 1984), making them ideal for studying habitat quality and community dynamics.

Two of my study species, *Fundulus grandis* and *Poecilia latipinna,* are abundant resident salt marsh Cyprinodontiformes in the Gulf of Mexico (Boschung and Mayden 2004, Lee et al. 1980). Both species have a wide salinity tolerance (*F. grandis*: 0-76 ppt, *P. latipinna*:0-90 ppt) and a high tolerance for hypoxic conditions (Landry et al. 2007, Timmerman and Chapman 2004). *F. grandis* reaches an adult size of 70-138 mm and is a generalist feeder, consuming plant matter, invertebrates, and small fish (Boschung and Mayden 2004, Lee et al. 1980). *P. latipinna* has an adult size of 15-150 mm and feeds primarily on algae, detritus, and mosquito larvae (Lee et al. 1980). *F. grandis* and *P. latipinna* are capable of spawning multiple times in one year, although *P. latipinna* is a livebearer while *F. grandis* is not (Nordlie 2000, Boschung and Mayden 2004).

Not much research has been done on using *F. grandis* as a bioindicator species for the northern Gulf of Mexico. However, it has been used to study the toxicity of oil and oil dispersants (Liu et al. 2006, Ernst et al. 1977, Russel and Fingerman 1984). Fingerman (1980) found that *F. grandis* fin regeneration in response to fuel oil exposure varied with season. Liu et al. (2006) found *F. grandis* had a high survival rate when exposed to oil for 24hrs in a field setting but were sensitive to oil in low dissolved oxygen conditions in the lab. Although *F. grandis* has not been studied extensively outside of toxicology, the closely related *Fundulus heteroclitus* has been well studied. *F. heteroclitus* has been used as a bio-indicator for point-source pollution in Canada due to its high site fidelity and great abundance (Skinner et al. 2005, Finley et al. 2009). *F. grandis* is also thought to have high site fidelity, or small home range, because the two species are closely related (Lee et al. 1980). This small home range may mean that salt marsh fragmentation, a common effect of urban land-use, can restrict *F. grandis* movement between marshes, which can impede gene flow, as well as leave populations vulnerable to extirpation (Meyer and Posey 2009). Many studies have looked at the impacts of habitat conditions on *F. heteroclitus* populations. For instance, *F. heteroclitus* in a polluted marsh in New York had reduced growth rates, higher metabolic rates, and higher food consumption (Goto and Wallace 2010). Small *F. heteroclitus* were also lacking in a New Jersey marsh dominated by the invasive species, *Phragmites australis,* which is likely due to the lack of standing water at low tide on the marsh surface (Hagan et al. 2007). In a restored salt marsh *F. heteroclitus* were found to have similar growth, abundance, and reproduction compared to natural marshes (Teo and Able 2003). Thus, *F. heteroclitus* has proven to be a useful indicator of salt marsh quality and fish community health. Other marsh residents have been used for land-use studies as well, including *Gobiosoma bosc* and *Gillichthys mirabilis*. They were found to be less abundant (Hendon et al. 2000), smaller, and have higher mortality rates within urban salt marshes than reference marshes (McGourty et al. 2009).

P. latipinna is similar to *F. grandis* in that it has been less researched as a bioindicator although its mating habits have been extensively studied (Meffe and Snelson 1993, Schlupp and Ryan 1997, Ptacek and Travis 1997, Witte and Ryan 1998, Witte and Ryan 2002), and it has also been used for toxicity studies involving pesticides. These studies determined the lethal dose of the pesticides, and argued for using *P. latipinna* because it was an abundant fish in freshwater and estuarine environments that were likely to have high concentrations (Lane and Livingston 1970). Benton et al. (1994) studied the sub-lethal effects of DDT on *P. latipinna* and found that DDT caused decreased growth and lipid storage. *P. latipinna's* tolerance to extreme salinity ranges has also been studied. In hypersaline conditions above 70 ppt, *P. latipinna* had increased concentrations of plasma ions and high metabolic rates, but below that the fish were able to maintain normal concentrations (Gonzalez et al. 2005). Surprisingly, growth was never affected even at the highest salinity concentrations of 90 ppt. McManus and Travis (1998) found no effect from salinity on male *P. latipinna* growth or maturation. However, rapid changes in salinity, especially from salt water (35 ppt) to freshwater, had detrimental effects on fish growth and resulted in 40% mortality (Backman and Rand 2008). Similarly, over winter survival was higher in salt marshes than freshwater marshes and for larger individuals, possibly because *P. latipinna* does not osmoregulate efficiently in freshwater (Trexler et al. 1992). This sensitivity to freshwater could be important if salinity is reduced in marshes due to increased freshwater run-off from nearby urban areas. Rapid decreases in salinity are also likely to occur in urban salt marshes given that storm events in urban areas tend to result in rapid freshwater inputs due to storm run-off (Holland et al. 2004). *P. latipinna* has also been used for assessing habitat quality (Troutman et al. 2007, Gelwick et al. 2001, Stolen et al. 2009). Since urban land-use can result in marsh fragmentation, this suggests that fragmented salt marshes may also have lower *P. latipinna* densities than continuous marsh.

In this study I will focus on assessing changes in salt marsh residents *F. grandis* and *P. latipinna* size distributions, abundances, and condition. Condition will be measured through length-weight regressions, liver somatic index, and caloric density as measured by bomb calorimetry. While condition measures can vary seasonally, they have been shown to be useful in environmental monitoring (Leamon et al. 2000, Galloway and Munkittrick 2006). *F. heteroclitus* has also shown lower LSI scores and smaller average length and weight at highly impacted urban sites (Ferraro et al. 2001). Similarly, lower lipid levels were found in *F. heteroclitus* at a restored marsh compared to a reference marsh (Weinstein et al. 2009). In addition, *F. grandis* pollution exposure in a tidal creek receiving industrial and treated wastewater inputs was assessed using liver enzymes (Schoor et al. 1988). Caloric density and fish body weight were lower in *Oncorhynchus gorbuscha* (pink salmon) when exposed to oil for 40 days in a laboratory experiment (Moles and Rice 2012). Caloric density was also lower in *Coregonus hoyi* (bloater) in Lake Superior compared to Lake Michigan (Vondracek 1996). *F. heteroclitus* had different caloric densities with different diets (Weisberg and Lotrich 1982). In addition, cyprinodontiform community structure, which includes *F. grandis, P. latipinna,* and other salt marsh residents (Lee et al. 1980), will be assessed. The results of this study will be useful in assessing urban impacts on other *Juncus*-dominated salt marshes. Also, this study will further our understanding of how altering habitat and prey sources of commercial fish due to increasing human populations in coastal areas will affect local fisheries.

I identified 3 major goals for this research:

- Determine the effects of urban land-use on salt marsh habitat for fish through changes in the cyprinodontiform community.
- Determine if salt marsh residents *Fundulus grandis* and *Poecilia latipinna* exhibit differences in size and abundance in urban salt marshes compared to populations in reference salt marshes.
- Analyze *F. grandis* and *P. latipinna* condition through length-weight regressions, liver somatic index, and caloric density at urban salt marshes compared to fish condition at reference salt marshes.

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Chapter 2: Urban Land-use Effects on the Resident Fish Community in Alabama and West-Florida Salt Marshes

Abstract

Urban land-use has been shown to impact salt marshes. However how this may change salt marsh habitat for fish species is unknown. In this study I compared resident fish in urban and reference salt marshes in tidal creeks of Alabama and west-Florida. Reference creeks had very little surrounding development (<3.0 houses km shoreline^{-1}) while urban creeks had ≥30.0 houses km shoreline^{-1}. Fish were sampled seasonally for one year along salt marsh edges using baited minnow traps and results were used to characterize fish communities. To help interpret fish data, marshes also had various habitat attributes assessed including: plant species composition and biomass, sediment contaminants, slope, salinity, and temperature. Fish abundance and length-weight regressions were compared for common species in addition to characterizing fish communities at both urban and reference marshes. Fish communities varied with season, but reference creek communities were consistently dominated by *Fundulus grandis*. Urban creeks had higher abundance of other species including *Poecilia latipinna, Fundulus confluentus, Gambusia holbrooki,* and *Adinia xenica*. Length-weight relationships showed that *F. confluentus, A. xenica, C. variegatus*, and *F. confluentus* were larger at urban marshes, while *G. holbrooki* was smaller. Based on the results of a nonmetric multidimensional scaling (NMDS) ordination and a Poisson generalized linear model, urban and reference fish assemblages were significantly correlated with salinity, slope, and sediment contaminants.

Introduction

Human populations in coastal areas of the United States have nearly doubled from 1960 to 2008 (Wilson and Fischetti 2010), and increasing populations have exerted greater pressure on the natural resources found in coastal areas (Beach 2002). One impact is a corresponding increase in land classified as urban land-use, which is projected to nearly triple from 2000 to 2050 (Nowak and Walton 2005). Urban land-use encompasses a wide range of conditions from commercial use to suburban neighborhoods and has been shown to have a number of hydrologic effects on tidal creeks. For example, salinity in tidal creeks has been shown to increase in range and magnitude of fluctuations with impervious surface cover above 10-20% of the watershed (Holland et al. 2004). This pattern is caused by impervious surfaces increasing the amount of surface runoff received by tidal creeks, which increases the amount of freshwater input. Also, urban land-use has been found to increase pollutant loads (Van Dolah et al. 2008), change sedimentation rates and composition (Reed et al. 2006, Partyka and Peterson 2008) and erode stream channels (Walsh et al. 2005).

These watershed level changes caused by increasing urban development can also impact salt marshes within tidal creeks. Urban land-use has been linked to the direct loss of salt marshes (Currin et al. 2010), as well as changing plant communities within salt marshes by altering competition associated with increased nutrients (McFarlin et al. 2008), facilitating invasion of non-native plants (Bertness et al. 2009), and altering plant density and height (Wigand et al. 2003). Lower salinities associated with urban land-use can also convert salt marsh plant communities to plant assemblages composed of more freshwater or brackish species (Greer and

Stow 2003). By replacing or altering salt marshes, urbanization may result in very different habitats than non-impacted marshes and ultimately affect the organisms dependent on them.

Estuarine fishes are one group of organisms that rely on salt marshes (Boesch and Turner 1984). Over 90% of the economically valuable fish in the United States are considered estuarine dependent (Chambers 1992). Because urban land-use may influence salt marshes it may also impact these valuable fish species by altering the habitat provided by salt marshes. Urban impacts to fish habitat may occur from the structural and/or vegetation changes in the salt marsh. *Phragmites australis* is an invasive plant species to the salt marshes in the United States often associated with urban disturbance, lower salinity and increased nutrients (Silliman and Bertness 2004) and has been shown to correspond to lower quality habitat for fish. For instance, no young *Fundulus heteroclitus,* a common small fish found in Atlantic salt marshes, were found in a New Jersey marsh dominated by *P. australis* while reference marshes had young *F. heteroclitus* (Hagan et al. 2007). Several studies have found that hardened shorelines, (i.e., bulkheads, riprap) which are common to developed shorelines, are associated with declines in fish diversity and abundance relative to vegetated shorelines (Partyka and Peterson 2008, Bilkovic and Roggero 2008, Bradley 2011, Peterson et al. 2000). Also, developing shorelines can fragment and isolate salt marshes, which can cause changes in fish assemblages based on the species' dispersal ability (Meyer and Posey 2009). Bilkovic and Roggero (2008) found a correlation between increased urban land-use within a 100 m radius of the shoreline and changes in fish and decapod crustacean communities, although this relationship was confounded by shoreline type. Significant changes to marshes (plant species, fragmentation) and shorelines clearly cause habitat changes to fish. However, urban effects may exist where salt marshes are still relatively intact, but this has not been studied.

To understand potential urban impacts, the differences in fish species use of the marsh are important to note. Fish species use salt marsh in two different ways. Some fish species use salt marshes as a part of a suite of estuarine habitats, while others use salt marshes as their primary habitat. Species in the order Cyprinodontiformes that live in salt marshes depend on the marshes their entire lives and are considered salt marsh residents (Stout 1984). Like other residents, these Cyprinodontiformes are food for a variety of bird and predatory fish species, including economically valuable species such as red fish (*Sciaenops ocellatus*), and provide an important link between marsh productivity and estuarine waters (Stout 1984). A high diversity of Cyprinodontiformes reside in marshes, and high diversity has been shown to increase stability of fish communities (Franssen et al. 2011).Their close association with salt marshes makes Cyprinodontiformes and other resident fish well suited for use as an indicator of salt marsh habitat quality (Finley et al. 2009). Studies that have looked at urban land-use impacts on individual resident species have often found decreased abundances (Hendon et al. 2000), smaller sizes, and higher mortality rates (McGourty et al. 2009). *F. heteroclitus* had reduced growth rates, higher metabolic rates, and higher food consumption in a polluted urban marsh in New York compared to a reference marsh (Goto and Wallace 2010). Although evidence of an urban effect on fish certainly exists, not all studies have detected impacts. Holland et al. (2004) found no relationship between watershed impervious surface cover and *F. heteroclitus* abundance in South Carolina salt marshes. However, few studies have looked specifically at resident communities, specifically Cyprinodontiformes, which may be particularly sensitive to land-use change.

In this study I focused on the impacts of urban land-use on Cyprinodontiformes in salt marshes dominated by *Juncus roemerianus* (black-needle rush, henceforth *Juncus*) in the Gulf of

Mexico. These marshes are common along the coasts of Mississippi, Alabama, and western Florida (Stout 1984). While there have been a few studies on how urban land-use affects fish and salt marshes in the Gulf of Mexico (Partyka and Peterson 2008, Hendon et al. 2000, Peterson et al. 2000), none have looked at *Juncus* marshes. Cyprinodontiformes make up the majority of the resident species in *Juncus* marshes (Stout 1984), making them ideal for studying habitat quality and community dynamics. The objectives for this study were to determine the effects of low- to medium-density urban land-use on salt marsh habitat and resident fish through the following measures: 1) various salt marsh habitat attributes (plant biomass, marsh slope, sediment conditions) and their relation to cyprinodontiform communities, 2) the composition of the cyprinodontiform communities compared to reference marshes, and 3) the size and abundance of various cyprinodontiform species compared to reference marshes. I hypothesized that the diversity of Cyprinodontiformes would be lower at urban marshes compared to reference marshes. I also hypothesized that size and abundance of species with a higher salinity preference would be lower at urban marshes while those with a lower salinity preference would be larger and more abundant.

Methods

Site Descriptions

To evaluate the effect of urbanization on salt marsh fish along the northern Gulf of Mexico, I examined numerous tidal creeks (urban and non-urban) throughout coastal Alabama and the west-Florida Panhandle. To minimize confounding factors, creeks were selected to have a similar watershed size, have several *Juncus*-dominated salt marshes near the mouth, similar salinity range (based on occurrence of *Juncus*), and have similar land-use and shoreline characteristics within each treatment (urban, reference). Based on this criteria six second-order tidal creeks (three urban and three reference) were selected along the Alabama and Florida coast (Fig. 2.1). Two reference creeks, Long Bayou and Graham Creek, flow into Wolf Bay in Baldwin County, Alabama. Emmanuel Bayou (urban), Stone Quarry Bayou (reference), and Weekley Bayou (urban) flow into Perdido Bay, and Grande Bayou (urban) flows into Pensacola Bay. Urban land use in the study area is typically low- to medium-density residential development, consisting of single family homes and many boat docks on along tidal creeks. To characterize the extent of urban land-use, USGS aerial photos (2004) were used to calculate urban measures within the 500m radius of a central point along the lower reach of each creek. Measures were validated in the field and adjusted for newer development observed. The number of houses counted inside the 500m-radius was used to determine house density (houses ha^{-1}) as well as the mean number of houses per km of shoreline. Mean number of boat slips per km shoreline (an indicator of shoreline disturbance and pollution) were also enumerated. Road area (m^2 ha^{-1}) was calculated by determining the total length of road multiplied by the mean width of the roads within the 500m radius. Road density was the total length of road per hectare. Based on surrounding urban conditions (Table 2.1) Long Bayou, Graham Creek, and Stone Quarry Bayou were classified as reference creeks, having a housing density of <3.0 houses km $shoreline^{-1}$ and a road density of <10.0 m ha^{-1} . Emmanuel Bayou, Weekley Bayou, and Grande Bayou were classified as urban. They had ≥ 10.0 houses km $shoreline^{-1}$ and >30.0m ha^{-1} road density. Four salt marshes closest to the creek mouth were selected for sampling, except for Emmanuel Bayou which only had three *Juncus* marshes.

Creek and Marsh Physio-Chemical Measures

To provide indications of marsh habitat, various biotic and physiochemical measures were made at each marsh. Water salinity (ppt) and water temperature (˚C) were measured using a YSI 30 meter at the midpoint of each salt marsh during four seasonal sampling events between December 2011 and September 2012 (see fish sampling below). Between April 2012 and March 2013, a HOBO U24 conductivity logger was placed just below subtidal depth at each creek between the second and third marsh. Loggers were set to record every 5 minutes and data were averaged per hour for each creek.

Vegetation Surveys

Although all marshes were dominated by *Juncus,* marsh vegetation surveys were conducted to evaluate potential differences in minor species composition and overall structure (stem density, biomass). Differences in minor species abundance may indicate longer trends in salinity than that collected with the conductivity loggers. Surveys along the marsh water-edge consisted of percent cover of all species in 3 random 1-m^2 plots (only vegetation that exceeded 10% cover was reported). For a randomly selected 0.25m^2 within each plot, all vegetation w cut at the ground level and returned to the laboratory. Stems were counted (stems m^{-2}) and dry-weighed to measure plant biomass and reported as g m^{-2}.

For each marsh, a single random vegetation transect was also conducted, extending perpendicular from the marsh water-edge to the upland edge. Along this transect, percent vegetation cover by each species in a 1-m^2 plot was measured at 10 points evenly spaced along the transect. Vegetation species cover data was collected at each point similar to those taken at the marsh edge. The data were used to characterize overall marsh halophytic plant cover and habitat diversity. Salinity preference of plant species (Tiner 1993) was taken into consideration when characterizing the plant community at each marsh. In particular, *Cladium jamaicense* and *Sagittaria lancifolia* were noted as common evidence of more brackish or freshwater conditions, while *Spartina alterniflora* was noted as evidence of polyhaline conditions (Eleuterius 1973).

Sediment Analysis

Within the three vegetation plots along the marsh water-edge, sediment samples (0-8 cm depth) were taken with a 7.5-cm diameter sediment auger. Sediment samples were combined by marsh, placed in an iced cooler, and returned to the laboratory where they were frozen in a sub-0˚C freezer until analyzed. Sediment concentrations of P and metals (Cd, Cr, Cu, Fe, Mn, Mo Ni, Pb, Zn) were analyzed using Mehlich I extraction (Mehlich 1953) with inductively coupled plasma spectrometry. Concentrations of certain metals in sediments (Cd, Cr, Zn, Pb, Cu, Mn and Mo) were considered a proxy measure of exposure to urban runoff (Steele et al. 2010). Similarly, total petroleum hydrocarbon (TPH) concentration was analyzed for each marsh using the Florida residual petroleum organic method (FDEP, 1995). Total C and N concentration were determined using dry combustion on a LECO CNS-2000 analyzer (Kowalenko 2001).

Marsh-edge Slope Analysis

The marsh water-edge was also qualitatively assessed for slope steepness at low tide at each marsh. The subtidal slope was considered from the edge of vegetation to 2.0m out perpendicular from the edge. The assessment began at the downstream point where the salt marsh joined the upland and concluded at the upstream junction of marsh and upland. Slope was visually assessed along its entire length and the percentage of shallow, moderate, and steep slope was estimated. Shallow slopes were those areas that gradually dropped to ≤0.5m. Moderate slopes dropped to between 0.5m and 1.0m. Steep slopes were those that dropped >1.0m. Each category was calculated as a percentage of the total perimeter for each marsh during assessment.

Fish Sampling

Fish were sampled from each creek in December 2011 and March, July, and September 2012 to capture seasonal variation. For each sampling event, salt marshes were sampled for three consecutive days (two creeks per day) to minimize short-term temporal variation during sampling events. At each salt marsh, five baited minnow traps (22.9 cm x 44.5cm with 2.5cm opening) were deployed (25 per creek) randomly along the edges of each marsh at the falling tide. Traps were retrieved after four hours. Fish caught in traps were immediately put on ice and frozen as soon as possible for later identification and processing in the laboratory. All fish were thawed prior to being processed. For each sampling event, fish were identified and counted by species for each salt marsh. The length of each fish was measured (nearest mm) and weighed (nearest mg). Total numbers of Cyprinodontiformes and total numbers of each species were cacluated as a catch per unit effort (fish $trap^{-1}$). Total cyprinodontiform biomass was also determined using combined fish weights for each salt marsh per trap (g $trap^{-1}$). For each marsh, total cyprinodontiform diversity was calculated per salt marsh using The Shannon-Weiner Diversity Index. Fish abundance was calculated for each creek as the mean number of fish caught per trap.

Statistical Analysis

Nested analysis of variance (ANOVA) in the program R was used to assess significance of differences between urban and reference treatments for physio-chemical measurements (temperature, salinity, element concentrations in marsh sediment) marsh habitat measurements (plant biomass, plant species cover, stem counts, marsh slope) and fish measurements (total abundance, species abundance, total biomass, species richness, and Shannon Index scores). Model nesting structure was marsh measures nested within creek nested within treatment. To compare length-weight relationships between urban and reference creeks, a dummy-coded regression was run on all species that exceeded 20 individuals per creek with weight as the response and length and urban as parameters. Length and weight measurements were log transformed to meet assumptions of a linear regression and statistical significance level was $p<0.05$.

Nonmetric Multidimensional scaling (NMDS) ordination was used to describe differences in fish species composition between urban and reference creeks. Total species composition for each marsh was square-root transformed to reduce the influence of highly abundant species (Quinn and Keough 2002).Each marsh was standardized to values between 0 and 1.0 to balance marshes that had very high and very low abundance, and each species was divided by its maxima to adjust for unequal abundance between species (Quinn and Keough 2002). Data were then put in a Bray-Curtis dissimilarity matrix and then the ordination was run using the matrix. Stress coefficients represent the goodness of fit, and NMDS models are acceptable for interpretation when stress is below <0.2 (McCune and Grace 2002). Species composition data were then correlated to marsh level plant biomass, percent shallow and steep slope, mean salinity, mean temperature, and significant sediment element concentrations (Cd, Cr, Pb, and Zn). Data for salinity and temperature were marsh-level data from the seasonal YSI measures. An analysis of similarities (ANOSIM) was used on the Bray-Curtis dissimilarity matrix of the fish community data by marsh to assess the significance of any differences between the communities. To determine the relationship of marsh habitat characteristics on total fish abundance, a generalized linear model with a Poisson distribution was developed at the marsh level to relate total fish abundance to abiotic factors with the parameters plant biomass, percent shallow and steep slopes, temperature, salinity, treatment, and Zn, Cd, Cu, and Ni concentrations in the sediment. The sediment parameters were chosen based on significance and correlation with abundance data. Fish data were marsh-level total abundance per season. All statistical analyses were run in the program R.

Results

Creek and Marsh Physio-Chemical Measures

Urban and reference marshes had comparable mean temperature when fish were sampled (23.2±1.1 °C and 23.5±1.0 °C respectively, $F=0.03$, $p=0.85$). However, the urban marshes had a larger salinity range (4.2±1.6ppt) than the reference marshes (1.4±0.5ppt, $F=10.41$, $p=0.005$, Table 2.2) and urban marshes had significantly lower mean salinity compared to reference marshes (10.8±0.2ppt vs. 14.4±0.1ppt, $F=5.85$, $p=0.018$). The conductivity logger data also indicated greater variability in salinity and temperatures in urban creeks compared to reference creeks particularly if examined seasonally. Urban creeks also went below 1.0ppt an average of 133±60 times (Grande Bayou 191, Weekley Bayou 194, Emmanuel Bayou 14), while reference creeks only went below 1.0ppt 14±7 times (Graham Creek 20, Long Bayou 23, Stone Quarry Bayou 0). Urban creeks often had longer periods of low salinity and occasional periods of freshwater flow compared to reference creeks during and following heavy rain events (e.g. Fig. 2.3). The logger data also showed urban creeks having more rapid salinity changes compared to reference creeks.

Vegetation Surveys

Along the marsh edge, urban and reference marshes had similar mean percent cover of *Juncus* (Table 2.3). Brackish and freshwater species (*C. jamaicense* and *S. lancifolia*) were found at both reference and urban marshes in low abundance and mean percent cover was not significantly different. Only two creeks had *C. jamaicense* on the marsh edge, one urban (Weekley Bayou, 0.8±0.6%) and one reference (Graham Creek, 0.8±0.8%). Urban marshes had lower mean stem density than reference marshes (671±2 no. m^{-2} vs. 896±2 no. m^{-2}, F=4.91, p=0.041, Table 2.3). Graham Creek, a reference creek, had the highest stem density (1072± 85 no. m^{-2}) while Weekley Bayou, an urban creek, had the lowest (553±76 no. m^{-2}). Plant biomass was also significantly lower at urban marshes compared to reference marshes (783±35 g m^2 vs. 1135±32 g m^2, F=5.32, p=0.034, Table 2.3).

Evaluating transects extending across marshes, urban and reference marshes also had similar mean cover of *Juncus.* However, urban marshes had a higher mean cover of *C. jamaicense* (4.9±0.2%) in transects than reference marshes (1.9±0.1%) although differences were not significant. *Distichlis spicata, Spartina patens*, and *S. lancifolia* were all similar between urban and reference marshes in mean cover of the marsh transect (Table 2.4).

Sediment Analysis

Sediment concentrations of metals and other elements were frequently different between urban creeks and reference creeks (Table 2.5). Urban salt marshes had significantly higher concentrations of lead (6.14±0.44ppm vs. 2.37±0.08ppm, F=8.00, p=0.012), zinc (6.95±0.23ppm vs. 4.81±0.15ppm, F=4.89, p=0.012), chromium (0.13±0.01ppm vs. 0.08±0.00ppm, F=8.61, p=0.009), molybdenum (0.11±0.01ppm vs. 0.06±0.00ppm, F=5.13, p=0.037) and cadmium

(0.07±0.00ppm vs. 0.04±0.00ppm F=15.33, p=0.001) than reference marshes. Manganese was significantly lower at urban marshes compared to reference marshes (3.41±0.23ppm vs. 9.98±0.64ppm F=10.36, p=0.005). Carbon and nitrogen concentrations were higher at urban marshes than reference marshes but only carbon was significantly higher (17.25±0.46% vs. 9.98±0.35%, F=12.04, p=0.003). Phosphorus was higher at urban marshes compared to reference creeks, but not significantly. Total petroleum hydrocarbons were below detection levels (<20ppm) in urban or reference marsh sediments.

Marsh-edge Slope

Marsh slope was different between urban and reference marshes (Fig. 2.4). Emmanuel Bayou had the highest mean percentage of shallow slope (51.7±21.7%), while Graham Creek, a reference creek, had the lowest (1.8±1.1%). Overall, urban marshes had a higher percentage of shallow slope (38.2±8.7% vs. 13.8±4.5%, F=6.29, p=0.023). Mean percentage of moderate slope was similar between urban and reference marshes (22.2±6.2% and 26.5±5.2% respectively, F=0.5334, p=0.48) Reference marshes had a higher percentage of steep slope (59.8±8.4%) compared to urban marshes (39.6±10.0%) but it was not significant (F=2.93, p=0.11). A reference creek (Graham Creek) had the highest mean percent steep slope (88.3±3.0%).

Fish Communities

Over all seasons, a total of 8 cyprinodontiform species were observed in urban marshes and reference marshes. These included F*undulus grandis* (Gulf killifish) *Poecilia latipinna* (Sailfin molly), *Adinia xenica* (Diamond killifish), *Cyprinodon variegatus* (Sheepshead minnow), *Fundulus confluentus* (Marsh killifish), *Fundulus pulvereus* (Bayou killifish), *Fundulus similis* (Longnose killifish), *Gambusia holbrooki* (Eastern mosquitofish), and *Lucania* *parva* (Rainwater killifish). *F. grandis* were significantly less abundant at urban marshes (4.94±0.11 fish trap^{-1}) compared to reference marshes (11.04±0.19 fish trap^{-1}, F=24.19, p<0.001), while *F. confluentus* was significantly more abundant at urban marshes (0.93±0.03 fish trap^{-1} vs. 0.15±0.01 fish trap^{-1}, F=12.94, p<0.001, Table 2.6, Fig. 2.5). *P. latipinna, G. holbrooki,* and *A. xenica,* were more abundant at urban marshes while *C. variegatus* were less abundant at urban marshes, but the differences were not statistically significant. *F. similis* was only found at reference marshes, although it was rarely encountered. Community composition also varied with season (Fig. 2.6). Mean Shannon-Weiner Index scores were significantly higher in urban marshes (1.14±0.11) than in reference marshes (0.78±0.11, F=10.05, p=0.006, Table 2.6). The creek with the highest score was Weekley Bayou, an urban creek (1.29±0.01), and the lowest was Long Bayou, a reference creek (0.41±0.07). Species richness was similar for urban marshes (5.6±0.3) and reference marshes (6.2±0.2, Table 2.6).

Fish Abundance

Mean total fish abundance was significantly lower at urban marshes (10.1±0.2 fish trap^{-1}) compared to reference marshes (14.3±0.1 fish trap^{-1}, F=7.59, p=0.007 Table 2.6). Urban marshes also had significantly lower fish biomass than reference marshes (372±5 g trap^{-1} vs. 924±15 g trap^{-1}, F=24.07, p<0.001, Table 2.6). Spring (March 2012) had the highest mean abundance of any season (15.6±0.4 fish trap^{-1}), and winter (December 2011) had the lowest abundance (8.3±0.3 fish trap^{-1} , Fig. 2.6). Long Bayou, a reference creek, had the highest mean abundance (19.9±0.6 fish trap^{-1}, Table 2.6) and the urban creek Grande Bayou had the lowest mean abundance (5.19±0.30 fish trap^{-1}). The most abundant species trapped during the study were *F. grandis* (7.89±0.28 fish trap^{-1}, Table 2.6). Three species had 6 or fewer individuals captured (*L. parva, F. similis*, and *F. pulvereus)*.

Several marsh characteristics were found to be significantly correlated with fish abundance. The results from the GLM with a Poisson distribution found reference marshes had significantly more fish than urban marshes (2.71,1.10-6.68 95%CL, p=0.027). Also, salinity (1.04, 1.03-1.04 95%CL, p<0.0001) and shallow slope (1.02, 1.01-1.03 95%CL, p=0.001) were significantly correlated with total fish abundance. No other parameters were significantly correlated with total fish abundance. Results from NMDS showed clustering of marshes that was not solely based on the marsh location (Fig. 2.13). Correlations revealed significant relationships between the species abundance data and creek, treatment, salinity, Cd concentration in sediment, and percent steep slope which were potentially driving some of the differences. ANOSIM analysis found that urban fish communities were significantly different than reference creeks (R= 0.14, p<0.01).

<u>Fish Length-Weight Relationships</u>

Length-weight regressions revealed different fish sizes at urban marshes depending on the species. For *P. latipinna* and *F. grandis*, length-weight regressions for urban marshes were not significantly different from reference marshes (t=0.884, p=0.082, Fig. 2.8 and t=1.742, p=0.38, Fig. 2.9). However *A. xenica* (t=2.194, p=0.029 Fig. 2.10), *C. variegatus* (t= 2.109, p=0.036 Fig. 2.13), and *F. confluentus* (t=4.176, p=0.036, Fig. 2.12) were all significantly larger (per mm length) at urban marshes compared to reference marshes. Only *G. holbrooki* (t=-6.679, p<0.01, Fig. 13) was significantly smaller (per mm length) at urban marshes. However, these differences are likely not biologically significant.

Discussion

Based on the results of this study, there were distinguishable differences in salt marsh physio-chemical measures, vegetation, and fish communities between urban and reference marshes. Many of the differences in fish community composition between urban and reference marshes were likely related to salinity. Although these fish have broad ranges of salinity tolerance (Nordlie 2006), the fish community at both urban and reference marshes changed with seasonal shifts in salinity. As seen in the continuous salinity data and the sampling measures, urban salt marsh salinity tended to fluctuate much more rapidly, had a larger range and lower average than reference marshes. The fact that species with low salinity preference (e.g., *G. holbrooki, P. latipinna,* and *F. confluentus;* Boschung and Mayden 2004) were often more abundant at urban marshes also suggests that salinity is an important driver of differences between creeks. Similarly, *F. similis* prefers higher salinity and was only found at reference marshes. These results are consistent with other studies that have examined fish communities and salinity. Marsh fish communities along a salinity gradient in Texas were found to be driven by salinity (Gelwick et al. 2001). Tidal freshwater and oligohaline marshes were also found to have the highest diversity, and this was hypothesized to be due to freshwater species and euryhaline marine species co-occurring. While not measured here, the variability in salinity is likely due to increased freshwater runoff from surrounding impervious surfaces. Urban land-use has been shown to increase surface runoff in freshwater streams (Paul and Meyer 2001), which results in more frequent large flow events and rapid flood peaking (Walsh et al. 2005). Holland et al. (2004) found a similar pattern of increased salinity range and "flashiness" when impervious cover exceeded 10-20% in South Carolina tidal creeks. Fish communities in an estuarine Florida river also varied with the amount of freshwater flow in the spring. (Greenwood et al. 2007).

Florida fish and decapod crustacean communities in bays that received large input of freshwater from flood control measures were significantly different from a natural creek and bay system (Shirley et al. 2005).

In a community profile of *Juncus*-salt marshes in the northern Gulf of Mexico, Stout (1984) described *F. similis, F. grandis*, and *C. variegatus* as the dominant resident Cyprinodontiformes. In this study, *F. similis* was rarely encountered and only at reference creeks. *F. grandis* was dominant at both urban and reference creeks, but *P. latipinna* was more often a dominant species in these marshes than *C. variegatus*. Stout (1984) also listed *P. latipinna, C. variegatus, L. parva, A. xenica*, and *F. confluentus* as common dominant species in isolated ponds within the salt marsh. This was supported by the high abundances of these species found by Harrington and Harrington (1961) in Florida salt marsh ponds. Interestingly, all of these species (except *C. variegatus* and *L. parva* which was rare) were more abundant at urban creeks than at reference creeks. These species may be better adapted to wide salinity swings from freshwater to high salinities, conditions that may commonly occur in salt marsh ponds where salinity ranges may be wider due to less frequent tidal flushing of pools. If similar salinity patterns are occurring along the marsh edges of urban creeks, these pond dominants may be better suited to urban marshes.

Mean fish abundance and total fish biomass were significantly greater at reference marshes than urban marshes. Mean total fish biomass in reference marshes was higher (2.5x) than urban marshes reflecting both greater abundance and more frequent larger species (*F. grandis*). These results suggest that continued urban development in the region may reduce fish productivity even if salt marsh habitats are available. A few other studies have detected relationships between land use and fish abundance in tidal systems. Sanger et al. (2011) found a non-significant negative relationship between fish density and impervious cover through sampling with a trawl in tidal creeks of Mississippi and Alabama. Similar to this study, Vernberg et al. (1992) found lower annual and monthly biomass of fish and decapod crustaceans at a high density residential inlet compared to a reference inlet in North Carolina. The Poisson model revealed that total fish abundance was related to marsh salinity and the amount shallow slope. Shallow slopes had greater abundance of fish compared to moderate slopes. McIvor and Odum (1988) also found that shallow slopes had higher abundances of small fish at freshwater marshes in Virginia, and steep sloped marshes were found to have lower abundance of resident fish along them because of increased predation risk. In this study, urban marshes had greater percent shallow slope than reference creeks which may mitigate somewhat for lost fish abundance.

Species abundance also differed between urban and reference marshes. *F. grandis* was significantly more abundant in reference creeks, and *F. similis* was only found in reference creeks. In contrast, *P. latipinna, F. confluentus, A. xenica, C. variegatus,* and *G. holbrooki* were more abundant at urban creeks, although only *F. confluentus* was significantly so. Sanger et al. (2011) also found *P. latipinna*, *C. variegatus,* and *G. holbrooki* to be associated with urban tidal creeks in Alabama and Mississippi through seining. Differences in species abundance could be due to a number of factors in addition to salinity and slope. Another possible factor could be the lower plant biomass on the marsh edge in urban creeks. While Wigand et al. (2003) found urban land-use was associated with increased nutrient inputs and plant growth, I found *Juncus* had less percent cover. Less plant biomass means more bare sediment, where algae can grow (Deegan et al. 2007), as well as less cover from predators (Minello 1993, Stolen 2009). This may change the food sources and habitat to favor certain cyprinodontiform species over others, such as the more herbivorous *P. latipinna* and *C. variegatus* (Harrington and Harrington 1961).

The resident Cyprinodontiformes also displayed different sizes between urban and reference creeks. Species *A. xenica, C. variegatus*, and *F. confluentus* were significantly larger at urban creeks than reference creeks while *G. holbrooki* was significantly smaller at urban creeks. However, these differences were small, and may not biologically significant. This difference was unexpected, considering *G. holbrooki* is typically found in freshwater or very low salinities. However, the majority of individuals were captured after a heavy rain event in the fall. *G. holbrooki* may have moved into the salt marshes from upstream marsh habitats not assessed in this study. In addition, the two most dominant species, *F. grandis* and *P. latipinna* not significant in size at urban marshes compared to reference. The previous factors that affect abundance and community composition (salinity, slope, and plant biomass) may also be influencing fish size (Trexler et al. 1992, Dunson et al. 1998), especially for *F. confluentus, A. xenica,* and *C. variegatus*. Another factor that may affect fish size is pollution. Sediment in urban salt marshes had higher levels of certain heavy metals commonly associated with urban runoff than reference salt marshes. However, percent carbon was also significantly higher at urban creeks. Organic matter, which is indirectly measured by the percent carbon, has been shown to increase adsorption of metals (Sanger et al. 1999a). Nevertheless, increased urban development was expected to result in greater exposure to pollutants. Van Dolah et al. (2008) found a relationship between sediment contaminants and urban and suburban land-use. Some species may be more tolerant to the pollutants or may have adapted to the contaminants found in the sediment. *F. heteroclitus* was found to have adapted to polychlorinated biphenyls (PCBs) and was less sensitive to exposure in New England salt marshes (Nacci et al. 2010). Further research is needed to into the pollutant exposure and bioaccumulation within each species to conclude how much pollution is influencing fish size.

Conclusions

Urban land-use has the potential to change salt marsh habitat for fish. This study looked at urban and reference *Juncus*-dominated salt marshes in tidal creeks of west Florida and Alabama. Fish were sampled seasonally for one year using minnow traps, and various habitat measures were taken, including sediment concentrations of metals and nutrients, plant composition and density, salinity, and water temperature. Fish abundance and length-weight regressions were compared for common species in addition to characterizing fish communities at both urban and reference marshes. Urban salt marshes were found to have lower total abundance of resident fish, but higher abundance of certain species, namely those with a lower salinity preference. Resident communities were significantly different at urban creeks, and urban creeks had higher Shannon Index scores. These differences were related to the altered salinity regimes of urban tidal creeks, the steepness of the marsh slope, decrease in plant biomass, and concentrations of heavy metals in the sediment.

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Figure 2.1 Map of the study sites. Triangles represent reference creeks and circles represent urban creeks.

Figure 2.2 Boxplots for continuous salinity measures of each sampled creek in (a) winter and spring (December-May) (b) summer and fall (June-November) and (c) annual total (March 2012-March 2013). See Fig. 1 for creek abbreviations.

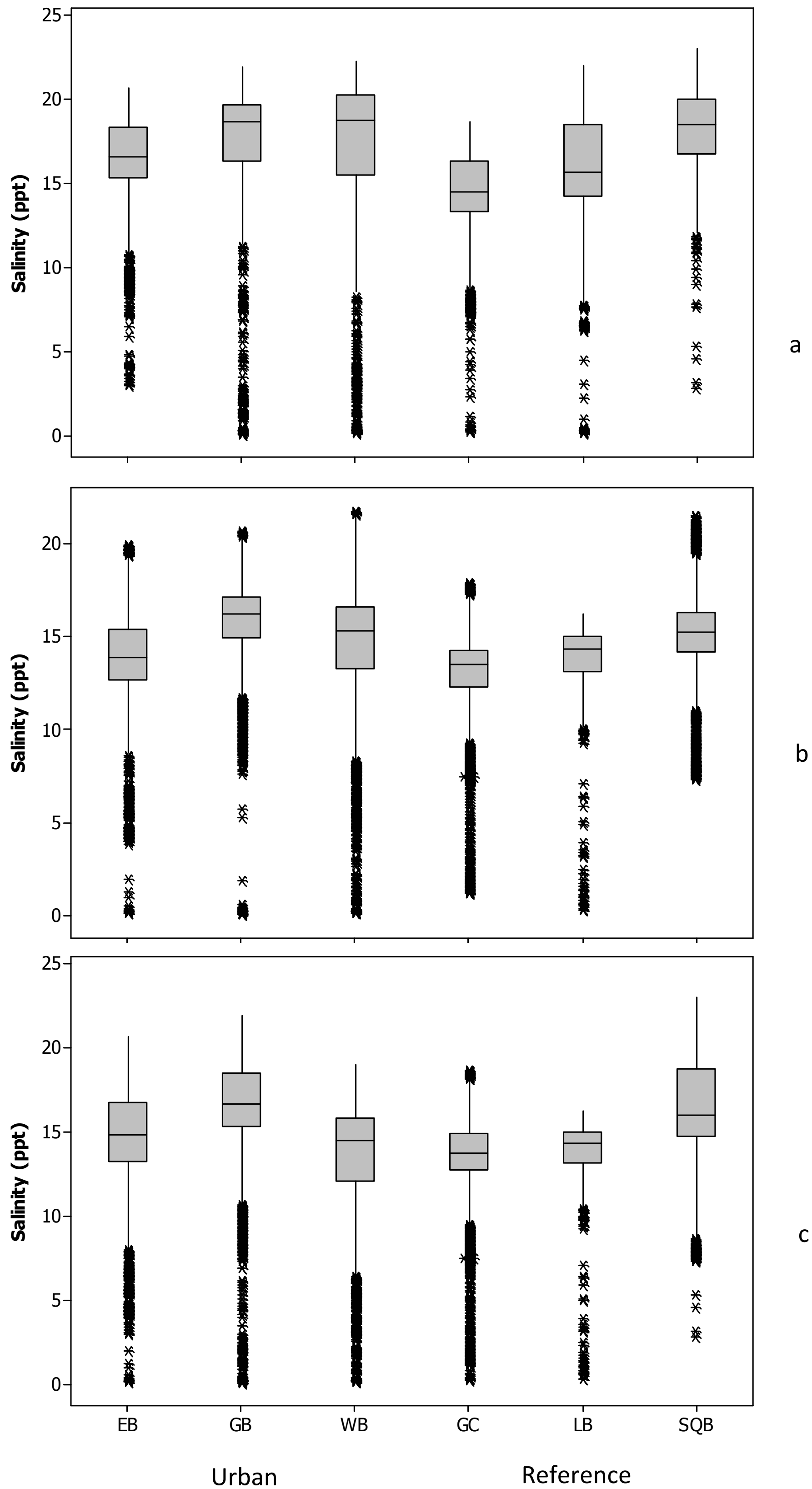

Figure 2.3 Mean hourly salinity at an urban (Emmanuel Bayou) and reference (Stone Quarry Bayou) creek during a 26cm rain event which occurred from 10-12 June 2012. Creek salinity is from data from 1 June through 4 July 2012.

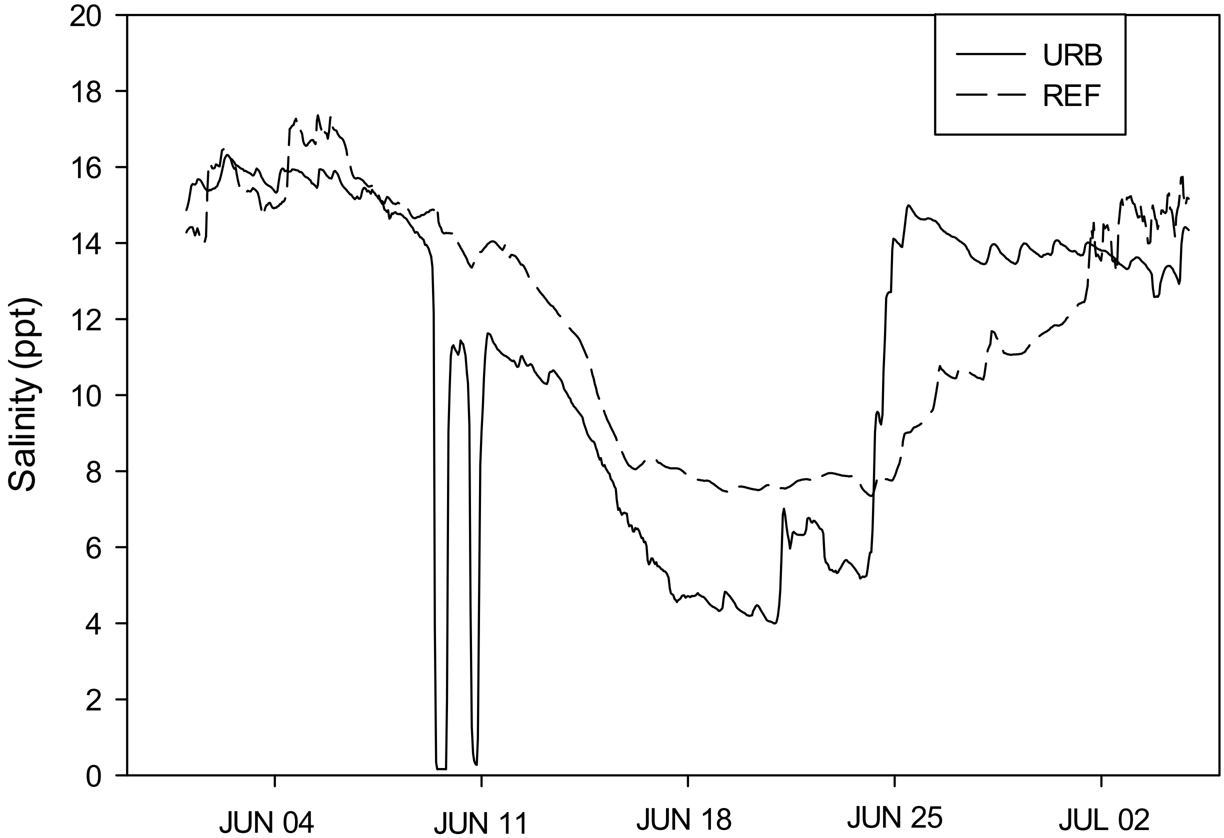

Figure 2.4 Mean percentage of marsh edge slope categories per creek. See Fig. 1 for creek abbreviations.

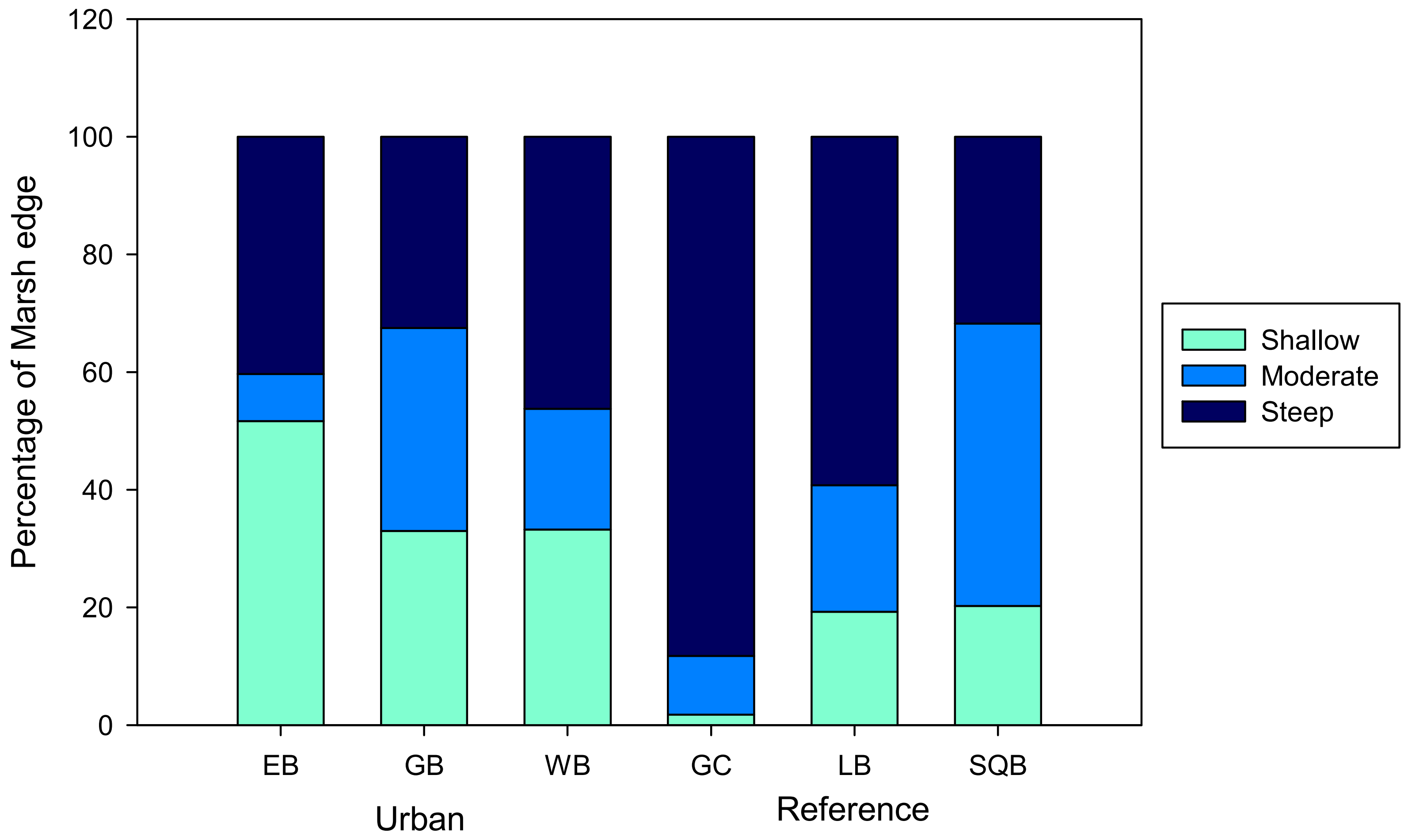

Figure 2.5 Mean total abundance per trap of major cyprinodontiform species within each creek. See Fig. 1 for creek abbreviations.

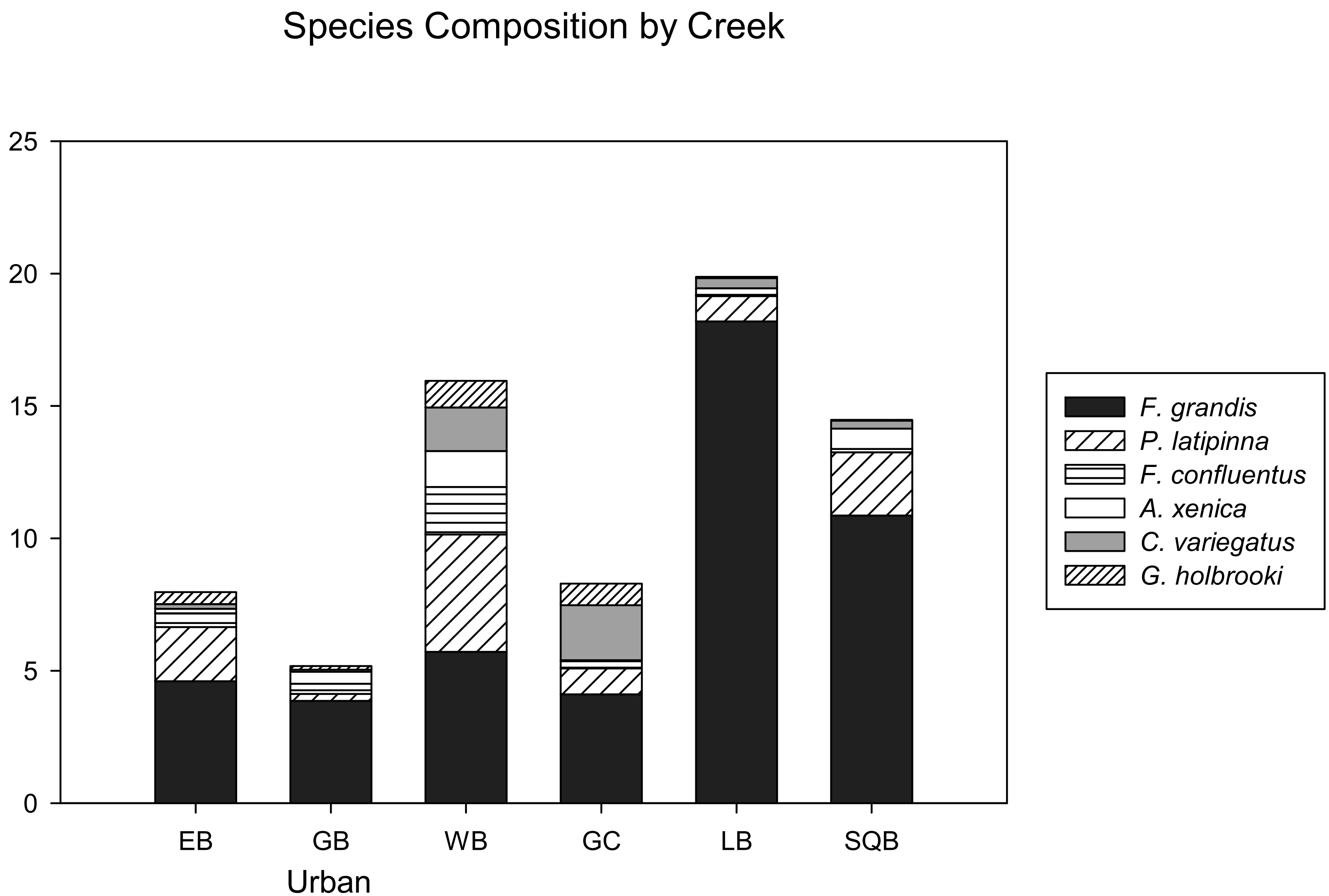

Figure 2.6 Seasonal species abundance per trap for each creek. See Fig. 1 for abbreviations.

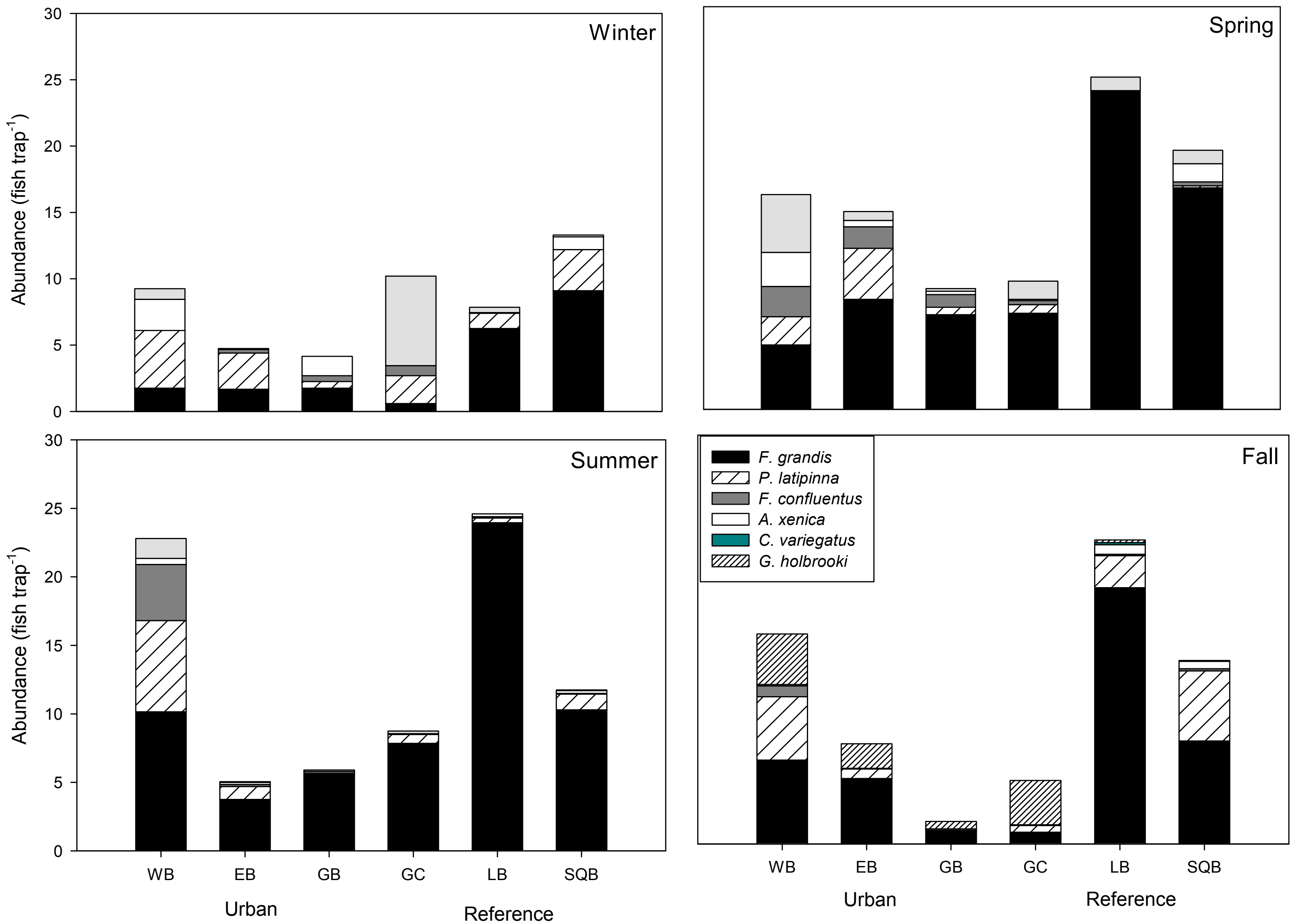

Figure 2.7 Length-weight plot, trend line and regression results for *F. grandis* (n=3590).

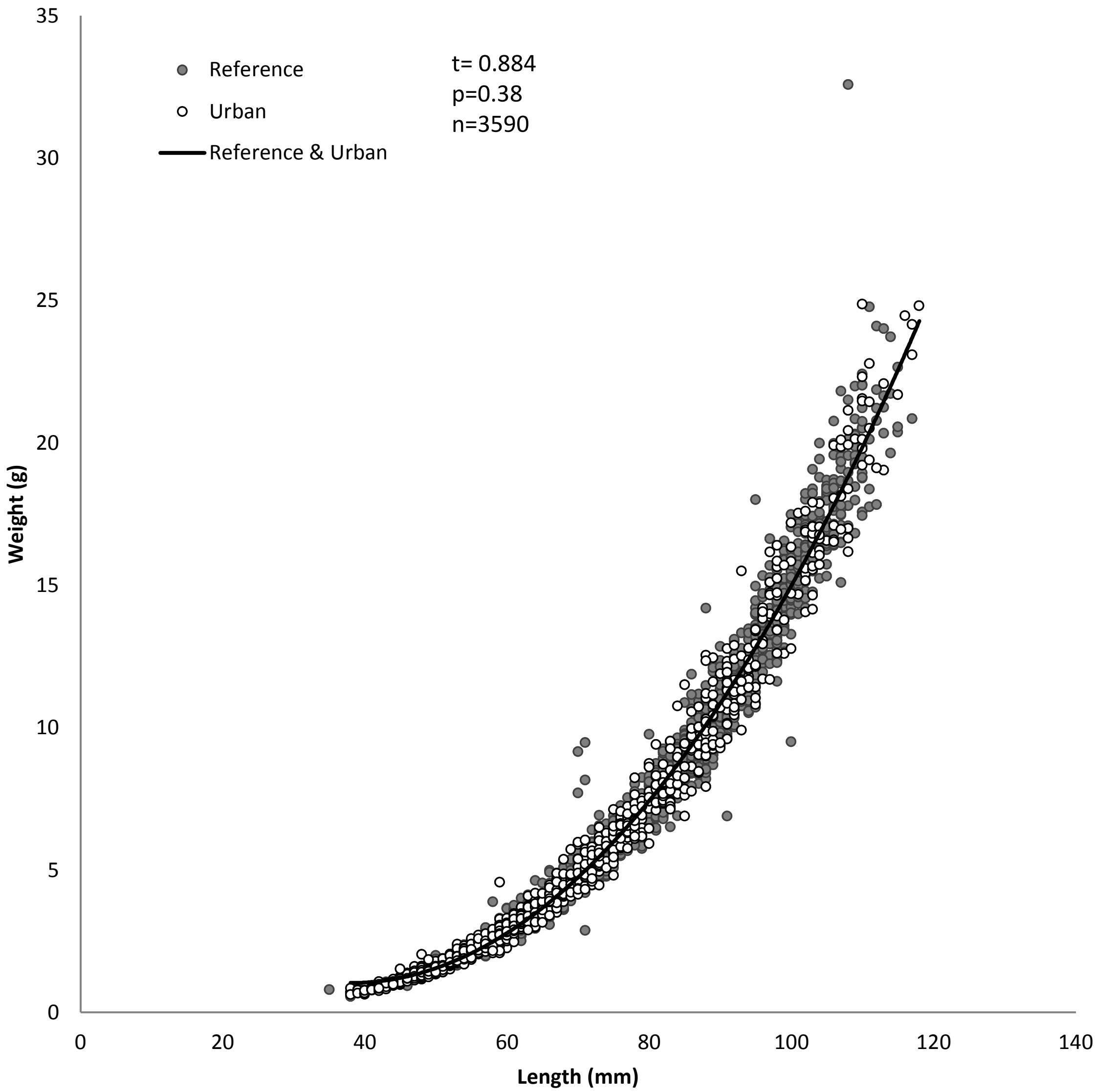

Figure 2.8 Length-weight plot, trend line and regression results for *P. latipinna* (n=780).

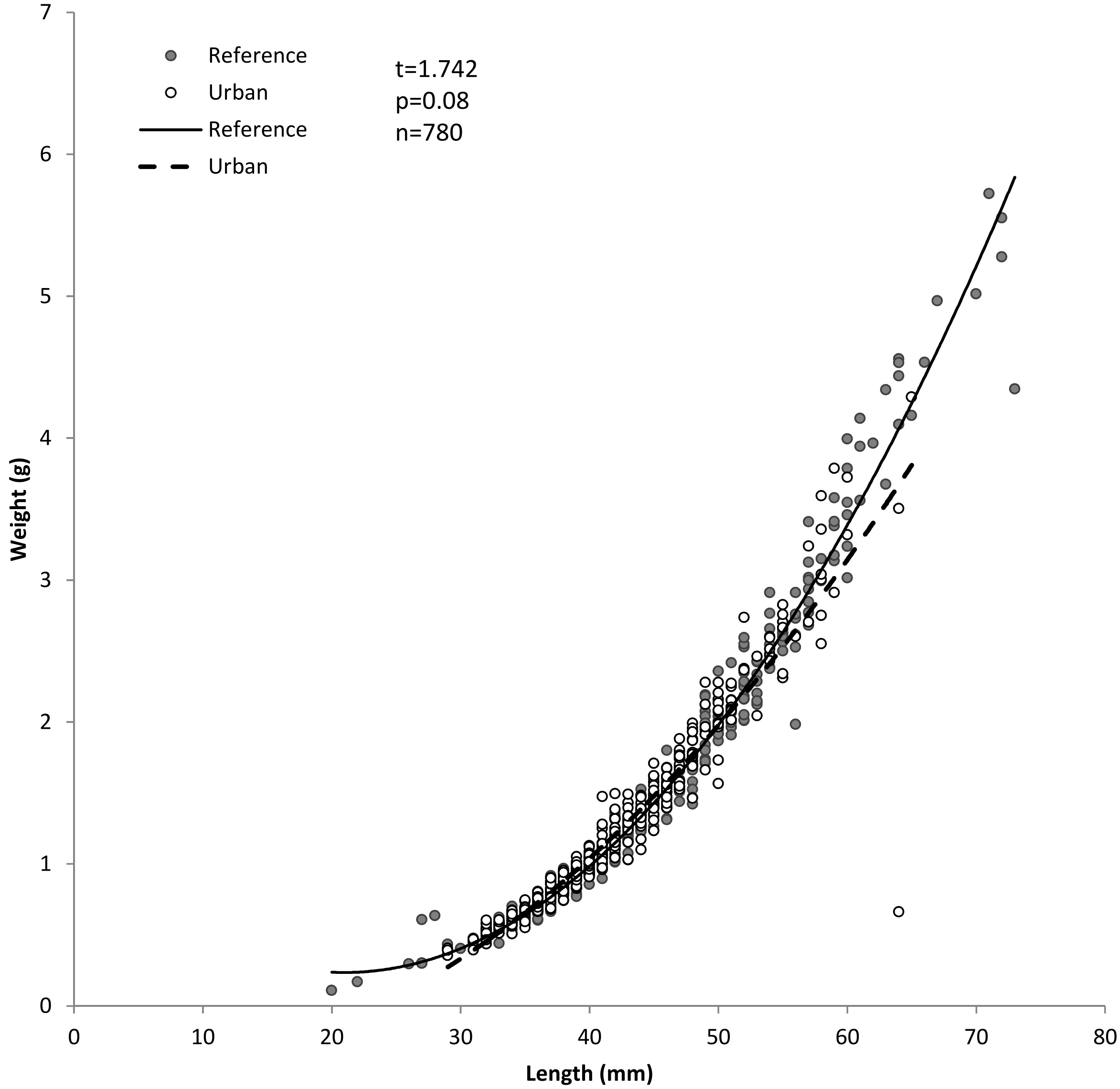

Figure 2.9 Length-weight plot, trend line and comparative regression results for *A. xenica* (n=232).

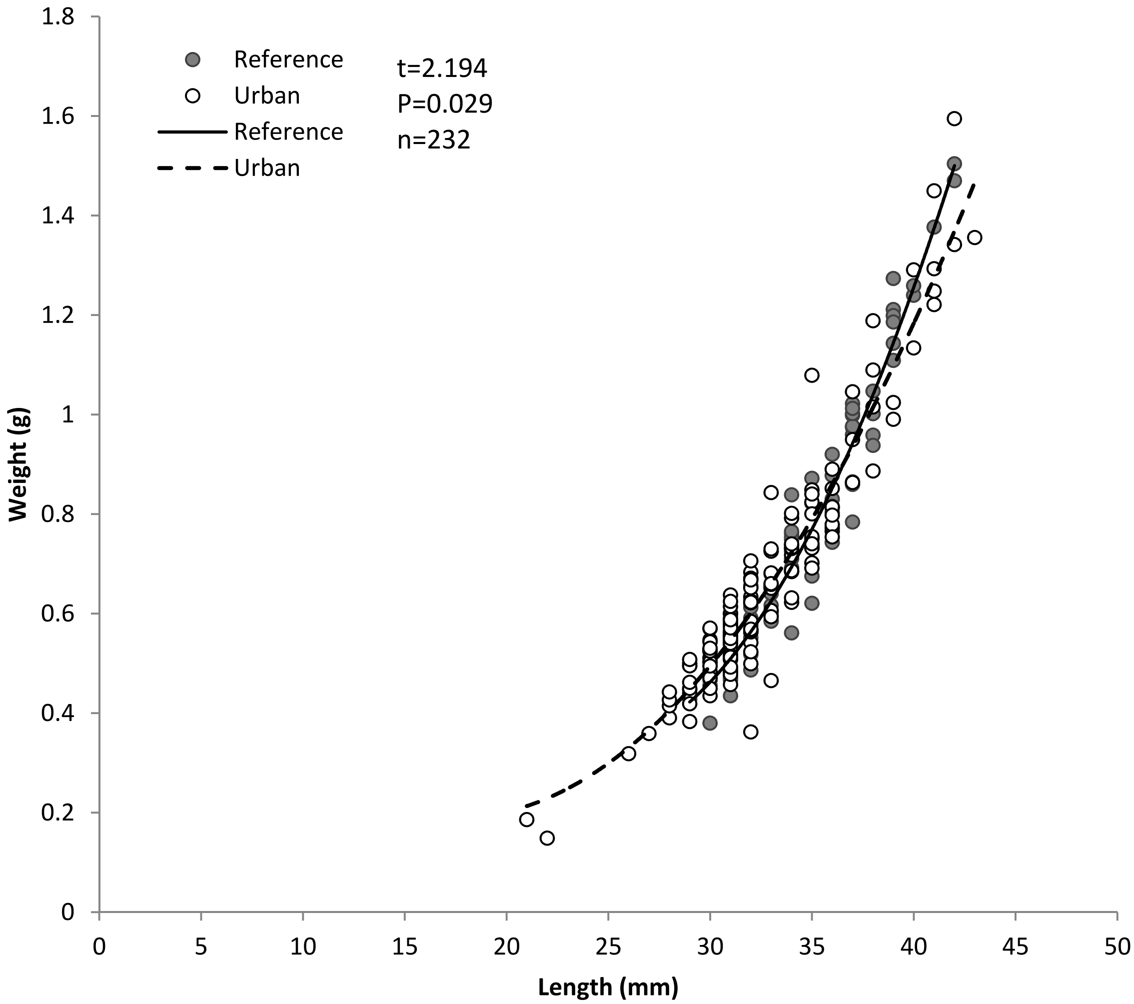

Figure 2.10 Length-weight plot, trend line and comparative regression results for *G. holbrooki* (n=174).

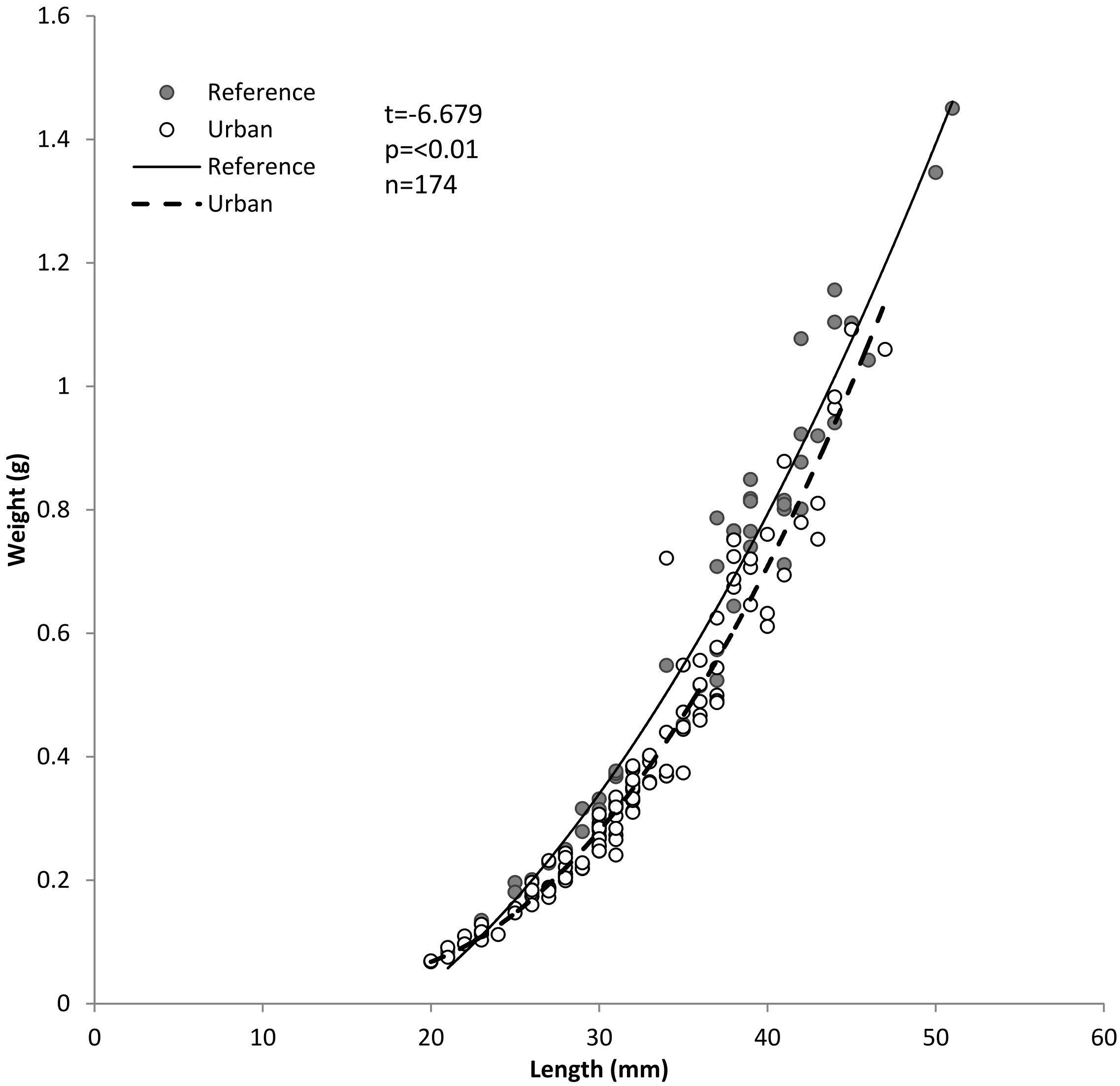

Figure 2.11 Length-weight plot, trend line and comparative regression results for *F. confluentus* (n=299).

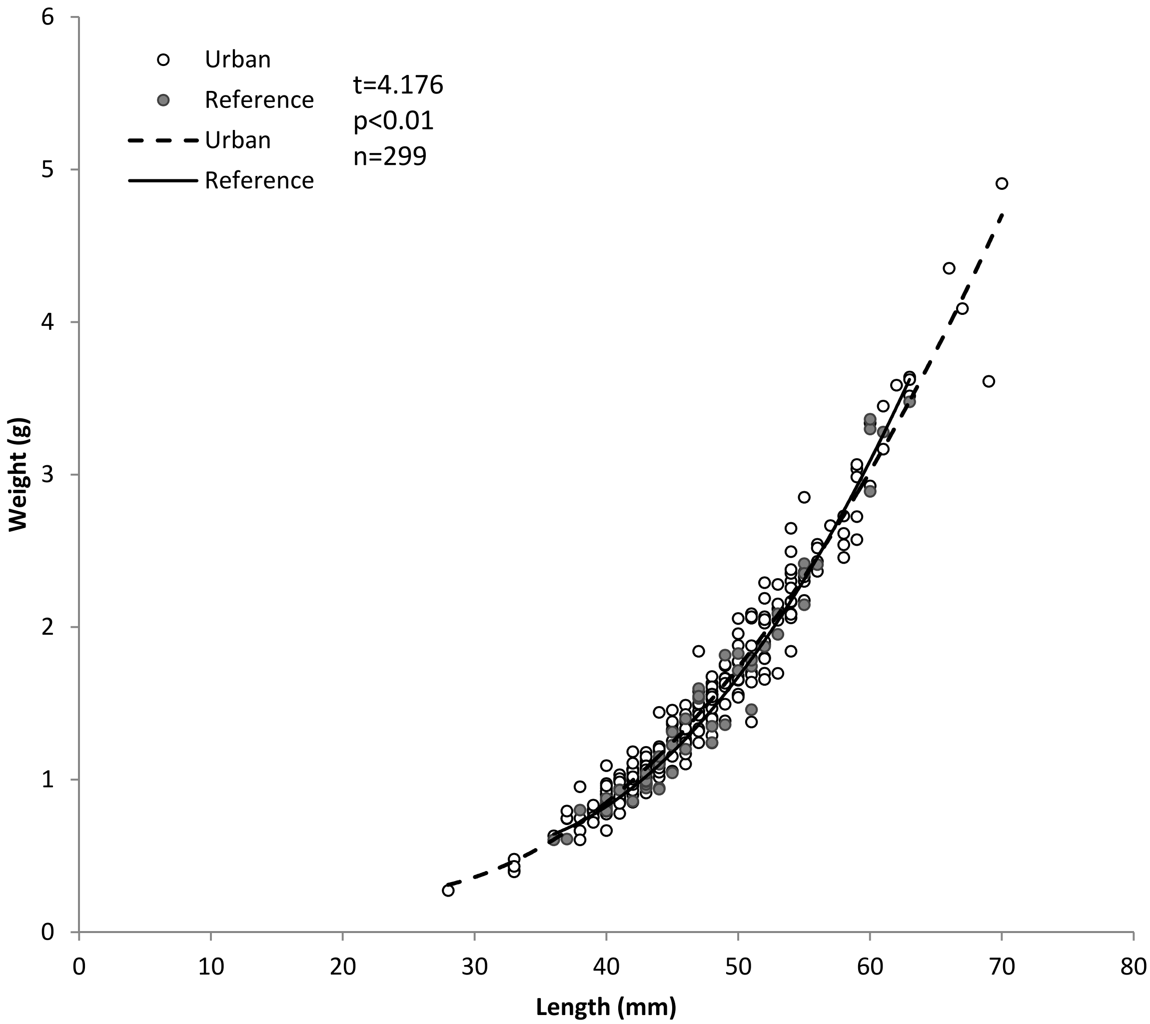

Figure 2.12 Length-weight plot, trend line and comparative regression results for *C. variegatus* (n=346).

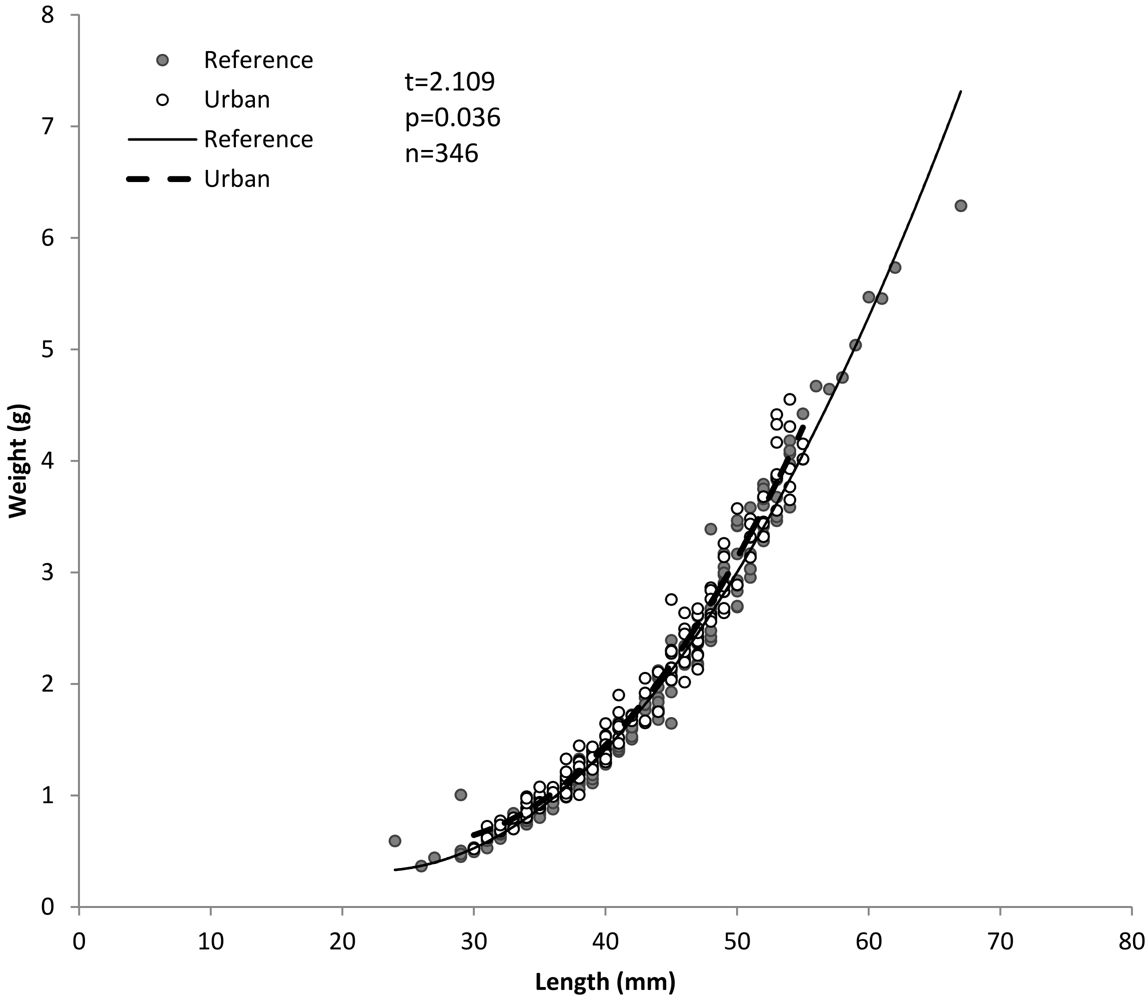

Figure 2.13 NMDS plot run with 6 dimensions at the marsh level. Vectors are for significant environmental variables (percent steep slope, salinity, sediment Cadmium concentration) ($p \leq 0.05$). Reference creeks are represented by black points and urban by white points.

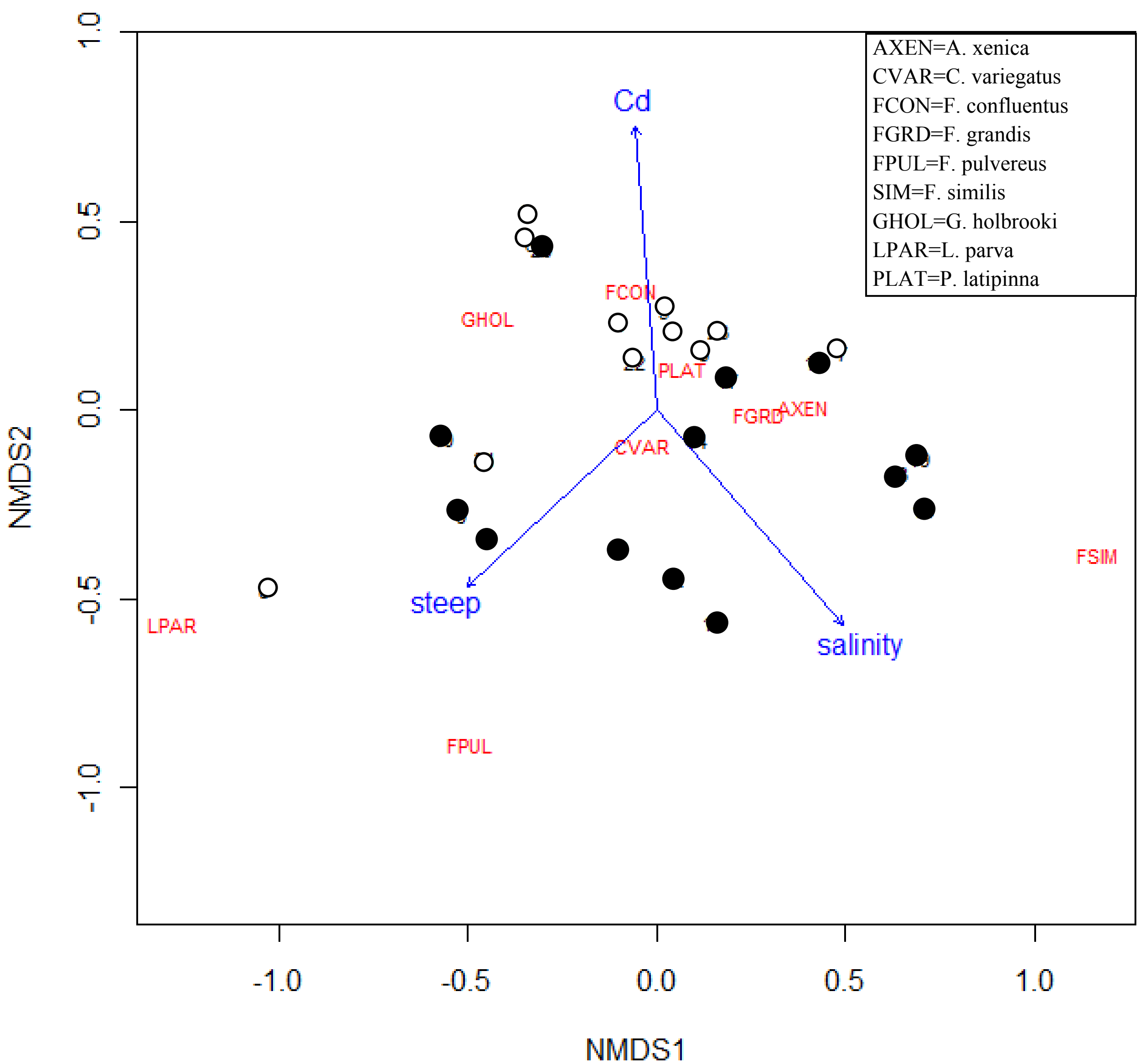

Table 2.1 Urban land-use characteristics within 500m radius of each study creek. See Fig. 1 for creek abbreviations.

Urban land-use measures	Urban			Reference				
	WB	GB	EB	GC	LB	SQB	Urban	Reference
Road area (m^2 ha^{-1})	562.4	281.1	544.2	19.7	0	5.6	462.6±90.9	8.44±5.8
Road density (m ha^{-1})	61.1	36.0	95.5	3.5	0	0.3	64.2±17.2	1.3±1.1
House density (no. ha^{-1})	1.4	1.4	1.0	0.1	0	0.1	1.3±0.1	0.1±0.0
Shoreline house density (no. km $shoreline^{-1}$)	10.2	14.6	10.3	2.7	0	0.0	11.7±1.5	0.9±0.9
Boat slips (no. km $shoreline^{-1}$)	6.3	6.7	6.8	1.9	0	0.0	6.6±0.2	0.6±0.6

Table2.2 Mean (±SE) creek salinity and temperature measures from seasonal fish sampling (n=92) (YSI) and from conductivity loggers (n=8041) (HOBO). See Fig. 1 for creek abbreviations.

	Urban			Reference				
	EB	GB	WB	GC	LB	SQB	Urban	Reference
YSI								
Salinity mean (ppt)	11.5±0.7	8.6±0.9	12.6±1.2	11.6±0.4	14.9±0.3	16.7±0.1	10.8±1.3	14.4±1.1
Salinity range (ppt)	11.2±0.4	18.4±0.9	17.0±1.2	16.2±0.6	15.6±0.9	9.5±0.3	15.9±1.8	13.8±1.7
Salinity min (ppt)	7.8±0.8	2.4±0.5	5.0±1.4	3.5±0.8	7.9±0.9	13.5±0.1	4.8±1.4	8.3±2.2
Salinity max (ppt)	19.0±0.5	20.8±1.2	21.9±0.6	19.7±0.3	23.4±0.1	23.0±0.2	20.7±1.0	22.0±0.9
Temperature mean (°C)	22.7±0.1	23.5±0.9	23.4±0.4	23.8±1.7	24.1±1.6	22.6±1.7	23.2±1.1	23.5±1.0
Temperature range (°C)	15.8±0.2	19.3±0.1	17.2±0.7	15.8±0.7	15.0±0.4	15.9±0.3	17.6±0.8	15.6±0.5
Temperature min (°C)	13.7±0.2	13.4±0.2	14.2±0.3	15.1±0.2	16.4±0.5	13.6±0.4	13.7±0.3	15.0±0.7
Temperature max (°C)	29.5±0.1	32.7±0.3	31.4±0.5	30.9±0.5	31.4±0.1	29.4±0.1	31.3±0.7	30.6±0.5
HOBO								
Salinity mean (ppt)	14.8±0.0	16.2±0.0	15.6±0.0	13.6±0.0	14.7±0.0	16.4±0.0	15.5±0.4	14.9±0.8
Salinity range (ppt)	20.5	21.9	22.1	18.4	21.9	20.2	21.6±0.5	21.3±1.0
Salinity min (ppt)	0.2	0.1	0.2	0.2	0.2	2.8	0.1±0.0	1.1±0.9
Salinity max (ppt)	20.7	22.0	22.3	18.7	22.1	23.0	21.5±0.5	20.2±1.3
Temperature mean (°C)	24.6±0.1	25.9±0.1	25.9±0.1	26.4±0.1	258±0.1	24.6±0.1	25.5±0.4	25.6±0.5
Temperature range (°C)	19.7	22.9	24.8	18.0	23.9	23.6	34.0±1.5	34.2±1.9
Temperature min (°C)	12.9	11.9	9.7	16.0	10.0	11.1	11.5±1.0	12.4±1.9
Temperature max (°C)	32.6	34.8	34.5	34.1	34.0	34.7	22.4±0.7	21.9±0.2

Table 2.3 Mean (±SE) percent cover of dominant species, stem densities, and biomass at marsh edge for urban and reference creeks. Significant differences in mean measurement between urban and reference creeks reported per nested ANOVA. See Fig. 1 for creek abbreviations.

	Urban			Reference					
	EB	GB	WB	GC	LB	SQB	Urban	Reference	F, p
Juncus roemarianus	60.6±10.5	71.7±7.6	60.7±9.4	53.2±7.8	48.8±7.4	56.7±6.7	64.6±5.2	52.9±4.1	NS
Cladium jamaicense	0	0	0.8±0.6	0.8±0.8	0	0	0.4±0.2	4.0±0.3	NS
Distichlis spicata	0	1.1±0.8	0	11.3±4.2	0	0.8±0.6	0.4±1.6	4.0±0.3	NS
Spartina alterniflora	0	0	0	0	2.5±2.5	0	0	0.8±0.8	NS
Sagittaria lancifolia	1.1±0.6	0	0	0	0	1.3±1.3	0.4±0.2	0.4±0.4	NS
Stem density (no. m^{-2})	897±95	553±111	718±152	716±170	755±103	1072±65	671±72	896±77	4.91, 0.041
Biomass (g m^{-2})	1085±231	610±121	875±190	930±197	847±65	1444±59	783 ±87	1135 ±84	5.32, 0.034

Table 2.4 Mean (±SE) percent cover of dominant species per marsh transect for urban and reference creeks. Significant differences in mean cover between urban and reference creeks reported per nested ANOVA. See Fig. 1 for creek abbreviations.

	Urban			Reference					
Species	GB	EB	WB	GC	LB	SQB	Urban	Reference	F, p
Juncus roemarianus	43.7±3.7	35.4±5.3	34.9±3.7	38.8±4.3	35.8±3.6	39.3±3.0	38.4±2.4	37.9±5.3	NS
Cladium jamaicense	1.2±1.0	9.4±3.5	5.1±2.9	5.0±2.2	0.9±0.3	0.2±0.1	4.8±1.5	1.9±0.8	NS
Distichlis spicata	9.5±3.1	0	0	6.8±2.2	0.1±0.1	1.9±2.0	3.4±1.2	2.9±1.0	NS
Spartina patens	1.5±1.5	0	0	0	3.0±1.6	0.9±02.8	0.5±0.6	1.3±1.0	NS
Sagittaria lancifolia	0	0.5±0.3	0	0	0	0	0.1±0.1	0	NS
Solidago sempervirens	0.2±0.1	0	0	0.7±0.4	2.0±1.1	0	0.1±0.0	0.9±0.4	8.54, 0.010
Lilaeopsis chinensis	0	0	0	0	0.4±0.2	0.6±0.4	0	0.3±0.2	4.56, 0.048
Salicornia europaea	0	0	0	0	0.8±0.6	0	0	0.3±0.2	NS

Table 2.5 Mean (±SE) element concentration of sediment for each creek and treatment. Significant differences in mean concentration between urban and reference creeks reported per nested ANOVA. See Fig. 1 for creek abbreviations.

	Urban			Reference					
Element	EB	GB	WB	LB	SQB	GC	Urban	Reference	F, p
Cd (ppm)	0.05 ± 0.01	0.08±0.02	0.08±0.01	0.02±0.00	0.05±0.02	0.04±0.01	0.07±0.01	0.04±0.01	15.33, 0.001
Cr (ppm)	0.16±0.02	0.121±0.03	0.11±0.02	0.07±0.01	0.08±0.00	0.08±0.03	0.13±0.01	0.08±0.01	8.61, 0.009
Cu (ppm)	1.01±0.06	0.27±0.06	0.50±0.11	0.36±0.02	0.53±0.17	0.31±0.04	0.56±0.10	0.40±0.06	NS
Fe (ppm)	76.86±4.76	57.60±8.16	39.66±8.89	79.53±11.09	51.78±12.51	67.79±7.33	56.33±6.23	66.37±6.49	NS
Mn (ppm)	1.92±0.59	5.55±1.71	2.37±0.80	10.14±3.34	3.94±0.78	15.86±4.29	3.41±0.82	9.98±2.21	10.36, 0.005
Mo (ppm)	0.12±0.03	0.08±0.00	<0.01	<0.01	0.06±0.01	<0.01	0.11±0.02	0.06±0.00	5.13, 0.037
Ni (ppm)	0.41±0.08	0.22±0.03	0.22±0.04	0.30±0.06	0.31±0.05	0.40±0.07	0.27±0.04	0.34±0.03	NS
Pb (ppm)	4.08±0.28	9.55±3.51	4.27±1.16	2.65±0.27	1.88±0.55	2.59±.57	6.14±1.47	2.37±0.27	8.00, 0.012
Zn (ppm)	7.40±2.81	6.43±0.34	7.14±0.97	4.12±0.58	5.03±0.94	5.27±1.21	6.95±0.75	4.81±0.52	4.89, 0.041
P (ppm)	44.54±6.95	41.75±2.91	46.91±6.35	56.59±16.98	33.27±3.41	47.64±18.59	44.38±2.91	45.84±8.19	NS
C(%)	16.48±1.98	17.02±3.82	18.06±1.99	9.22±1.88	9.16±1.59	11.56±2.99	17.25±1.51	9.98±1.21	12.04, 0.003
N(%)	0.86±0.10	0.85±0.17	0.92±0.10	0.59±0.12	0.56±0.08	0.79±0.21	0.88±0.07	0.65±0.08	NS

Table 2.6 Mean (±SE) species and total abundance (no. fish $trap^{-1}$), total biomass, Shannon Index and species richness per creek and treatment. Significant differences in mean abundance between urban and reference creeks reported per nested ANOVAs. See Fig. 1 for creek abbreviations.

	Urban			Reference					
	EB	GB	WB	GC	LB	SQB	Urban	Reference	F, p
F. grandis	5.33±1.39	3.88±1.18	5.71±1.15	4.11±1.80	18.14±2.55	10.86±1.09	4.94±0.70	11.04±1.41	24.19, <0.001
P. latipinna	1.83±0.91	0.26±0.15	4.44±1.15	0.98±0.37	0.96±0.46	2.39±0.63	2.21±0.55	1.44±0.31	NS
F. confluentus	0.52±0.30	0.39±0.14	1.79±0.54	0.28±0.16	0.05±0.02	0.13±0.05	0.93±0.24	0.15±0.06	12.94, <0.001
F. pulvereus	0	0	0.01±0.01	0.06±0.04	0.04±0.04	0.03±0.03	0	0.04±0.02	NS
F. similis	0	0	0	0	0.03±0.02	0.04±0.04	0	0.02±0.01	NS
A. xenica	0.18±0.12	0.45±0.33	1.36±0.54	0.04±0.02	0.24±0.10	0.76±0.018	0.71±0.24	0.35±0.09	NS
C. variegatus	0.18±0.21	0.08±0.04	1.64±0.77	2.08±1.22	0.39±0.14	0.3±0.017	0.67±0.30	0.92±0.42	NS
G. holbrooki	0.6±0.44	0.14±0.09	1.01±0.48	0.81±0.45	0.05±0.04	0.04±0.02	0.58±0.22	0.30±0.16	NS
L. parva	0	0	0.01±0.01	0.03±0.02	0	0	0	0.01±0.01	NS
Mean abundance	8.65±1.62	5.19±1.22	15.98±2.63	8.38±2.13	19.89±2.47	14.54±1.07	10.05±1.32	14.27±1.35	7.59, 0.007
Total biomass (g $trap^{-1}$)	101	104	166	104	532	290	372	924	20.32, <0.001
Shannon Index	1.01±0.24	0.94±0.12	1.42±0.12	1.15±0.17	0.39±0.13	0.80±0.01	1.14±0.11	0.78±0.11	10.05, p=0.006
Sp. richness	5.0±0.6	5.5±0.3	6.3±0.6	6.8±0.3	6.0±0.4	5.8±0.3	5.6±0.3	6.2±0.2	NS

Chapter 3: Urban land-use effects on *Fundulus grandis* and *Poecilia latipinna* condition

Abstract

Urbanization has been shown to impact coastal fisheries by reducing the quality of important habitats, including salt marshes. Increasing urban land-use surrounding tidal creeks may impact the health of fish by changing salinities, altering habitat structure, and increasing exposure to pollution. In this study I evaluated the impacts of urban land-use on *Fundulus grandis* and *Poecilia latipinna*, two common salt marsh resident fish along the northern Gulf of Mexico. Fish were sampled seasonally along salt marshes near the mouth of six second-order tidal creeks (three surrounded by urban development and three surrounded by forest cover) in Alabama and west-Florida. Because urban runoff commonly contains elevated concentrations of heavy metals, *F. grandis* was also analyzed for metal contaminants. Results showed *F. grandis* had lower LSI and caloric density at urban salt marshes compared to reference. However, *P. latipinna* did not have significantly different condition measures at urban salt marshes compared to reference. Both species showed seasonal patterns related to conditional measures that were likely related to reproduction and annual fattening cycles. Except for zinc, no significant differences were detected in metal concentration between urban and reference *F. grandis* and many metals associated with urban runoff (Cd, Cr, Pb) were below detection levels for fish from both creek types. Lower fish condition in urban creeks for *F. grandis* is likely a result of an altered salinity regime.

Introduction

Urbanization and associated anthropogenic impacts have been shown to have a number of effects on estuarine systems. Urban land-use has been associated with increased runoff of nutrients (Arismendez et al. 2009, Yang 2012), heavy metals (Holland et al. 2004, Sanger et al. 1999), pesticides (Sanger et al. 2011), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) (Van Dolah et al. 2008) and other contaminants (Eom et al. 2010, DiDonato et al. 2009). Some contaminants (e.g. PAHs, PCBs) may remain in a creek system for long periods and organisms continue to be exposed to them (Teal et al. 1992). A range of urban measures, including residential land-use, was significantly correlated with PCB concentration in white perch (*Morone americana*) fillets in Chesapeake Bay (King et al. 2004). Increased urban runoff into tidal creeks has also been correlated with altered hydrology (Sahoo and Smith 2009) and salinity regimes that can induce osmotic regulatory energy cost and reduce fish habitat suitability (Shirley et al. 2005). For instance, salinity range increased with increasing impervious cover in South Carolina tidal creeks (Holland et al. 2004). Considering at least 90% of commercially valuable fish are considered estuarine dependent (Chambers 1992) understanding how urbanization affects habitat and fish health is important.

Measures of fish health and condition have commonly been used to assess environmental effects caused by surrounding land use. For instance, fish have been shown to accumulate toxins after exposure and even develop resistance to them (Yuan et al. 2006). Fish condition and abundance measures have been shown to be useful in environmental monitoring (Leamon et al. 2000, Galloway and Munkittrick 2006, Anderson et al. 2006). Striped bass in the Hudson River showed significant declines in several health measures, including liver weight: body weight ratios, RNA:DNA ratios, swimming ability and bone development, all of which were likely related to the high pollution load from urban and industrial sources (Buckley et al. 1985). While sportfish have often been the focus of studies, small forage fish have also been shown to exhibit comparable responses (Yeardley 2000). Mummichogs (*Fundulus heteroclitus*), a small resident fish of salt marshes along the Atlantic coast of North America, have been used in numerous studies to evaluate the impact of anthropogenic changes on fish condition, including pulp mill effluent (Le Blanc et al. 1997), pollutants (Pait and Nelson 2009, Nacci et al. 2010) invasive species (Weinstein et al. 2009) and restoration efforts (Teo and Able 2003). For instance, mummichogs in a polluted marsh in New York had reduced growth rates, higher metabolic rates, and higher food consumption compared to reference fish (Goto and Wallace 2010). Thus, the condition of mummichog has proven to be a useful indicator of salt marsh quality. Within the Gulf of Mexico, a species closely related to the well-studied mummichog, *Fundulus grandis* (Gulf killifish) is abundant in salt marshes. Both of these species are salt marsh residents that use the marsh surface extensively for spawning and foraging habitats and then retreat to marsh edges or pools at low tide (Boschung and Mayden 2004, Knieb 1986). Because of its dependence on marsh habitat and tendency to stay within a close home range, *F. grandis* is a good species for studying anthropogenic impacts on fish condition in the northern Gulf of Mexico. Another resident species that has been used for toxicology experiments is *Poecilia latipinna*. Its abundance in impacted areas and sensitivity to toxicants (e.g., dieldrin, Lane and Livingston 1970) also make it well suited to studies of anthropogenic impacts in the northern Gulf of Mexico.

Potential differences in species condition may be related to increased runoff from urban land-use, which could alter salinity regimes and increase pollutant exposure. Although both species have a wide salinity tolerance range, *F. grandis* and *P. latipinna* have slightly different salinity preferences. *F. grandis* is more common in higher salinities within its range (2-28ppt, Fivizzani and Meier 1978) while *P. latipinna* is more common in lower salinities (<10ppt, Boschung and Mayden 2004). Both species are common in *Juncus roemarianus*-dominated marshes, which commonly occur along the Mississippi, Alabama, and west Florida coasts in salinities of 10.1 to 24.4ppt (Stout 1984). This understudied marsh type is less common than *Spartina alterniflora* habitats in the United States, but represents a higher proportion of the marshes along these coasts than in any other area of the country (Stout 1984). Many studies have looked at how fish differ in condition in due to industrial or high density urban land-use (King et al. 2004, Buckley et al. 1985, Yuan et al. 2006), but a paucity of studies exists concerning how low to medium-density urban land-use may impact estuarine fish condition. While a multitude of condition measures exist, this study focused on using changes in liver size and caloric density to assess potential urban effects on *F. grandis* and P. *latipinna*. Liver measures such as size and enzyme activity have been used to assess anthropogenic impacts such as dense urban and industrial land-use and pollutant exposure (Ferraro et al. 2001, Schoor et al. 1988). The liver can also store energy in the form of glycogen and a decrease or increase in size to reflect differences in nutrition, reproductive state, condition, sex, season, and toxicant exposure (Hinton and Laurén 1990). Caloric density can be used as a measure of the whole fish, so it accounts for changes in protein, carbohydrates, and lipids, and any change in the relative contribution of these is reflected in caloric density. Caloric density has been used in other studies to compare differences in productivity (Vondracek 1996) and toxicant exposure (Moles and Rice 2012).

The objective for this study was to determine if *F. grandis* and *P. latipinna* exhibit differences in condition as measured through Liver Somatic Index scores and caloric density in urban salt marshes compared to reference salt marshes. As a potential predictor of fish health, the concentrations of urban derived metals in fish were also compared between creek type. I expected that *F. grandis* and *P. latipinna* from urban salt marshes would have lower Liver Somatic Index scores, lower caloric density, and higher metal concentrations compared to those from reference salt marshes.

Methods

Site Description

This study focused on six second-order tidal creeks along the Alabama and Florida coast (Fig. 1). Creeks were selected as part of a broader examination of urban effects on salt marsh habitat in the region (see Methods, Chapter 2). Two creeks were in the Wolf Bay drainage basin (in Alabama), three in the Perdido Bay drainage basin (in Alabama and Florida), and one in the Pensacola Bay drainage basin (in Florida). Three creeks were classified as reference (Long Bayou, Graham Creek, and Stone Quarry Bayou) and the other three as urban (Emmanuel Bayou, Weekley Bayou, and Bayou Grande). Reference creeks had a housing density of <3.0 houses km shoreline^{-1} and a road density of <10.0 m ha^{-1}within a 500 m radius of the creek while urban creeks had a housing density of ≥10.0 houses km shoreline^{-1} and >30.0m ha^{-1} road density within a 500 m radius of the creek (see Chapter 2, Table 2.1). Shoreline hardening and other alterations were present along all the urban creeks while only minor alterations occurred on a small portion of one reference creek (Graham Creek) and the others had no alterations (Table 3.1). In each creek four salt marshes near the mouth were selected as study sites (Emmanuel Bayou only had three salt marshes). Marshes were dominated by *J. roemerianus* (henceforth *Juncus*) and were selected to be of comparable size and condition between creeks.

Fish Sampling

Fish were collected from each creek once per season (i.e., winter, spring, summer, and fall: December 2011, March 2012, July 2012, and September 2012 respectively) since condition measures have been shown to change seasonally (Leamon et al. 2000, Galloway and Munkittrick 2006). For each sampling event, fish were collected for three consecutive days (each day two creeks were sampled) using baited minnow traps (22.9 cm x 44.5cm with 2.5cm opening) randomly set along water edge of each marsh at the falling tide. At each salt marsh, 5 minnow traps were deployed (20 per creek) and collected four hours later. Fish caught in traps were immediately put on ice and frozen as soon as possible for identification and processing in the laboratory.

Fish Condition

All fish were thawed prior to being processed. *F. grandis* and *P. latipinna* were enumerated per marsh and per sampling event. The length of each fish was measured (nearest mm) and weighed (nearest mg). A representative subset of 10 fish of each species per marsh was used for the condition measures. The subset consisted of 2 fish, a male and female if possible, of five size classes for *F. grandis* (≥90cm, 89-73cm, 72-57cm, 56-41cm and ≤40cm) and *P. latipinna* (≥60cm, 50-59cm, 40-49cm, 31-39cm ≤30cm). In cases where the entire breadth of size classes were not present, size classes with the greatest abundance were sampled again to fill the subset. The subset of fish had their liver removed and weighed (nearest mg). Liver Somatic Index (LSI) was calculated for each fish as follows:

$$\text{LSI} = 10^3 \cdot (\text{liver weight/body weight})$$

Livers were then placed with the rest of the fish in a drying pan for analysis of caloric density. The same subset was dried in an oven at 70^{0}C and weighed every day until constant mass was achieved. Each fish was then ground to homogenize the sample and re-dried until a constant mass was reached again. Two 0.1 -0.2g pellets per fish were ignited for caloric content in a semi-mirco bomb calorimeter (Parr Instrument Co., Model 1425 and Model 6725). If the two subsamples were not within 2% of each other, a third subsample was run. However, when fish dry weight was 0.2-0.4g, only two pellets were run. In the event that the dry weight of the fish was <0.2g, the whole fish was analyzed in one pellet without being ground. Results of pellet incineration were averaged per fish to get caloric density per gram of dry weight. Caloric density per gram of wet weight was calculated by multiplying caloric density per gram of dry weight to the ratio of dry weight to wet weight (Glover et al. 2010). This was calculated for each fish and used for statistical comparison.

Ground *F. grandis* that remained after bomb calorimetry was combined per creek for the summer and fall sampling and analyzed for heavy metal contaminants and other metals commonly associated with urban runoff (Al, Fe, As, Cd, Cr, Ni, Pb, Zn, and Cu; Paul and Meyer 2001) using Inductively Coupled Plasma (ICP) Atomic Emission Spectroscopy with a Varian Vista-MPX Axial Spectrometer (Odom and Kone 1997). *P. latipinna* was not analyzed due to insufficient sample being left after bomb calorimetry.

<u>Statistical Analysis</u>

To determine the effect of treatment (urban vs. reference), fish condition measures were analyzed with nested Analysis of Variance (ANOVA). Seasonal fish measures were averaged per marsh and nested within creek and then within treatment. To compare seasonal trends related to fish measures, fish measures were averaged per creek and plotted per sampling event. Significance level was set at $p<0.05$ and all analyses were run in the program R.

Results

A total of 291 *P. latipinna* and 741 *F. grandis* were used for analyzing fish LSI while 366 *P. latipinna* and 741 *F. grandis* were used for the caloric density analysis (Table 3.1). There was a lower number of *P. latipinna* were analyzed for LSI due to some fish thawing for too long and the livers broke down into an immeasurable state. LSI had different responses based on species and treatment. Urban marshes had similar *P. latipinna* LSI (1046±66) compared to reference creeks (1163±70, Table 3.2). Weekley Bayou, an urban creek, had the lowest LSI for *P. latipinna* (969±49) while a reference creek, Graham Creek, had the highest LSI (1407±136, Table 3.2). *F. grandis* LSI was significantly lower at urban marshes compared to reference marshes (788±38 vs. 921±26, F=10.11, p=0.002, Table 3.3). A reference creek, Long Bayou, had the largest *F. grandis* LSI (984±49) and the lowest was an urban creek, Emmanuel Bayou (786±102 Table 3.4). LSI also varied across seasons for both species (Figs. 3.1a, 3.2a).

Caloric density also differed between species and treatments. *P. latipinna* had similar caloric density at urban marshes (1039±45 cal g^{-1}) compared to reference marshes (1074±30 cal g^{-1}, Table 3.2). A reference creek, Long Bayou, had the highest caloric density (1100±36 cal g^{-1}) for *P. latipinna* and an urban creek, Emmanuel Bayou, had the lowest (981±30 cal g^{-1}, Table 3.2). *F. grandis* caloric density was significantly lower at urban marshes compared to reference creeks (982±13 cal g^{-1} vs. 1005±9 cal g^{-1}, F=5.41, p=0.023, Table 3.3). A reference creek, Long Bayou, had the highest caloric density for *F. grandis* (1019±9 cal g^{-1}) and an urban creek, Emmanuel Bayou, the lowest (950±19 cal g^{-1}, Table 3.3). Caloric density also varied across season for both species, but both species in urban and reference marshes followed similar patterns (Figs. 3.1b, 3.2b).

Most metal concentrations were not significantly different in the *F. grandis* from reference or urban marshes (Table 3.4), and many were below detection levels (e.g. arsenic, lead, chromium). *F. grandis* did have significantly higher zinc at urban marshes (134.9±3.3 vs. 118.6±2.6, F=9.30, p=0.023) but all other trace elements were not significantly different in urban marshes compared to reference marshes.

Discussion

Urban salt marshes were shown to have *F. grandis* with lower condition, while *P. latipinna* had similar condition to reference marshes. The lack of significance for *P. latipinna* may have been partially caused by the difficultly in acquiring consistent numbers of *P. latipinna* from all sites. While both LSI and caloric density showed variation with season, urban creeks were lower than reference creeks for both measures for most of the year. Higher LSI measures in reference creeks suggest that these fish were generally more fit which may relate to better food quality, less exposure to pollutants or a combination of these factors. Seasonal fluctuations were likely related to reproduction, which in Alabama is from April to September for *P. latipinna* and March through August for *F. grandis* (Boschung and Mayden 2004). Cyprinodontiformes, including *F. grandis* and *P. latipinna,* invest large amounts of energy into reproduction (Meffe and Snelson 1993), and lipid reserves have been shown to vary seasonally in a number of Cyprinodontiformes in the Gulf of Mexico (de Vlaming et al. 1978). In *F. heteroclitus,* LSI scores were shown to decrease as gonadal somatic index increased (Galloway and Munkittrick 2006) further suggesting that seasonal LSI shifts may be related to reproduction.

The liver has been shown to respond with morphological changes to toxicant exposure and most research relating measures of fish liver size has assessed pollutant effects. For example, *P. latipinna* had lower percent lipid and weight gain when exposed to DDT (Benton et al. 1994). *G. affinis*, which is related to *P. latipinna*, had smaller livers in freshwater creeks contaminated by mining activity (Franssen 2009). *F. heteroclitus*, which is closely related to *F. grandis*, had smaller livers at urban-industrial impacted sites in Connecticut, and liver glycogen content (a form of energy storage) showed higher variation at impacted sites than at reference sites (Ferraro et al. 2001). In this study however there was very little evidence that toxic exposure was substantially higher. Sediment analyses indicated no significant levels of polycyclic aromatic hydrocarbons (see Chapter 2 Results) although there were instances of statistically higher metal concentrations in urban creeks, these differences may not have been substantial enough to generate a difference in fish health, since *F. grandis* metal concentration was not significantly different at urban marshes.

The lower condition of urban fish of both species may also be a result of the metabolic costs of having to deal with salinity swings. While these species have been shown to be very tolerant of a wide range of salinities and temperatures, metabolic costs to living in such conditions still occur (Gonzalez and Head 2005, Nordlie 2006). Also, the rate of change in salinity can affect fish health and survival. *C. variegatus,* commonly found along the Gulf of Mexico, has one of the widest ranges of salinity tolerances for a cyprinodontiform species, yet it had 100% mortality when salinity was changed from 32ppt to freshwater and back in two hours (Serafy et al. 1997). Urban creeks in this study had wider ranges of salinity and more rapid salinity changes, especially after rain events (Figs. 2.2 and 2.3, Chapter 2). *P. latipinna* has been shown to have increased metabolic demands in low salinity water (Trexler et al. 1992) and considering *F. grandis* has a higher salinity preference (Nordlie 2006), both species would likely exhibit responses to rapidly changing salinity in urban salt marshes.

Similar to LSI, caloric density was significantly higher in reference creeks for *F. grandis* but not for *P. latipinna*. The *F. grandis* mean caloric density was slightly higher at both urban (4.32 Kcal g dry wt.$^{-1}$) and reference (4.29 Kcal g dry wt.$^{-1}$) sites compared to average values reported from Mississippi *Juncus* marshes (4.04Kcal g dry wt.$^{-1}$) (de la Cruz 1983). Caloric density for *F. grandis* at urban (0.98 Kcal g wet wt^{-1}) and reference creeks (1.00 Kcal g wet wt^{-1}) were lower than caloric density measured for *F. heteroclitus* from North Carolina *S. alterniflora* marshes (1.31 Kcal g wet wt^{-1},Thayer et al. 1973). Thayer et al. (1973) reported that differences in caloric density can be related to reproductive state and lipid content. *F. heteroclitus* had higher lipid content in *Spartina alterniflora*–dominated marshes compared to marshes dominated by *Phragmites australis*, an invasive species in the United States (Weinstein et al. 2009). The authors reported that *F. heteroclitus* in marshes with *P. australis* had lower caloric density because of reduced access to the marsh surface by adults, less frequent flooding of the marsh, and less refuge for young fish. The differences in caloric density could also reflect a change in food sources. *F. heteroclitus* fed different diets exhibited different caloric density (Weisberg and Lotrich 1982) and *F. grandis* lipid content was higher when fed fish-feed in brackish mariculture ponds compared to wild fish (MacGregor et al. 1983). Caloric density was found to vary seasonally for three fish species in the Great Lakes, although it was not found to be significantly correlated with productivity of the lake, except for one species (Vondracek 1996). Although diet could not be assessed in this study, other research in urban estuaries has found different benthic infauna communities and decapod crustaceans compared to reference sites (Partyka and Peterson 2008, Sanger et al. 2004, Lerberg et al. 2000, Washburn and Sanger 2010, Lawless 2008). These altered communities could be providing lower quality food resources for resident fish, which may be reflected in lower caloric density found in this study.

Conclusions

This study evaluated the impacts of low-medium density urban land-use on resident salt marsh fish condition. Salt marshes were located in six tidal creeks in west Florida and Alabama (3 urban and 3 reference). *F. grandis* and *P. latipinna* were collected seasonally using minnow traps and using a representative range of lengths for each species, LSI and caloric density were compared for differences between creek types. Results showed differences in condition of the two resident salt marsh fish in urban and reference habitats. Liver Somatic Index scores and caloric density were lower at urban creeks for both *F. grandis* but not for *P. latipinna*. These differences were likely related to changes in food resources, lipid stores, and reproduction caused by habitat modification and altered salinity regime.

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Figure 3.1 Mean (±SE) seasonal a) Liver Somatic Index and b) caloric density (cal g wet wt.$^{-1}$) for *P. latipinna* at urban and reference creeks. Urban is represented by black points and reference by white points.

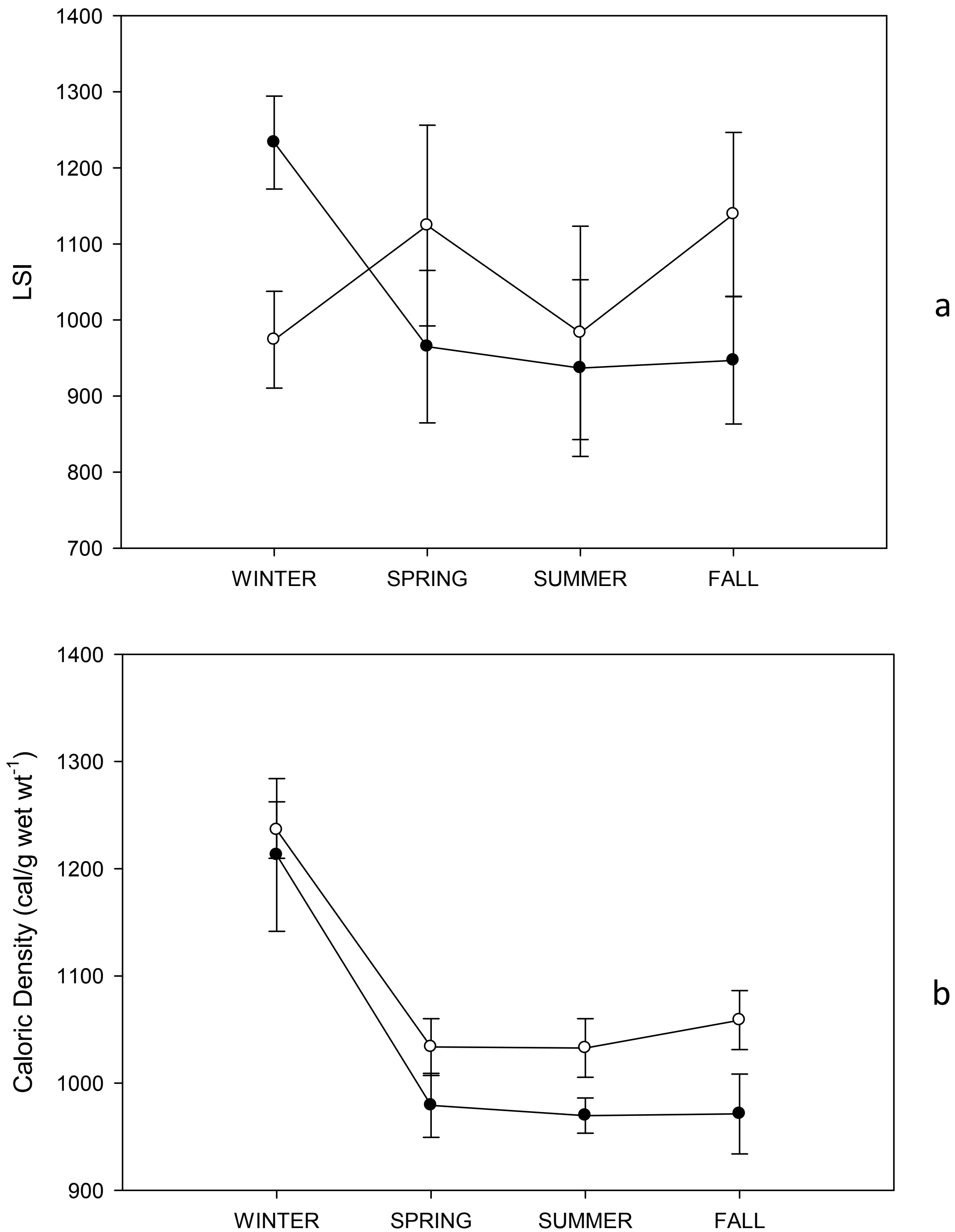
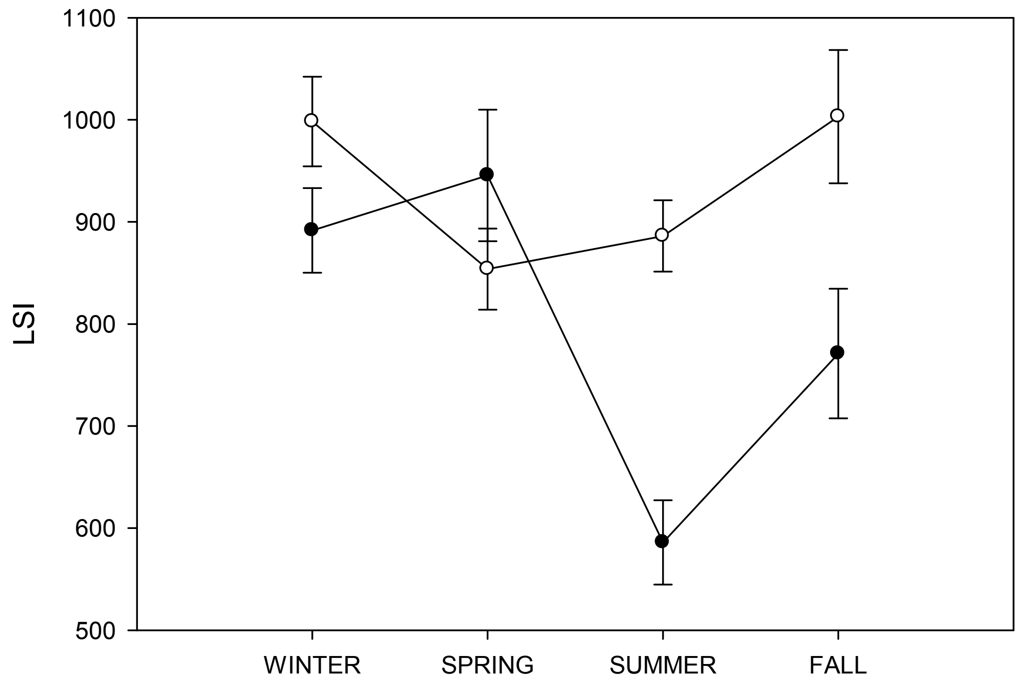
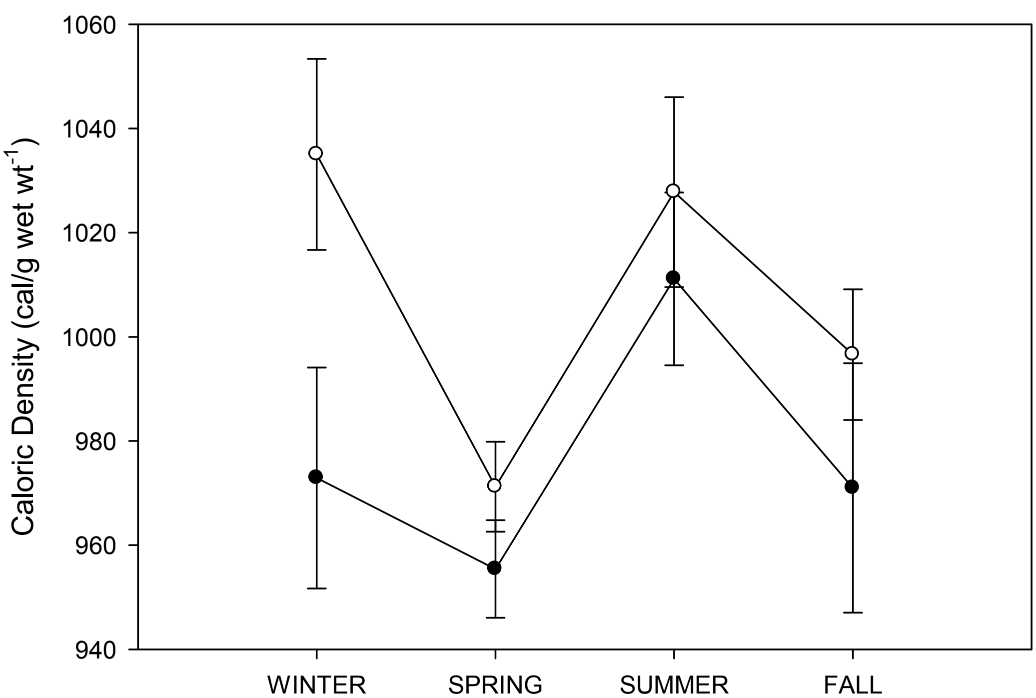


Figure 3.2 Mean (±SE) seasonal a) Liver Somatic Index and b) caloric density (cal g wet wt.$^{-1}$) for *F. grandis* at urban and reference creeks. Urban is represented by black points and reference by white points.



a



b

Table 3.1 Sample size for caloric density and Liver Somatic Index (LSI) seasonally by creek and treatment. Discrepancies for LSI are presented parenthetically.

	Urban			Reference				
	EB	GB	WB	GC	LB	SQB	Urban	Reference
P. latipinna								
Winter	23	10(9)	21(19)	23	10(9)	30	54(51)	63(62)
Spring	12(5)	11(7)	26(21)	21(9)	0	3(2)	49(33)	24(11)
Summer	2	0	33 (14)	5(4)	7(4)	16(5)	35 (16)	28(13)
Fall	14(10)	0	28(24)	10(9)	25(23)	40(39)	42(34)	75(71)
F. grandis								
Winter	11	22	21 (20)	12	27	40	54 (53)	79
Spring	30	40	38	40	40	40	108	120
Summer	30	36	40	28	40	40	106	108
Fall	25	12	40	10	40	40	77	90

Table 3.2 Mean (±SE) length, weight, condition measures and significant ANOVA results for *P. latipinna* per creek and treatment.

	Urban			Reference					
	EB	GB	WB	GC	LB	SQB	Urban	Reference	F,p
Length (mm)	40.6±3.4	40.4±2.5	42.9±0.4	39.8±2.5	48.7±1.7	47.9±1.0	41.4±1.2	45.5±1.5	4.50, p=0.04
Weight (g)	1.22±0.28	1.15±0.28	1.39±0.05	1.05±0.37	1.99±0.24	1.85±0.11	1.26±0.12	1.63±0.18	NS
Caloric density (cal g wet wt.$^{-1}$)	981±30	1048±100	1074±58	1065±71	1100±36	1057±80	1039±45	1074±30	NS
Liver weight (mg)	13.7±3.0	10.0±2.9	12.8±3.3	12.9±2.9	20.6±3.9	26.3±1.6	11.6±1.4	18.9±2.7	NS
LSI	979±76	1250±132	969±49	1407±136	1164±49	978±105	1046±66	1163±70	NS

Table 3.3 Mean (±SE) length, weight, condition measures and significant ANOVA results for *F. grandis* per creek and treatment.

	Urban			Reference					
	EB	GB	WB	GC	LB	SQB	Urban	Reference	F,p
Length (mm)	66.2±4.7	79.4±2.1	68.8±2.4	75.3±0.2	78.1±0.9	73.7±2.5	72.0±2.4	75.7±0.9	NS
Weight (g)	5.61±1.18	8.08±0.74	6.17±0.87	6.83±0.16	8.29±0.22	7.06±0.64	6.71±0.54	7.39±0.34	20.58, p<0.001
Caloric density (cal g wet wt.$^{-1}$)	950±19	1008±26	979±19	1009±14	1019±9	986±13	982±13	1005±9	5.41 p=0.023
Liver weight (mg)	55.8±16.4	70.0±7.8	60.1±4.6	70.7±4.8	88.5±4.6	72.2±10.1	62.5±6.0	77.2±3.4	6.21, p=0.015
LSI	786±102	787±45	792±25	856±39	984±49	923±76	788±38	921±26	10.11 p=0.002

Table 3.4 Element concentration and mean (±SE) urban and reference for *F. grandis* in summer (July 2012) and fall (September 2012) per creek and treatment.

	SUMMER						FALL								
	Urban			Reference			Urban			Reference					
Element	EB	GB	WB	GC	LB	SQB	EB	GB	WB	GC	LB	SQB	Urban	Reference	F, p
Al (ppm)	118	596	489	335	83	179	198	224	61	196	217	181	324.9±84.1	198.5±33.1	NS
B (ppm)	6	7	6	5	5	7	4	4	5	4	4	4	5±10.5	5±0.5	NS
Fe (ppm)	131	443	280	262	93	132	135	177	71	165	174	150	233.1±53.7	162.5±23.1	NS
As (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
Cd (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
Cr (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
Ni (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
Pb (ppm)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-
Zn (ppm)	133	132	129	108	117	125	149	131	115	122	116	123	134.9±3.3	118.6±2.6	9.30, p=0.023
Cu (ppm)	13	11	13	9	13	12	21	14	13	12	11	16	14.4±1.6	12.2±1.0	NS

Chapter 4. Thesis Summary

In this study I evaluated the impacts of urban land-use near *Juncus*-dominated salt marshes along the Gulf of Mexico through an evaluation of the resident cyprinodontiform community composition, size and abundance of individual species, and condition of two dominant species: *Fundulus grandis* and *Poecilia latipinna*. Most measures related to habitat conditions, fish abundance/biomass, and species composition showed significant differences at urban salt marshes compared to reference salt marshes. Plant biomass and stem density along the marsh edge were significantly lower at urban salt marshes compared to reference salt marshes. Salinity tended to fluctuate much more rapidly, had a larger range, and lower mean at urban marshes than reference marshes. Urban marshes had higher concentrations of metals (Cd, Cr, Mo, Zn, Pb) and carbon in the sediment compared to reference marshes. Urban marshes also had greater percent shallow slope than reference marshes. The cyprinodontiform community was significantly different at urban and reference salt marshes. Six species were more abundant at urban creeks, while only two were less abundant at urban creeks compared to reference creeks. Of the six species in greater abundance at urban creeks, five (*P. latipinna, F. confluentus, G. holbrooki, A. xenica, F. confluentus)* are often more abundant in brackish marshes than salt marshes (Boshung and Mayden 2004). The two species that were more abundant at reference salt marshes (*F. similis* and *F. grandis*) prefer higher salinities. Stout (1984) described *F. similis*, *F. grandis*, and *C. variegatus* as being dominant resident fish in *Juncus*-dominated marshes. Interestingly, two of these three were more common at reference marshes. Also the species more common at urban creeks (except *G. holbrooki*) were described by Stout (1984) as pond dominants in *Juncus*-marshes. These findings suggest that species found in urban marshes may be well adapted to the type of variable salinities expected in interior salt marsh ponds.

The condition of the fish at urban marshes was also different compared to reference marshes. Three species (*F. confluentus, A. xenica, F. confluentus)* were significantly larger (per mm length) at urban marshes compared to reference marshes (Figs. 2.8-2.12). One species, *G. holbrooki ,* was significantly smaller at urban creeks. The most abundant species, *P. latipinna* and *F. grandis*, were not significantly different in size at urban creeks. However, the other condition measures for these species did show a response. Liver Somatic Index and caloric density were lower for both *F. grandis* and *P. latipinna* at urban creeks compared to reference creeks, but not significantly for *P. latipinna*. It was expected that *P. latipinna* might show better condition measures in urban salt marshes because of its tendency to occur in less saline waters, and this was supported by the additional condition measures.

The changes in cyprinodontiform community and condition may be driven by a number of factors, but I believe that they are mainly driven by habitat alterations. Tolerance of contaminants from urban runoff likely played a role in the observed differences. Only heavy metals were evaluated in this study, and some were significantly elevated in marsh sediment of urban creeks (Table 2.3). Other contaminants may also be present that were not sampled, such as pesticides. These have been found to impact fish health (Lane and Livingston 1970, Benton et al. 1994, McCain et al. 1996) and might explain the lower condition of *F. grandis* and *P. latipinna* in urban creeks. *F. heteroclitus*, a closely related species, has been shown to adapt to pollutant loads (Nacci et al. 2010). If certain species are able to adapt better than others, their size and abundance may reflect this.

The lower condition and abundance may also be a result of the stress of having to deal with salinity swings. While all of the Cyprinodontiformes in this study have demonstrated wide ranges of salinity tolerance the range of salinities that they have been found at in the field is smaller (Griffith 1974, Nordlie 2006). For instance, F. Martin et al. (2009) found *P. latipinna* to be in higher abundance and better condition (greater weight) at brackish marshes compared to freshwater marshes in Louisiana. Thus *P. latipinna* may be best suited as a population in intermediate salinities, rather than in fresh or higher salinities, as seen in this study. Tolan and Nelson (2009) found salinity to be the driving factor in nekton community structure in Texas tidal creeks, more so even than dissolved oxygen, which was the original focus of their study. Perhaps more important than each species salinity preference is its ability to handle rapid increases and decreases in temperature. *C. variegatus* has the widest salinity range of all the species in this study, but it had 100% mortality in an experiment where it was rapidly changed from saltwater (32 ppt) to freshwater and back (Serafy et al. 1997).

Fish abundance and fish condition could be influenced by the change in food source that often accompanies urbanization near salt marshes. While not directly measured, a number of studies have found different benthic infauna at urban salt marshes compared to reference marshes (Sanger et al. 2004, Lerberg et al. 2000, Washburn and Sanger 2011, Lawless 2008). Intraspecific and interspecific competition could also be occurring (Weisberg 1986), but most of the fish caught in this study have broad diets (Boschung and Mayden 2004), which would alleviate any food competition. However, without quantifying the food resources a limited food resource for competition to occur is impossible to determine.

In addition to changing food resources, a reduction in plant cover may also increase spawning habitat for certain species. *F. confluentus* spawns on the substrate, typically on algal mats, which may explain partly the higher abundance of *F. confluentus* at urban marshes. *C. variegatus* also uses bare sediment for spawning, and *G. holbrooki* and *P. latipinna* as livebearers are not tied to a habitat for reproduction (Boschung and Mayden 2004). All three of these species had higher abundance at urban creeks, although not significantly. A decrease in plant biomass and plant cover could also be providing less cover from predators (Daiber 1982). Along the marsh edge this may mean an increase in predation by aquatic predators such as fish. This would be mediated by the amount of shallow slope along the marsh edge. This reasoning is supported by the high fish abundance at Weekley Bayou, where there was high percent shallow slope at the marshes. If little shallow slope exists, Cyprinodontiformes may shift from the marsh edge to interior habitats such as tidal pools and creeks that are too shallow for aquatic predators. This is likely why Graham Creek had such low abundance. The steep slopes along the marsh edge may have limited fish to interior habitats which were not sampled. The interior habitats also support fish and the sampling effort along the marsh edge likely results in a bias towards the fish that frequent the edge rather than the interior.

Habitat alterations may also mean urban marshes cannot support the same fish biomass. Meyer (2006) found salt marshes in North Carolina that were smaller and more isolated did not have self-sustaining populations of *F. heteroclitus*. These marshes were lacking small individuals, suggesting no recruitment or reproduction. Fish densities at tidal marshes in Louisiana, including *G. holbrooki, P. latipinna,* and *C. variegatus*, were lower at fragmented freshwater and oligohaline marshes compared to non-fragment marshes (Hitch et al. 2011).

While this study has demonstrated that development near salt marshes can affect the resident fish communities, many questions remain. Changes in food resources and reproduction may be driving some of the differences observed in this study, but these were not examined. This study did not assess contaminants within the water column. Evaluating the possible contaminant load would further understanding of how urban land-use may impact these systems. DDT and dieldrin, both pesticides, have been shown to impact *P. latipinna* (Benton et al. 1994, Lane and

Livingston 1970). *F. grandis* had accumulated PCBs, DDT, and polycyclic aromatic hydrocarbons (PAHs) in Tampa Bay, Florida. *C. variegatus* was shown to be sensitive to crude oil and an oil dispersant (Adams et al. 1999). Also, Sanger et al. (2011) found elevated levels of PCBs, DDT, and PAHs in a number of urban tidal creeks in the Gulf of Mexico, which makes these contaminants important to investigate.

Having demonstrated differences in abundance and condition, the effects of these changes on transient fish and other predators of these resident Cyrpinodontiformes are important to know. Transient fish are often economically valuable fish such as speckled trout (*Cynoscion nebulosus*), Southern flounder (*Paralichthys lethostigma*), and red drum (*Sciaenops ocellatus*). Maintaining healthy prey resources will help sustain these fisheries. Also, while not evaluated in this study, *F. jenkinsi* is a species of concern that is closely tied to salt marshes. Typically this species is abundant in salinities less than 16ppt and in marshes receiving significant freshwater inputs (Lopez et al. 2011). These fit the conditions found at this study's urban salt marshes. Peterson et al. (2003) suggests that the patchy and temporal nature of low salinity salt marshes may affect *F. jekinsi* recruitment. If that is the case, urban salt marshes may provide a more consistent, albeit with greater salinity swings, low salinity salt marsh habitat. Research into how valuable urban salt marshes are to this vulnerable species could be important for future management and protection of this species.

This study can inform future land development and planning near these tidal creeks. The differences observed in this study make it apparent that salt marshes need to be protected within the tidal creek systems of the Gulf of Mexico. Previous studies have shown the benefit of salt marshes compared to hardened shorelines for providing fish habitat (Partyka and Peterson 2008, Seitz et al. 2006, Bilkovic and Rogerro 2008), but not how salt marshes within an urban landscape may be impacted. This study has demonstrated that urban marshes are indeed altered in the fish habitat they provide. Thus, while it is important to keep salt marshes even in urban landscapes, it is even more important to maintain vegetated buffers and non-developed areas around salt marshes. Having vegetated buffers and stormwater retention may help alleviate some of the spikes in freshwater and help remove contaminants from runoff. Riparian buffers have been shown to decrease nutrient loads (Mayer et al. 2007) and remove metals and pesticides (Palone and Todd 1998, Castelle et al. 1994) flowing to streams. Another alternative could be creating areas for runoff to filter into the ground, such as rain gardens and ditches, rather than running directly into the tidal creeks. These would provide the same benefit as riparian buffers, while also allowing for waterfront access. Salt marshes themselves can act as a buffer by acting as a sink for excess nutrients (Mitch et al. 2009). While salt marshes are clearly altered with nearby development, benefits exist for having these habitats within the larger estuarine system even in an altered state. Salt marshes provide a number of ecological services including protecting coastlines from wave erosion, being a sink for certain nutrients/pollutants, and providing critical habitat for a variety of organisms, such as fish (Kennish 2001). While studies have found that development can impact salt marshes, they also have shown that certain ecosystem services may still be provided by urban marshes, which is why they are promoted as an alternative to hardened shorelines (Currin et al. 2010). By removing salt marshes from the estuarine system those ecosystem services are no longer available. Several studies have shown altered fish assemblages at altered shorelines (i.e. bulkheads and riprap, Bilkovic and Roggero 2008, Bradley 2011, Partyka and Peterson 2008), which may have consequences for the commercial and recreational fisheries. By maintaining saltmarshes within tidal creeks these important ecosystems are still able to provide a number of important ecosystem services, although perhaps in a diminished way.

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Appendix I. Habitat Data

Table 1. Mean percent plant cover for each plant species along each marsh transect. See Fig. 2.1 for creek abbreviations.

Site	*J. roemarianus*	*C. jamaicense*	*D. spicata*	*S.patens*	*S. lancifolia*	*S. sempervirens*	*L. chinensis*	*S. europaea*
GB1	60	0.5	0.5	6	0	0.1	0	0
GB2	35.5	4	0.8	0	0	0.2	0	0
GB3	38	0.1	36.5	0	0	0	0	0
GB4	42.8	0	0	0	0	0.5	0	0
EB1	39.4	9.5	0	0	0.1	0	0	0
EB2	38.3	14.1	0	0	1.5	0	0	0
EB3	28.5	4.6	0	0	0	0	0	0
WB1	24.9	0	0	0	0	0	0	0
WB2	31	0.5	0	0	0	0	0	0
WB3	29	20	0	0	0	0	0	0
WB4	54.5	0	0	0	0	0	0	0
SQB1	39.4	0.5	7.5	0	0	0	0	0
SQB2	40.7	0	0	0	0	0	0	0
SQB3	37.1	0	0.1	3.5	0	0	1.5	0
SQB4	40	0.1	0	0.1	0	0	1	0
GC1	49.5	0	17.5	0	0	1.6	0	0
GC2	27.5	7.6	0	0	0	0	0	0
GC3	33.5	10.5	0.1	0	0	0.5	0	0
GC4	44.6	2	9.5	0	0	0.5	0	0
LB1	46.5	1.5	0	0	0	0	0	0
LB2	22	1	0	8	0	2	0.5	0
LB3	34	1	0.5	0	0	3	0	0
LB4	40.5	0	0	4	0	3	1	3

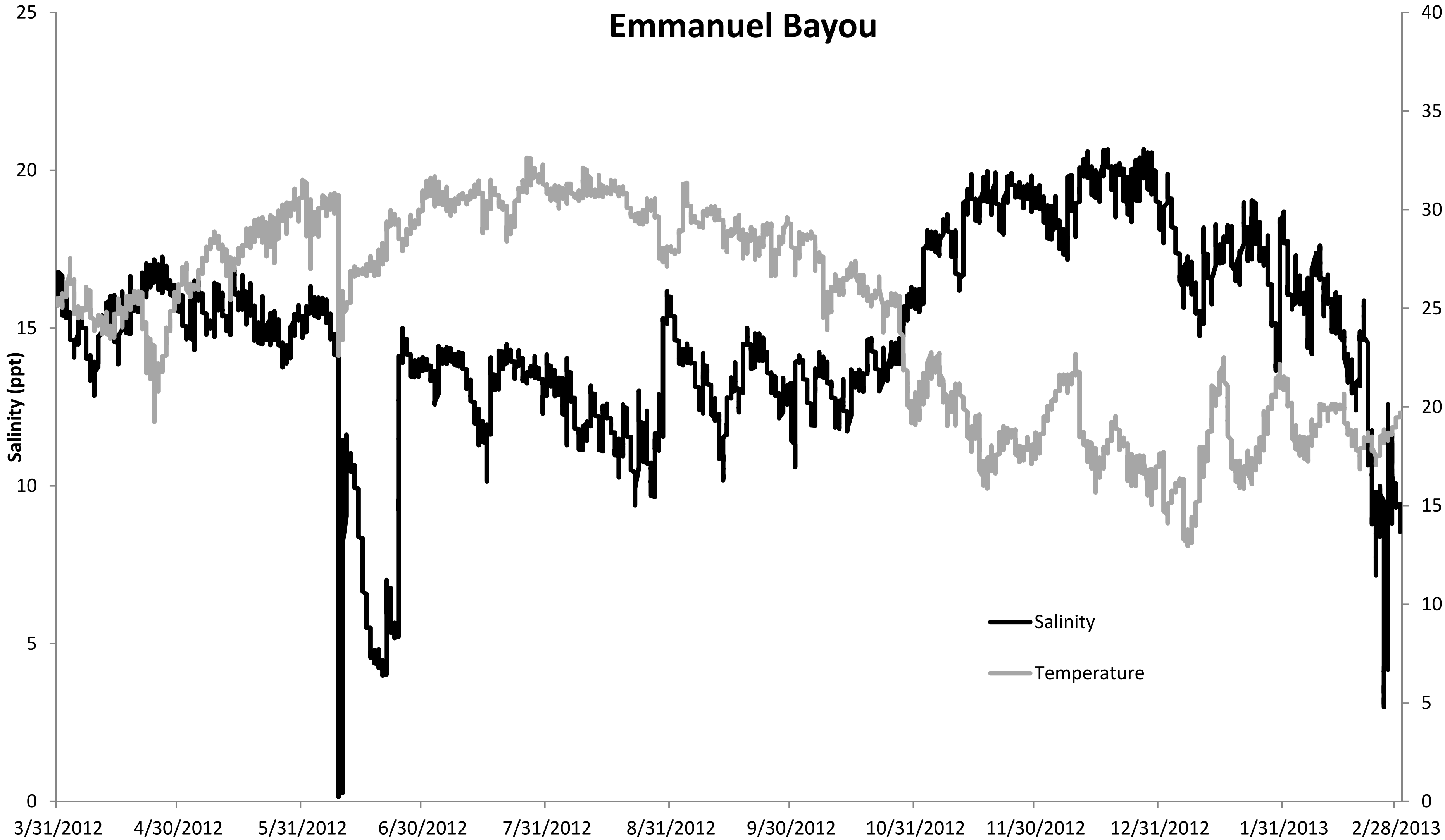
Table 2. Salinity and water temperature for each marsh at each seasonal fish sampling event measured with YSI

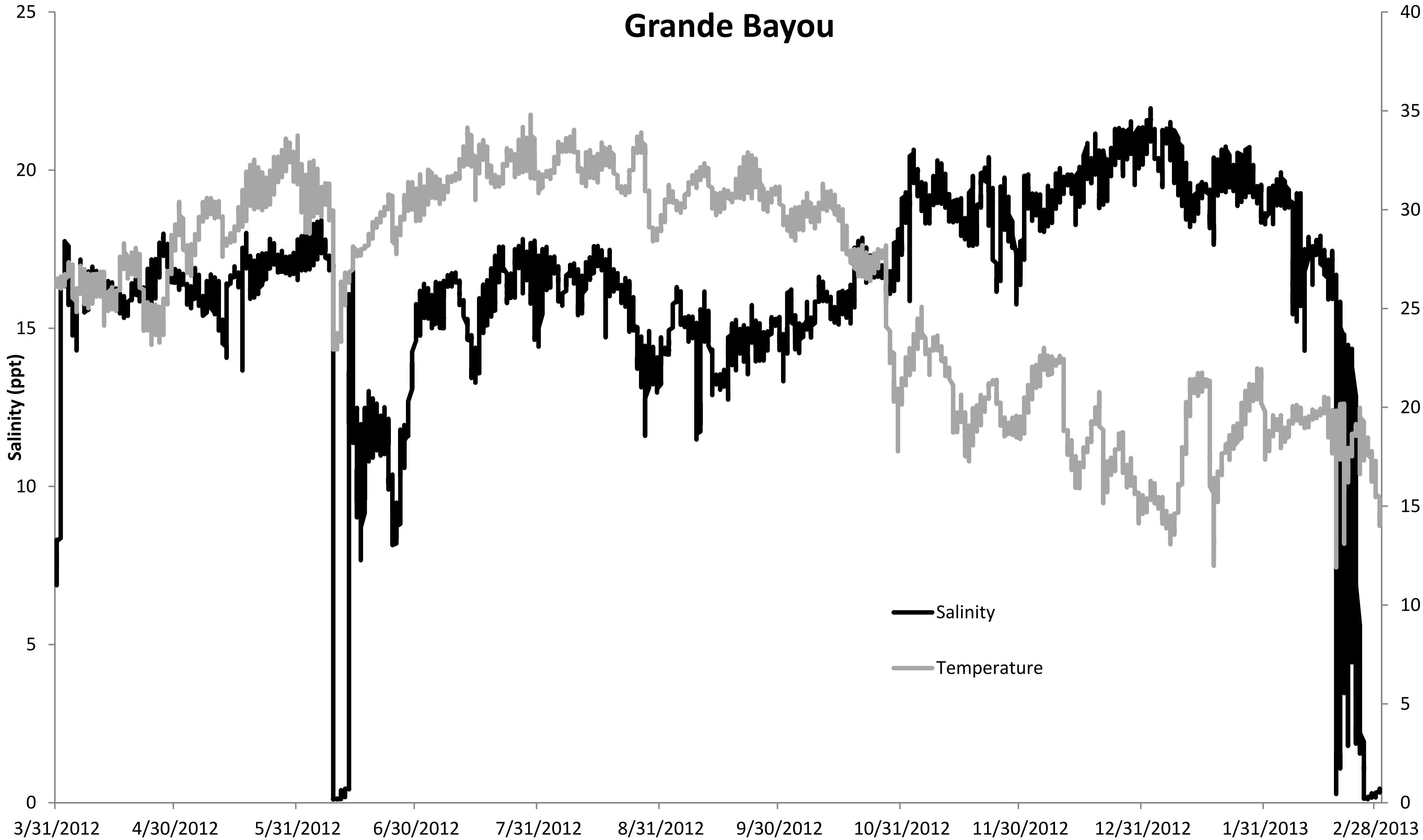
Season	Site	Salinity (ppt)	Temperature (˚C)
WINTER	EB1	18.2	13.4
SPRING	EB1	9.0	19.2
SUMMER	EB1	6.3	29.1
FALL	EB1	7.7	29.7
WINTER	EB2	18.7	13.8
SPRING	EB2	8.5	18.1
SUMMER	EB2	11.0	29.5
FALL	EB2	8.1	29.5
WINTER	EB3	20.0	13.9
SPRING	EB3	10.1	18.0
SUMMER	EB3	11.5	29.4
FALL	EB3	9.0	29.3
WINTER	GB1	17.7	13.7
SPRING	GB1	1.7	20.5
SUMMER	GB1	5.1	33.2
FALL	GB1	2.1	26.6
WINTER	GB2	20.1	13.7
SPRING	GB2	2.1	20.7
SUMMER	GB2	4.0	33.2
FALL	GB2	4.1	27.4
WINTER	GB3	22.3	13.1
SPRING	GB3	2.1	20.8
SUMMER	GB3	10.3	32.2
FALL	GB3	3.8	27.2
WINTER	GB4	23.2	13.0
SPRING	GB4	6.4	21.3
SUMMER	GB4	8.2	32.2
FALL	GB4	3.8	26.8
WINTER	GC1	18.7	15.3
SPRING	GC1	1.9	19.6
SUMMER	GC1	16.3	31.8
FALL	GC1	7.9	30.0
WINTER	GC2	20.0	15.6
SPRING	GC2	2.6	19.6
SUMMER	GC2	13.3	28.1
FALL	GC2	7.0	29.4
WINTER	GC3	19.9	14.7
SPRING	GC3	3.9	19.8

SUMMER	GC3	16.7	31.6
FALL	GC3	8.3	29.9
WINTER	GC4	20.0	14.7
SPRING	GC4	5.4	19.9
SUMMER	GC4	16.1	30.8
FALL	GC4	6.8	30.1
WINTER	LB1	23.4	17.8
SPRING	LB1	5.3	19.1
SUMMER	LB1	17.9	31.6
FALL	LB1	9.7	29.0
WINTER	LB2	23.7	15.5
SPRING	LB2	9.1	19.7
SUMMER	LB2	18.0	31.3
FALL	LB2	8.8	28.7
WINTER	LB3	23.3	16.4
SPRING	LB3	10.7	19.6
SUMMER	LB3	18.1	31.4
FALL	LB3	8.6	30.0
WINTER	LB4	23.3	15.8
SPRING	LB4	11.2	19.8
SUMMER	LB4	18.3	31.2
FALL	LB4	8.8	29.4
WINTER	SQB1	22.9	14.0
SPRING	SQB1	13.5	19.2
SUMMER	SQB1	16.1	29.4
FALL	SQB1	13.5	29.7
WINTER	SQB2	22.4	14.3
SPRING	SQB2	13.9	19.1
SUMMER	SQB2	16.1	29.3
FALL	SQB2	13.7	28.5
WINTER	SQB3	23.4	12.8
SPRING	SQB3	14.5	18.9
SUMMER	SQB3	16.2	29.4
FALL	SQB3	13.4	28.2
WINTER	SQB4	23.3	13.1
SPRING	SQB4	14.6	18.8
SUMMER	SQB4	16.2	29.3
FALL	SQB4	13.3	28.2
WINTER	WB1	20.9	14.6
SPRING	WB1	14.6	20.3
SUMMER	WB1	2.4	30.9
FALL	WB1	2.4	24.8
WINTER	WB2	22.7	14.1

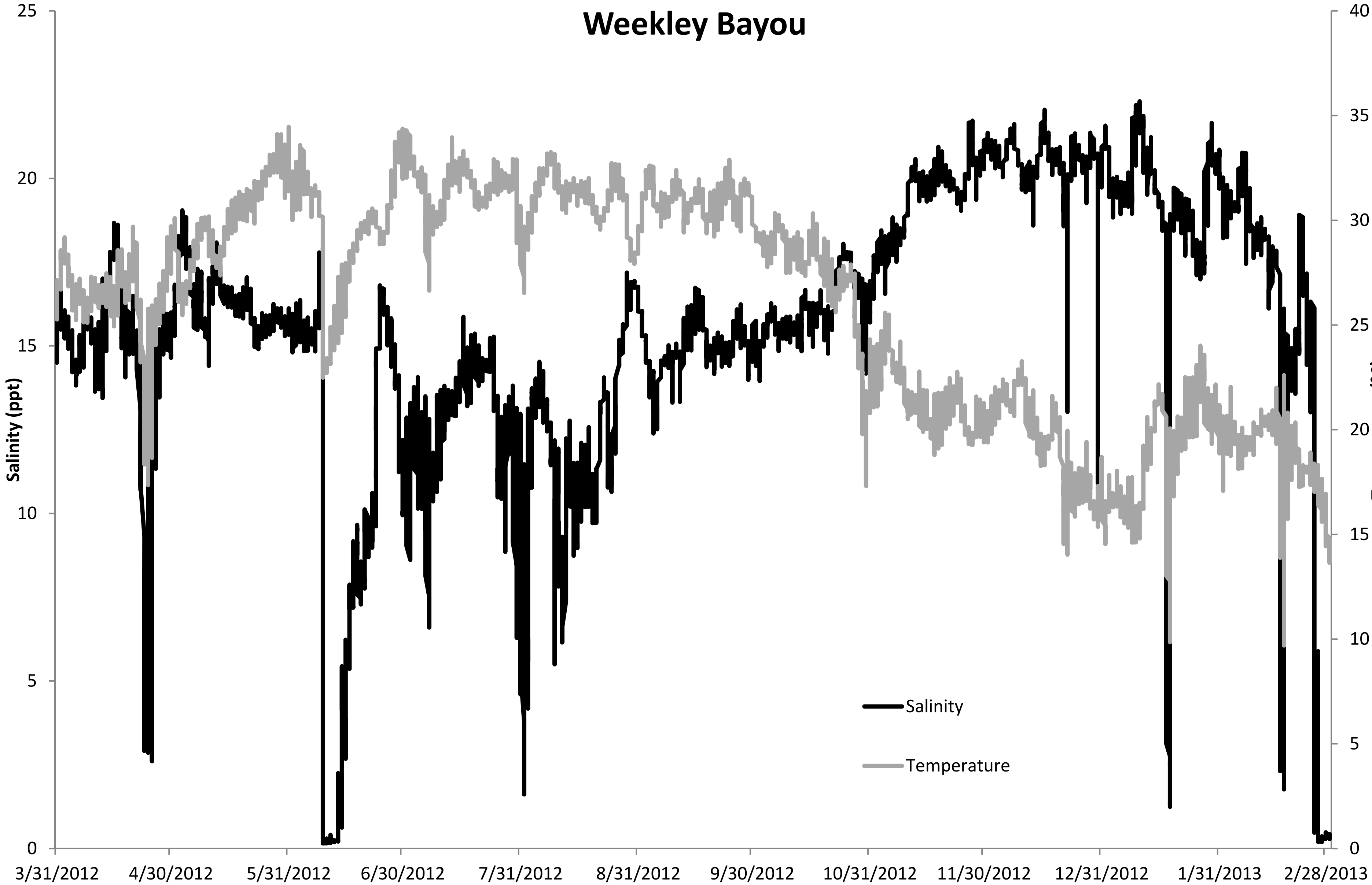
SPRING	WB2	15.4	20.5
SUMMER	WB2	3.8	30.1
FALL	WB2	3.1	26.0
WINTER	WB3	21.0	14.5
SPRING	WB3	15.0	20.9
SUMMER	WB3	5.8	32.0
FALL	WB3	13.2	29.4
WINTER	WB4	23.1	13.4
SPRING	WB4	16.5	20.6
SUMMER	WB4	8.5	32.4
FALL	WB4	13.7	29.1

Figure 1. Hourly averages of salinity and temperature data from conductivity loggers for each creek. Long Bayou is missing data from 9/8/12-1/4/13.

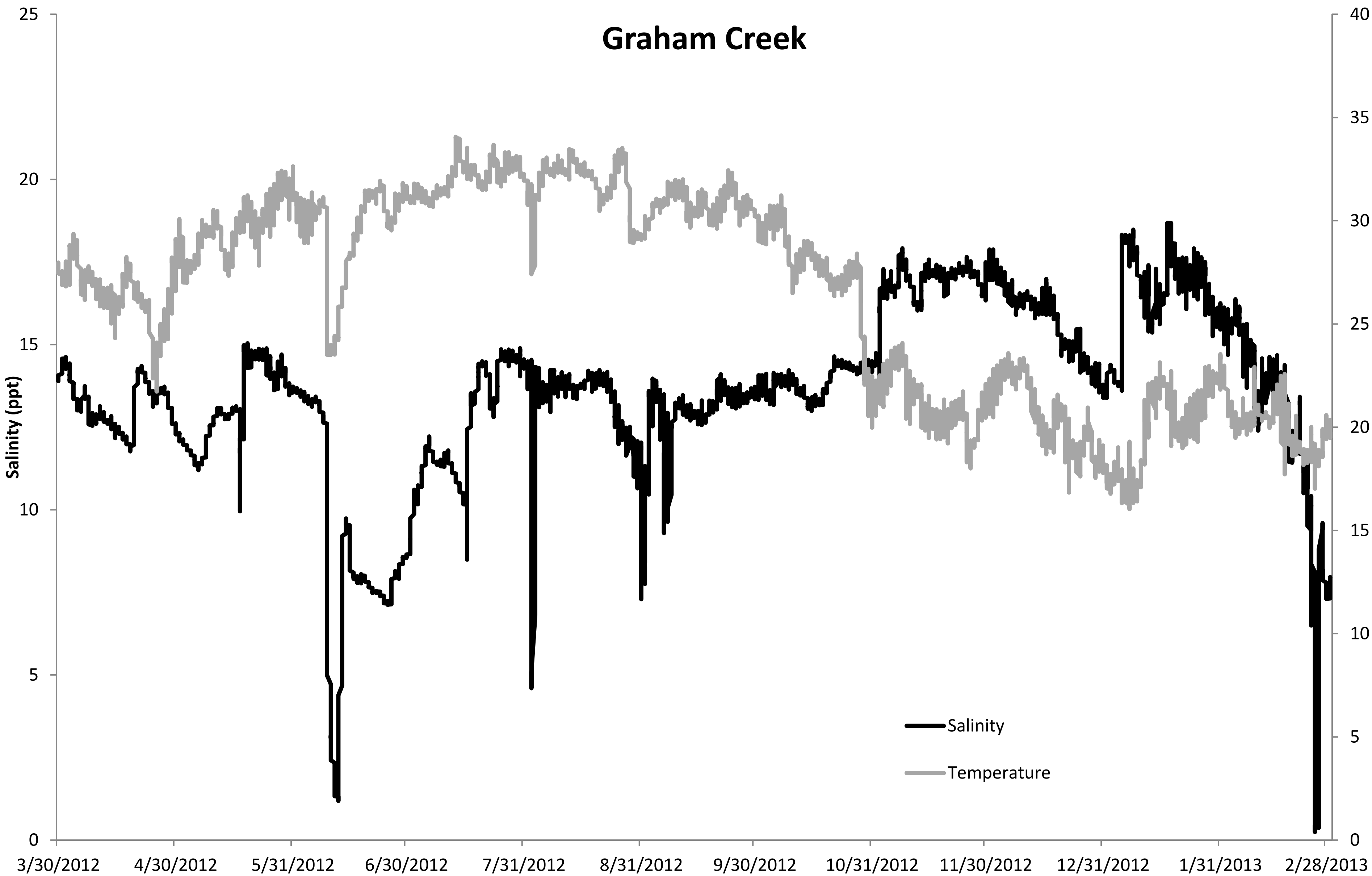


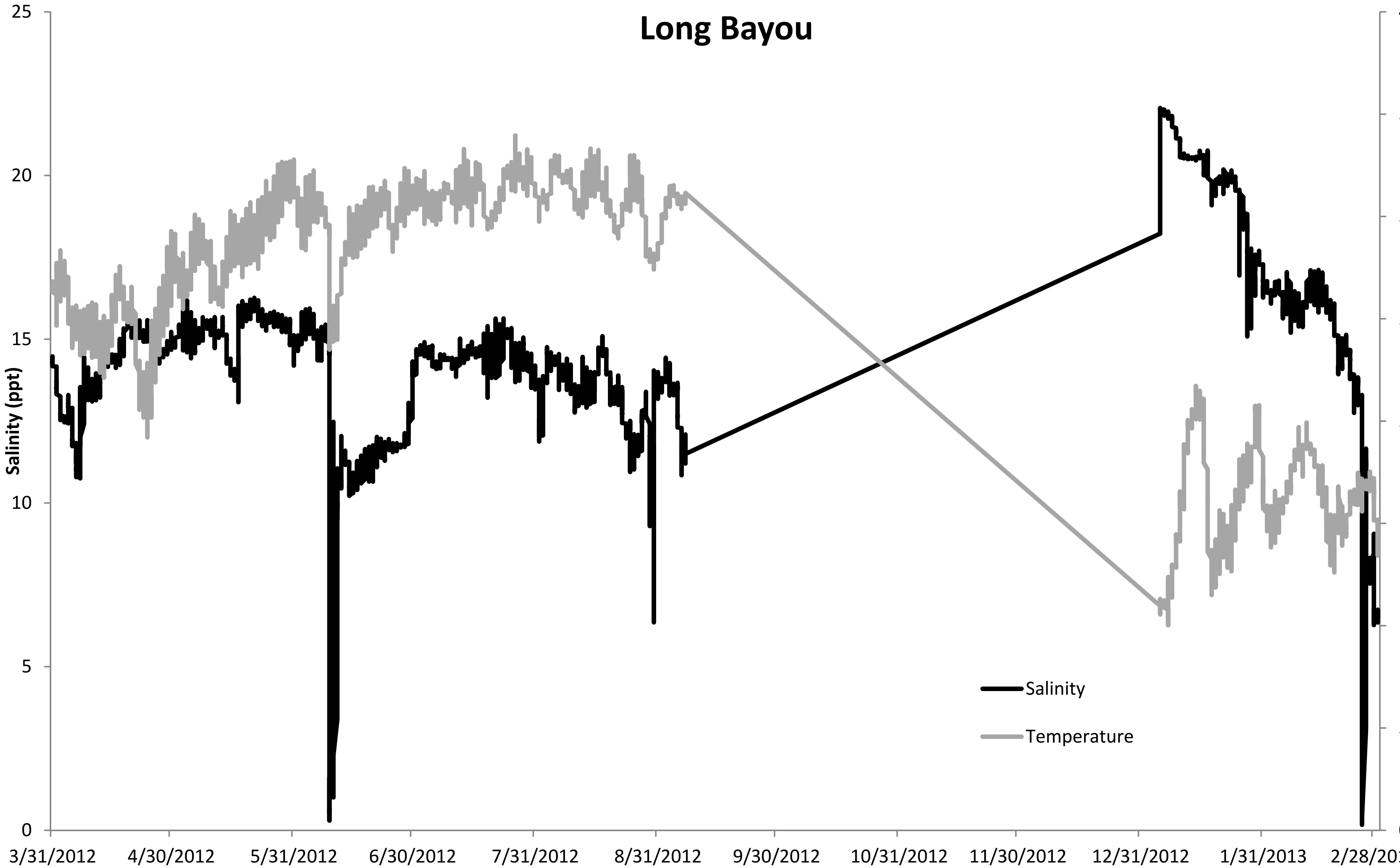


Grande Bayou
Salinity (ppt)
Temperature (°C)
25
20
15
10
5
0
40
35
30
25
20
15
10
5
0
3/31/2012
4/30/2012
5/31/2012
6/30/2012
7/31/2012
8/31/2012
9/30/2012
10/31/2012
11/30/2012
12/31/2012
1/31/2013
2/28/2013
Salinity
Temperature



Weekley Bayou
Salinity (ppt)
Temperature (°C)
25
20
15
10
5
0
40
35
30
25
20
15
10
5
0
3/31/2012
4/30/2012
5/31/2012
6/30/2012
7/31/2012
8/31/2012
9/30/2012
10/31/2012
11/30/2012
12/31/2012
1/31/2013
2/28/2013
Salinity
Temperature


Graham Creek
Salinity (ppt)
Temperature (°C)
25
20
15
10
5
0
40
35
30
25
20
15
10
5
0
3/30/2012
4/30/2012
5/31/2012
6/30/2012
7/31/2012
8/31/2012
9/30/2012
10/31/2012
11/30/2012
12/31/2012
1/31/2013
2/28/2013
Salinity
Temperature


Long Bayou
Salinity (ppt)
Temperature (°C)
0
5
10
15
20
25
0
5
10
15
20
25
30
35
40
3/31/2012
4/30/2012
5/31/2012
6/30/2012
7/31/2012
8/31/2012
9/30/2012
10/31/2012
11/30/2012
12/31/2012
1/31/2013
2/28/2013
Salinity
Temperature

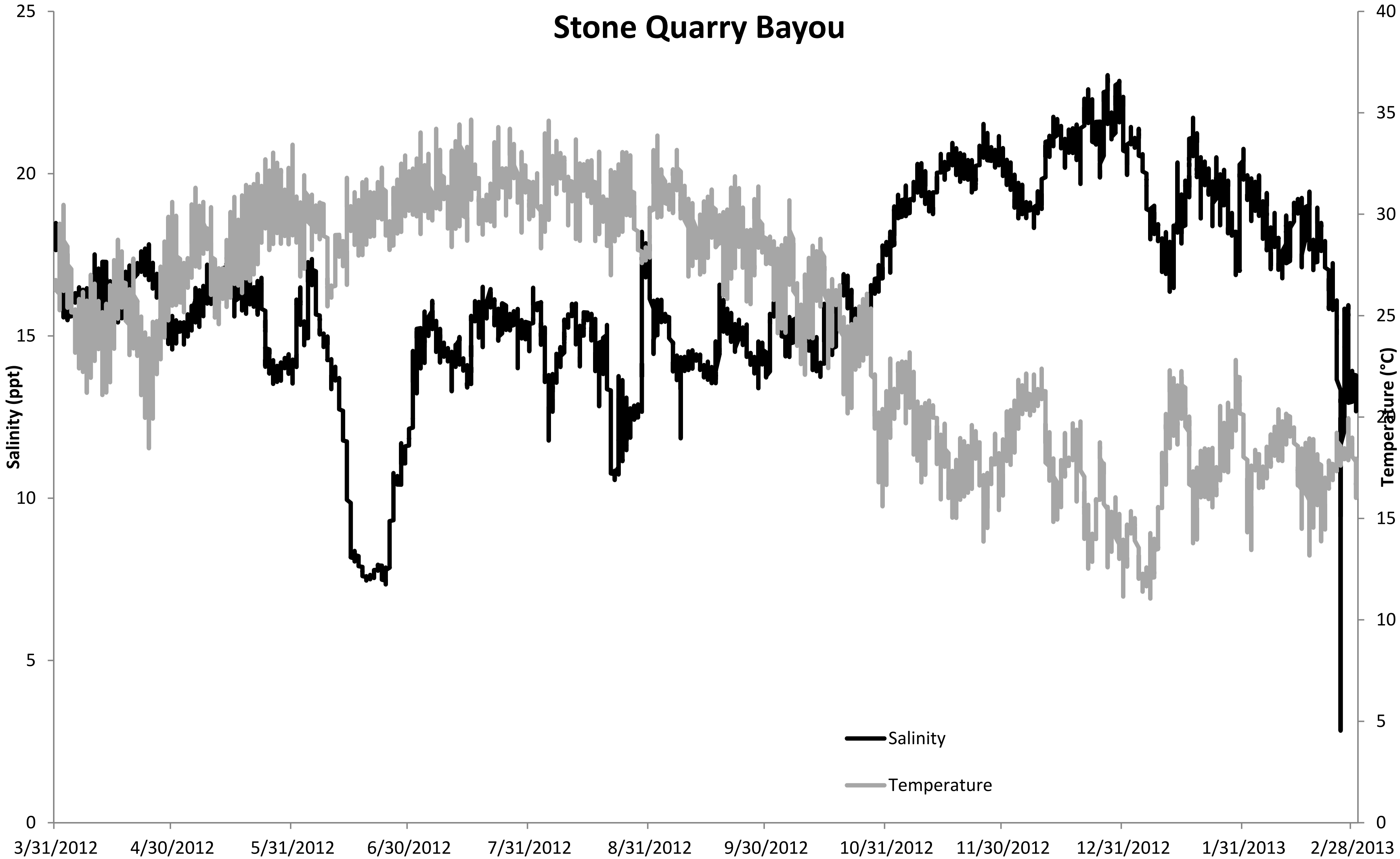

Stone Quarry Bayou
Salinity (ppt)
Temperature (°C)
0
5
10
15
20
25
0
5
10
15
20
25
30
35
40
3/31/2012
4/30/2012
5/31/2012
6/30/2012
7/31/2012
8/31/2012
9/30/2012
10/31/2012
11/30/2012
12/31/2012
1/31/2013
2/28/2013
Salinity
Temperature

Table 3. Soil concentrations of elements at each marsh.

Site	Ca (ppm)	Cd (ppm)	Cr (ppm)	Cu (ppm)	Fe (ppm)	K (ppm)	Mg (ppm)	Mn (ppm)	Mo (ppm)	Na (ppm)	Ni (ppm)	P (ppm)	Pb (ppm)	Zn (ppm)	%C	%N	%S
EB1	1198	0.07	0.17	0.89	71.5	472	1572	0.92	0.18	7527	0.30	31.0	3.80	3.40	13	0.68	0.76
EB2	2571	0.03	0.12	1.02	86.4	1064	3582	1.91	0.08	20243	0.57	48.6	3.81	5.99	19	1.00	1.71
EB3	2219	0.05	0.18	1.11	72.7	1058	3427	2.95	0.08	19691	0.37	54.0	4.64	12.81	18	0.90	1.45
GB1	1161	0.02	0.11	0.38	81.9	462	1582	2.25	<0.03	8654	0.13	37.0	4.14	5.77	7	0.37	0.47
GB2	2622	0.10	0.18	0.34	52.4	1639	5011	4.25	<0.04	31061	0.28	38.8	8.12	6.90	21	1.04	1.35
GB3	3448	0.11	0.05	0.25	47.9	1810	5489	10.28	0.07	36075	0.26	41.0	6.14	5.94	24	1.16	1.20
GB4	4434	0.08	0.15	0.10	48.2	1145	3546	5.44	<0.04	19030	0.22	50.1	19.79	7.13	16	0.81	1.12
GC1	2417	<0.02	0.07	0.33	87.7	1064	3417	25.21	<0.05	19059	0.59	35.2	3.46	6.48	18	1.20	0.45
GC2	4169	0.03	0.17	0.40	69.9	1033	3114	5.51	<0.05	18067	0.38	102.9	3.68	8.08	16	1.13	0.76
GC3	996	0.05	0.03	0.24	56.5	401	1333	12.77	<0.03	5945	0.28	29.0	1.64	2.91	7	0.42	0.29
GC4	1276	<0.01	0.03	0.25	57.0	379	1156	19.94	<0.03	6499	0.33	23.4	1.56	3.60	6	0.42	0.19
LB1	1979	0.02	0.09	0.39	68.9	1243	3121	9.09	<0.04	18018	0.38	106.5	3.08	5.19	13	0.88	0.53
LB2	900	<0.01	0.06	0.33	53.4	424	1179	2.43	<0.03	5550	0.18	30.4	1.87	3.09	5	0.32	0.17
LB3	1648	0.02	0.08	0.34	99.6	767	2205	10.33	<0.03	12523	0.22	45.7	2.78	3.13	8	0.47	0.53
LB4	1530	<0.01	0.06	0.40	96.2	1076	2874	18.72	<0.04	18112	0.43	43.7	2.89	5.06	12	0.68	0.57
SQB1	2999	0.08	0.07	0.95	77.6	637	1787	2.55	<0.04	8731	0.30	34.7	3.31	4.35	9	0.55	0.79
SQB2	4114	0.07	0.08	0.58	50.4	645	1753	3.46	<0.03	9585	0.32	37.9	1.84	4.67	6	0.39	0.50
SQB3	5893	0.02	0.09	0.48	60.9	1069	3080	6.18	0.07	17168	0.43	37.2	1.70	7.72	13	0.76	1.08
SQB4	6159	0.03	0.09	0.13	18.2	881	2309	3.57	0.05	14639	0.17	23.3	0.66	3.40	9	0.52	0.59
WB1	7475	0.07	0.15	0.24	17.3	749	2773	1.08	<0.04	12759	0.11	34.7	1.35	5.54	15	0.75	0.86
WB2	2507	0.09	0.11	0.67	43.2	874	3107	1.49	<0.04	15455	0.23	37.2	5.72	7.53	15	0.78	0.86
WB3	2972	0.05	0.13	0.69	60.5	1329	4560	2.26	<0.05	26944	0.31	58.2	6.51	9.71	23	1.16	1.71
WB4	2907	0.10	0.06	0.42	37.7	1166	3849	4.65	<0.04	22500	0.22	57.6	3.50	5.78	19	0.98	1.31

Table 4. Stem counts, stem density, and plant biomass for each marsh.

Site	Stem count	Stem density m^{-2}	Biomass m^{-2}
EB1	477	636.0	568.0
EB2	456	608.0	863.1
EB3	679	905.3	1358.9
GB1	530	706.7	862.1
GB2	615	820.0	862.3
GB3	361	481.3	534.3
GB4	759	1012.0	1127.6
GC1	843	1124.0	1653.5
GC2	439	585.3	710.5
GC3	1023	1364.0	1942.9
GC4	911	1214.7	1467.9
LB1	439	585.3	656.7
LB2	573	764.0	984.8
LB3	401	534.7	819.1
LB4	741	988.0	1041.3
SQB1	531	708.0	911.9
SQB2	721	961.3	1222.1
SQB3	752	1002.7	991.7
SQB4	686	914.7	1214.3
WB1	287	382.7	585.3
WB2	200	266.7	180.2
WB3	454	605.3	345.4
WB4	718	957.3	1328.4

Table 5. Percent shallow, moderate, and steep marsh edge slope for each marsh.

Site	Shallow	Moderate	Steep
LB1	5	25	70
LB2	0	15	85
LB3	45	35	20
LB4	27	11	62
GC1	1	5	94
GC2	1	10	89
GC3	0	10	90
GC4	5	15	80
SQB1	25	50	25
SQB2	13	54	33
SQB3	8	43	49
SQB4	35	45	20
WB1	13	12	75
WB2	15	5	80
WB3	70	30	0
WB4	35	35	30
EB1	90	9	1
EB2	15	5	80
EB3	50	10	40
GB1	15	75	10
GB2	50	30	20
GB3	2	18	80
GB4	65	15	20

Table 6. Mean percent plant cover of plant species along the marsh edge for each marsh.

Site	*J. roemarianus*	*C. jamaicense*	*D. spicata*	*S. alterniflora*	*S. lancifolia*	*S. sempervirens*	*I. sagittata*	*L. lineare*
GC1	79.7	0	0	0	0	0.3	0	0
GC2	43.3	0	0	0	0	0	0	0
GC3	51.3	3.3	23.3	0	0	0	0	0
GC4	38.3	0	21.7	0	0	0	0.3	0.3
LB1	63.3	0	0	0	0	0	0	0
LB2	50.0	0	0	0	0	0	0	0
LB3	18.3	0	0	10.0	0	0	0	0
LB4	63.3	0	0	0	0	0	0	0
GB1	66.7	0	0.7	0	0	0	0	0
GB2	61.7	0	3.7	0	0	0	0	0
GB3	56.7	0	0	0	0	0	0	0
GB4	101.7	0	0	0	0	0	0	0
WB1	25.0	1.7	0	0	0	0	0	0
WB2	47.7	1.7	0	0	0	0.3	0	0
WB3	66.7	0	0	0	0	0	0	0
WB4	103.3	0	0	0	0	0	0	0
EB1	36.7	0	0	0	3.3	0	0	0
EB2	75.0	0	0	0	0	0	0	0
EB3	70.0	0	0	0	0	0	0	0
SQB1	60.0	0	0	0	5	0	0	0
SQB2	55.0	0	0	0	0	0	0	0
SQB3	60.0	0	3.3	0	0	0	0	0
SQB4	51.7	0	0	0	0	0	0	0

Appendix II. Fish Data

Table 7. Fish LSI and associated measures averaged for each sampling event at each marsh. All lengths are total length unless indicated with an SL for standard length. See Fig. 2.13 for species abbreviations.

Date	Site	Species	Sex	Length (mm)	Weigh (g)t	N	liver weight (g)	LSI
12/12/2011	GB2	PLAT	M	58	3.0024	1	0.0212	1415.91
12/12/2011	GB4	PLAT	F	38	0.8259	6	0.0089	1351.27
12/12/2011	GB4	PLAT	M	37	0.8840	2	0.0055	1253.26
12/12/2011	GB1	FGRD	F	78	6.6123	4	0.0827	1131.38
12/12/2011	GB1	FGRD	M	77	6.7425	6	0.0519	842.36
12/12/2011	GB2	FGRD	F	82	7.6685	5	0.0571	742.43
12/12/2011	GB2	FGRD	I	45	1.0081	1	0.0059	585.26
12/12/2011	GB2	FGRD	M	77	6.6673	4	0.0395	6644.47
12/12/2011	GB4	FGRD	F	61	2.8438	1	0.0208	731.42
12/12/2011	GB4	FGRD	M	55	1.9377	1	0.0178	918.61
12/12/2011	WB2	FGRD	F	55	2.4289	5	0.0204	843.96
12/12/2011	WB2	FGRD	I	46	1.1974	2	0.0085	710.27
12/12/2011	WB2	FGRD	M	56	2.4510	3	0.0271	1081.83
12/12/2011	WB2	PLAT	F	39	1.0635	6	0.0089	1003.27
12/12/2011	WB2	PLAT	M	44	1.4771	3	0.0102	914.54
12/12/2011	WB3	FGRD	NA	52	1.8427	10	0.0161	883.80
12/12/2011	WB3	PLAT	NA	42	1.3097	10	0.0155	1035.38
12/12/2011	WB4	FGRD	F	57	2.3690	1	0.0279	1177.71
12/14/2011	EB1	PLAT	F	36	0.8013	7	0.0105	1529.86
12/14/2011	EB1	PLAT	M	45	1.5388	3	0.0203	1368.50
12/14/2011	EB2	FGRD	I	40	0.6370	1	0.0054	847.72
12/14/2011	EB2	PLAT	F	37	0.8080	7	0.0091	958.74

12/14/2011	EB2	PLAT	M	35	0.7386	3	0.0102	1331.11
3/11/2012	EB1	FGRD	F	73	7.2304	4	0.3153	960.30
3/11/2012	EB1	FGRD	M	75	7.5622	4	0.0319	354.96
3/11/2012	EB2	FGRD	F	84	11.2070	4	0.1982	1757.77
3/11/2012	EB2	FGRD	I	44	1.0059	2	0.0065	696.65
3/11/2012	EB2	FGRD	M	77	7.9618	5	0.0772	868.33
12/14/2012	EB3	FGRD	F	61	3.0501	3	0.0301	1042.61
12/14/2012	EB3	FGRD	I	45	1.1120	3	0.0106	856.38
12/14/2012	EB3	FGRD	M	72	5.4402	4	0.0402	716.67
12/14/2012	EB3	PLAT	F	42	1.1109	2	0.0142	1281.45
12/14/2012	SQB1	FGRD	F	78	7.0163	3	0.0625	935.57
12/14/2012	SQB1	FGRD	I	49	1.3886	3	0.0160	1114.84
12/14/2012	SQB1	FGRD	M	66	3.7509	4	0.0514	1396.53
12/14/2012	SQB1	PLAT	F	44	1.2672	6	0.0165	1329.20
12/14/2012	SQB1	PLAT	M	50	1.9803	4	0.0441	1047.51
12/14/2012	SQB2	FGRD	F	76	7.4400	4	0.0529	657.81
12/14/2012	SQB2	FGRD	I	52	1.6609	2	0.0238	1504.19
12/14/2012	SQB2	FGRD	M	81	8.4974	4	0.0894	733.18
12/14/2012	SQB2	PLAT	F	56	2.8041	5	0.0535	548.37
12/14/2012	SQB2	PLAT	M	57	3.1226	5	0.0453	621.87
12/14/2012	SQB3	FGRD	F	71	6.9547	4	0.0970	1246.65
12/14/2012	SQB3	FGRD	I	42	0.8025	2	0.0083	1038.50
12/14/2012	SQB3	FGRD	M	65	3.9910	4	0.0421	1127.80
12/14/2012	SQB4	FGRD	F	77	7.5159	3	0.0967	1079.96
12/14/2012	SQB4	FGRD	I	44	1.0588	4	0.0084	821.50
12/14/2012	SQB4	FGRD	M	76	6.0536	3	0.0476	805.39
12/14/2012	SQB4	PLAT	F	45	1.3986	6	0.0203	1088.61
12/14/2012	SQB4	PLAT	M	39	0.8507	4	0.0081	1319.00
12/15/2012	GC2	FGRD	M	55	2.1030	1	0.0239	1136.47
12/15/2012	GC2	PLAT	F	31	0.6018	3	0.0074	963.15

12/15/2012	GC3	FGRD	NA	71	5.1468	8	0.0497	935.71
12/15/2012	GC3	PLAT	NA	43	1.5138	10	0.0160	853.32
12/15/2012	GC4	PLAT	F	36	0.7474	5	0.0109	1032.01
12/15/2012	GC4	PLAT	M	34	0.5996	5	0.0089	1196.62
12/15/2012	LB1	FGRD	F	77	6.0428	1	0.0546	903.55
12/15/2012	LB1	FGRD	I	40	0.7768	1	0.0103	1325.95
12/15/2012	LB1	FGRD	M	110	18.7886	1	0.2407	1281.10
12/15/2012	LB1	PLAT	F	42	1.3238	6	0.0185	904.25
12/15/2012	LB1	PLAT	M	46	1.3414	3	0.0124	904.32
12/15/2012	LB2	FGRD	F	63	3.0043	3	0.0269	898.19
12/15/2012	LB2	FGRD	I	57	1.9902	1	0.0210	1055.17
12/15/2012	LB3	FGRD	F	86	10.1200	4	0.1115	1131.75
12/15/2012	LB3	FGRD	I	50	1.6473	2	0.0095	528.53
12/15/2012	LB3	FGRD	M	84	10.0073	4	0.0949	921.59
12/15/2012	LB4	FGRD	F	74	6.6626	5	0.0690	1040.35
12/15/2012	LB4	FGRD	M	77	7.8086	5	0.0850	1102.18
3/9/2012	GB1	FGRD	F	72	6.1951	5	0.0845	1392.92
3/9/2012	GB1	FGRD	M	75	6.9791	5	0.0355	592.49
3/9/2012	GB1	PLAT	F	42	1.1509	5	0.0054	1319.41
3/9/2012	GB2	FGRD	F	75	6.2645	5	0.0751	1264.68
3/9/2012	GB2	FGRD	I	50	1.3473	1	0.0036	267.20
3/9/2012	GB2	FGRD	M	83	8.5734	4	0.0408	458.74
3/9/2012	GB2	PLAT	F	37	0.9022	1	0.0134	563.60
3/9/2012	GB3	FGRD	F	85	9.9276	5	0.1341	1584.06
3/9/2012	GB3	FGRD	M	79	7.3909	5	0.0532	691.91
3/9/2012	GB3	PLAT	F	36	0.7149	1	0.0048	436.48
3/9/2012	GB4	FGRD	F	78	8.3075	5	0.0717	789.52
3/9/2012	GB4	FGRD	M	86	9.7472	5	0.0446	514.90
3/9/2012	WB1	FGRD	F	103	14.6406	4	0.1212	893.15
3/9/2012	WB1	FGRD	M	93	14.2022	4	0.0964	707.74

3/9/2012	WB2	FGRD	F	67	8.0627	5	0.1507	1904.58
3/9/2012	WB2	FGRD	I	45	1.2577	1	0.0097	771.25
3/9/2012	WB2	FGRD	M	77	7.7601	4	0.0509	713.50
3/9/2012	WB2	PLAT	F	47	1.6772	1	0.0114	699.88
3/9/2012	WB2	PLAT	M	43	1.4653	5	0.0093	1006.28
3/9/2012	WB3	FGRD	F	76	7.3758	4	0.1037	1302.74
3/9/2012	WB3	FGRD	I	44	0.9807	1	0.0043	438.46
3/9/2012	WB3	FGRD	M	70	5.5044	5	0.0285	513.65
3/9/2012	WB3	PLAT	F	45	1.5005	5	0.0195	973.70
3/9/2012	WB3	PLAT	M	58	2.7583	2	0.0171	534.06
3/9/2012	WB4	FGRD	F	80	9.6172	4	0.1285	1284.87
3/9/2012	WB4	FGRD	M	74	7.6056	5	0.0486	725.88
3/9/2012	WB4	PLAT	F	39	1.0012	6	0.0144	1114.66
3/9/2012	WB4	PLAT	M	46	1.6023	2	0.0095	1165.42
3/10/2012	GC1	FGRD	F	84	10.1698	4	0.1331	1148.02
3/10/2012	GC1	FGRD	M	71	5.8435	4	0.0269	466.56
3/10/2012	GC2	FGRD	F	82	9.0396	5	0.0981	977.86
3/10/2012	GC2	FGRD	M	85	9.0945	5	0.0459	513.62
3/10/2012	GC2	PLAT	F	51	2.1072	1	0.0293	959.09
3/10/2012	GC3	FGRD	F	81	8.8258	6	0.1062	1225.07
3/10/2012	GC3	FGRD	M	90	11.4100	4	0.0845	727.64
3/10/2012	GC3	PLAT	F	35	0.6623	1	0.0031	699.64
3/10/2012	GC4	FGRD	F	75	6.8625	6	0.0572	741.52
3/10/2012	GC4	FGRD	M	74	6.0327	4	0.0418	658.97
3/10/2012	GC4	PLAT	F	46	1.6932	5	0.0286	2138.65
3/10/2012	GC4	PLAT	M	49	1.7364	2	0.0154	1003.49
3/10/2012	LB1	FGRD	F	83	9.6422	5	0.0997	1093.71
3/10/2012	LB1	FGRD	F	80	8.6768	5	0.0556	523.80
3/10/2012	LB2	FGRD	F	90	11.6466	4	0.1297	1039.51
3/10/2012	LB2	FGRD	I	45	1.1415	1	0.0095	832.24

3/10/2012	LB2	FGRD	M	82	8.6066	5	0.0424	472.81
3/10/2012	LB3	FGRD	F	81	9.4513	4	0.1209	1041.58
3/10/2012	LB3	FGRD	M	79	8.4794	5	0.0374	380.74
3/10/2012	LB4	FGRD	F	91	11.8238	4	0.1702	1303.96
3/10/2012	LB4	FGRD	I	44	0.9762	1	0.0084	860.48
3/10/2012	LB4	FGRD	M	94	12.5839	4	0.0467	367.17
3/11/2012	EB1	FGRD	F	73	7.2304	4	0.0788	960.30
3/11/2012	EB1	FGRD	M	75	7.5622	4	0.0319	354.96
3/11/2012	EB1	PLAT	F	42	1.4703	4	0.0185	1130.25
3/11/2012	EB2	FGRD	F	84	11.2070	4	0.1982	1757.77
3/11/2012	EB2	FGRD	I	47	1.3747	1	0.0075	545.57
3/11/2012	EB2	FGRD	M	77	7.9618	5	0.0772	858.33
3/11/2012	EB3	FGRD	F	86	11.7406	5	0.1604	1212.43
3/11/2012	EB3	FGRD	I	41	0.7935	1	0.0035	441.08
3/11/2012	EB3	FGRD	M	81	9.7399	4	0.0836	909.18
3/11/2012	EB3	PLAT	F	42	1.2013	1	0.0093	1339.05
3/11/2012	SQB1	FGRD	F	84	11.3037	4	0.1933	1528.43
3/11/2012	SQB1	FGRD	I	42	0.8592	1	0.0135	1571.23
3/11/2012	SQB1	FGRD	M	81	9.1106	4	0.0578	600.25
3/11/2012	SQB1	PLAT	F	38	0.8553	1	0.0048	1345.36
3/11/2012	SQB2	FGRD	F	85	10.0572	4	0.1379	1261.95
3/11/2012	SQB2	FGRD	M	78	8.6268	5	0.0720	716.04
3/11/2012	SQB2	PLAT	M	70	5.0146	1	0.0240	802.50
3/11/2012	SQB3	FGRD	F	83	9.4946	4	0.0941	1121.07
3/11/2012	SQB3	FGRD	M	80	8.3231	5	0.0706	847.70
3/11/2012	SQB4	FGRD	F	81	9.2719	5	0.1031	1107.65
7/17/2012	GB1	FGRD	F	75	6.4423	3	0.0289	335.24
7/17/2012	GB1	FGRD	M	63	3.5393	3	0.0108	307.17
7/17/2012	GB2	FGRD	F	76	7.1843	6	0.0625	718.54
7/17/2012	GB2	FGRD	M	66	4.2047	3	0.0186	403.60

7/17/2012	GB3	FGRD	F	63	3.2558	1	0.0218	669.57
7/17/2012	GB4	FGRD	F	87	10.0643	4	0.0737	707.27
7/17/2012	GB4	FGRD	I	48	1.2932	1	0.0037	286.11
7/17/2012	GB4	FGRD	M	84	9.8540	5	0.0529	513.62
7/17/2012	WB1	FGRD	F	69	4.9609	5	0.0343	557.31
7/17/2012	WB1	FGRD	M	56	2.4962	2	0.0078	318.35
7/17/2012	WB1	PLAT	F	39	1.0537	6	0.0065	1107.46
7/17/2012	WB2	FGRD	F	68	5.1357	4	0.0457	642.43
7/17/2012	WB2	FGRD	I	43	0.8821	2	0.0024	275.72
7/17/2012	WB2	FGRD	M	69	5.2539	3	0.0349	576.82
7/17/2012	WB2	PLAT	F	41	1.2193	5	0.0105	1010.41
7/17/2012	WB3	FGRD	F	69	5.9640	4	0.0378	421.00
7/17/2012	WB3	PLAT	F	50	2.2129	3	0.0151	1251.83
7/17/2012	WB4	FGRD	F	77	8.0900	4	0.1233	1030.12
7/17/2012	WB4	FGRD	I	45	1.3023	2	0.0027	198.14
7/17/2012	WB4	FGRD	M	88	10.0938	3	0.0961	938.31
7/18/2012	LB1	FGRD	F	80	8.9419	4	0.1042	1027.87
7/18/2012	LB1	FGRD	I	45	1.0627	1	0.0148	1392.68
7/18/2012	LB1	FGRD	M	75	7.6385	5	0.0650	851.06
7/18/2012	LB1	PLAT	F	41	1.2491	2	0.0148	1182.12
7/18/2012	LB2	FGRD	F	84	9.3239	4	0.0781	797.49
7/18/2012	LB2	FGRD	I	44	1.0388	1	0.0078	750.87
7/18/2012	LB2	FGRD	M	82	8.6822	5	0.0842	789.87
7/18/2012	LB3	FGRD	F	86	11.1213	4	0.1348	1417.85
7/18/2012	LB3	FGRD	I	45	1.1852	2	0.0047	395.98
7/18/2012	LB3	FGRD	M	81	9.2039	4	0.0803	879.03
7/18/2012	LB4	FGRD	F	86	10.0875	4	0.1156	1155.90
7/18/2012	LB4	FGRD	I	43	1.0214	1	0.0077	753.87
7/18/2012	LB4	FGRD	M	78	7.8158	5	0.0762	1007.40
7/18/2012	LB4	PLAT	F	43	1.2085	1	0.0058	561.21

7/18/2012	LB4	PLAT	M	48	1.7582	1	0.0125	1248.73
7/19/2012	EB1	FGRD	F	55	2.1361	3	0.0132	637.44
7/19/2012	EB1	FGRD	I	41	0.9176	6	0.0057	636.57
7/19/2012	EB1	FGRD	M	55	2.3980	1	0.0174	725.60
7/19/2012	EB1	PLAT	F	40	0.9072	1	0.0069	1046.43
7/19/2012	EB2	FGRD	F	73	6.6604	4	0.0690	795.62
7/19/2012	EB2	FGRD	I	44	0.9551	2	0.0020	200.13
7/19/2012	EB2	FGRD	M	77	6.3803	5	0.0374	500.39
7/19/2012	EB2	PLAT	M	38 SL	1.3838	1	0.0037	267.38
7/19/2012	EB3	FGRD	F	83	9.7088	5	0.0795	753.54
7/19/2012	EB3	FGRD	I	47	1.2054	1	0.0048	398.21
7/19/2012	EB3	FGRD	M	86	9.4541	4	0.0864	823.09
7/19/2012	SQB1	FGRD	F	82	8.6686	4	0.0956	981.15
7/19/2012	SQB1	FGRD	I	52	1.6726	1	0.0110	657.66
7/19/2012	SQB1	FGRD	M	80	8.5604	4	0.0766	971.72
7/19/2012	SQB1	PLAT	F	45	1.6044	4	0.0086	614.22
7/19/2012	SQB2	FGRD	F	85	9.4067	4	0.1321	1359.58
7/19/2012	SQB2	FGRD	I	47	1.1825	1	0.0026	219.87
7/19/2012	SQB2	FGRD	M	83	9.3282	5	0.0925	885.67
7/19/2012	SQB3	FGRD	F	86	10.9933	4	0.1374	1188.94
7/19/2012	SQB3	FGRD	I	48	1.3232	2	0.0061	574.07
7/19/2012	SQB3	FGRD	M	82	8.8776	4	0.0859	757.28
7/19/2012	SQB3	PLAT	F	34	0.6998	1	0.0032	259.15
7/19/2012	SQB4	FGRD	F	83	9.3099	4	0.0697	737.04
7/19/2012	SQB4	FGRD	I	45	1.1740	2	0.0064	534.00
7/19/2012	SQB4	FGRD	M	71	5.4081	4	0.0469	861.77
7/29/2012	GC2	FGRD	F	67	4.7616	5	0.0531	951.59
7/29/2012	GC2	FGRD	M	98	4.4341	3	0.0335	735.10
7/29/2012	GC2	PLAT	M	44	1.2480	1	0.0031	1508.57
7/29/2012	GC3	FGRD	F	80	7.1631	3	0.0715	871.88

7/29/2012	GC3	FGRD	M	71	5.9994	7	0.0393	573.07
7/29/2012	GC3	PLAT	F	40	1.0659	3	0.0128	1428.99
7/29/2012	GC4	FGRD	F	82	8.6849	4	0.0955	972.93
7/29/2012	GC4	FGRD	I	57	2.3471	1	0.0251	1069.40
7/29/2012	GC4	FGRD	M	76	6.8573	5	0.0451	651.07
9/7/2012	GC3	PLAT	F	30 SL	0.6990	1	0.0089	1732.05
9/7/2012	GC3	PLAT	M	46	1.3968	1	0.0054	457.27
9/7/2012	GC4	FGRD	F	82	8.3033	8	0.0873	1046.03
9/7/2012	GC4	FGRD	M	78	7.3112	2	0.0747	1023.91
9/7/2012	GC4	PLAT	F	40	1.1832	6	0.0095	1723.25
9/7/2012	GC4	PLAT	M	51	1.9080	1	0.0134	1554.74
12/15/2011	GC4	FGRD	F	65	3.6972	1	0.0213	576.11
12/15/2011	GC4	FGRD	M	64	3.0305	1	0.0262	864.54
9/7/2012	LB1	FGRD	F	84	10.0361	4	0.1394	1197.35
9/7/2012	LB1	FGRD	M	84	10.2000	5	0.1532	1383.01
9/7/2012	LB1	PLAT	F	42	1.2695	6	0.0104	1019.31
9/7/2012	LB1	PLAT	M	49	1.8409	3	0.0167	1559.44
9/7/2012	LB2	FGRD	F	79	7.6817	5	0.0865	1168.50
9/7/2012	LB2	FGRD	M	81	9.1561	5	0.1038	1073.29
9/7/2012	LB2	PLAT	F	54	2.8835	2	0.0184	1148.15
9/7/2012	LB2	PLAT	M	57	3.1781	2	0.0258	1255.29
9/7/2012	LB3	FGRD	F	83	9.2957	4	0.1234	1137.07
9/7/2012	LB3	FGRD	I	41	0.8985	1	0.0032	356.15
9/7/2012	LB3	FGRD	M	80	8.9894	5	0.1226	1389.00
9/7/2012	LB3	PLAT	F	50	2.4700	3	0.0278	1819.21
9/7/2012	LB4	FGRD	F	82	9.6566	4	0.1296	1258.79
9/7/2012	LB4	FGRD	I	42	0.8233	1	0.0057	692.34
9/7/2012	LB4	FGRD	M	76	7.2609	5	0.0974	1208.64
9/7/2012	LB4	PLAT	F	44	1.2812	4	0.0137	1024.24
9/7/2012	LB4	PLAT	M	51	2.2871	3	0.0300	865.82

9/8/2012	EB1	FGRD	F	57	2.3566	4	0.0104	430.67
9/8/2012	EB1	FGRD	I	46	1.1428	2	0.0045	389.84
9/8/2012	EB1	FGRD	M	65	3.9609	4	0.0197	478.41
9/8/2012	EB1	PLAT	F	34 SL	1.0234	1	0.0062	579.17
9/8/2012	EB1	PLAT	M	39	0.9523	3	0.0079	949.84
9/8/2012	EB2	FGRD	F	56	2.4287	2	0.0159	653.66
9/8/2012	EB2	FGRD	I	44	1.0753	3	0.0123	1227.76
9/8/2012	EB2	PLAT	F	34	0.6678	3	0.0068	1142.93
9/8/2012	EB2	PLAT	M	45	1.4870	1	0.0170	969.57
9/8/2012	EB3	FGRD	F	81	9.3666	4	0.1231	956.64
9/8/2012	EB3	FGRD	I	45	0.9789	1	0.0054	551.64
9/8/2012	EB3	FGRD	M	83	9.7503	4	0.0889	848.97
9/8/2012	EB3	PLAT	F	54	2.7962	2	0.0265	878.29
9/8/2012	SQB1	FGRD	F	80	8.0409	4	0.0965	1121.20
9/8/2012	SQB1	FGRD	I	47	1.2042	1	0.0134	1112.77
9/8/2012	SQB1	FGRD	M	78	7.9018	5	0.0603	825.47
9/8/2012	SQB1	PLAT	F	46	1.9143	5	0.0224	1067.79
9/8/2012	SQB1	PLAT	M	48	1.7909	5	0.0221	1216.26
9/8/2012	SQB2	FGRD	F	83	9.3884	4	0.1113	1055.39
9/8/2012	SQB2	FGRD	I	48	1.3226	1	0.0098	740.96
9/8/2012	SQB2	FGRD	M	73	6.5208	5	0.0557	743.95
9/8/2012	SQB2	PLAT	F	45	1.5487	5	0.0155	936.39
9/8/2012	SQB2	PLAT	M	50	2.1875	5	0.0338	601.01
9/8/2012	SQB3	FGRD	F	79	8.0346	4	0.0651	721.88
9/8/2012	SQB3	FGRD	I	48	1.2427	1	0.0026	209.22
9/8/2012	SQB3	FGRD	M	73	6.5207	5	0.0406	568.85
9/8/2012	SQB3	PLAT	F	49	1.8371	8	0.0212	849.33
9/8/2012	SQB3	PLAT	M	50	1.7317	2	0.0188	442.99
9/8/2012	SQB4	FGRD	F	78	7.8176	5	0.0986	941.01
9/8/2012	SQB4	FGRD	M	76	7.3749	5	0.0459	594.43

9/8/2012	SQB4	PLAT	F	47	1.8510	5	0.0451	803.26
9/8/2012	SQB4	PLAT	M	54	2.5768	4	0.0395	658.25
9/9/2012	GB1	FGRD	F	101	15.8983	4	0.1663	966.76
9/9/2012	GB1	FGRD	M	91	11.7630	3	0.1209	991.42
9/9/2012	GB2	FGRD	F	76	6.6403	4	0.0509	742.52
9/9/2012	GB2	FGRD	M	73	5.5972	1	0.0402	718.22
9/9/2012	GB4	FGRD	F	100	13.6345	3	0.1356	953.48
9/9/2012	GB4	FGRD	M	98	14.6309	5	0.1029	687.80
9/9/2012	WB1	FGRD	F	71	5.5568	5	0.0391	597.12
9/9/2012	WB1	FGRD	M	64	3.6886	5	0.0164	441.67
9/9/2012	WB1	PLAT	F	45	1.7171	5	0.0154	1038.19
9/9/2012	WB1	PLAT	M	43	1.3794	4	0.0112	1227.27
9/9/2012	WB2	FGRD	F	70	6.2416	5	0.0312	447.51
9/9/2012	WB2	FGRD	M	70	6.0775	5	0.0432	574.30
9/9/2012	WB2	PLAT	F	47	1.7494	2	0.0109	1338.17
9/9/2012	WB2	PLAT	M	48	1.8499	6	0.0084	1395.11
9/9/2012	WB3	FGRD	F	80	7.9254	5	0.0968	1101.72
9/9/2012	WB3	FGRD	I	44	0.9939	1	0.0066	664.05
9/9/2012	WB3	FGRD	M	76	7.4782	4	0.0698	834.42
9/9/2012	WB3	PLAT	F	40	1.0889	4	0.0122	511.16
9/9/2012	WB3	PLAT	M	39	0.9023	2	0.0094	574.51
9/9/2012	WB4	FGRD	F	84	9.3966	4	0.1080	883.24
9/9/2012	WB4	FGRD	M	74	8.0308	6	0.0936	921.64

Table 8. Caloric density and associated fish measures averaged for each sampling event at each marsh. All lengths are total length unless indicated with an SL for standard length. See Fig. 2.13 for species abbreviations.

Date	Site	Species	Sex	Length (mm)	Wet weight (g)	N	Dry weight (g)	Calories dry wt.$^{-1}$ (cal g^{-1})	Calories wet wt.$^{-1}$ (cal g^{-1})
15-Dec-11	GC3	FGRD	NA	71	5.1468	8	1.2288	4119.73	977.51
15-Dec-11	GC3	PLAT	NA	43	1.6061	9	0.4258	4628.34	1183.40
12-Dec-11	GB1	FGRD	F	78	6.6123	4	1.6081	4274.98	1036.83
12-Dec-11	GB1	FGRD	M	77	6.7425	6	1.6733	4353.92	1074.62
12-Dec-11	GB2	FGRD	F	82	7.6685	5	1.8481	4393.94	1056.51
12-Dec-11	GB2	FGRD	I	45	1.0081	1	0.2457	4210.28	1026.15
12-Dec-11	GB2	FGRD	M	77	6.6673	4	1.6457	4328.53	1057.00
12-Dec-11	GB2	PLAT	M	58	3.0024	1	0.8586	4472.11	1278.89
12-Dec-11	GB4	FGRD	F	61	2.8438	1	0.6634	4037.70	941.91
12-Dec-11	GB4	FGRD	M	55	1.9377	1	0.4463	3940.49	907.59
12-Dec-11	GB4	PLAT	F	39	0.8691	7	0.2266	4755.65	1238.19
12-Dec-11	GB4	PLAT	M	37	0.8840	2	0.2218	4784.11	1139.67
12-Dec-11	WB1	PLAT	F	34	0.5063	1	0.1842	4837.53	1759.97
12-Dec-11	WB2	FGRD	F	55	2.4289	5	0.5396	4037.53	884.35
12-Dec-11	WB2	FGRD	I	44	1.1974	2	0.2517	4077.87	857.22
12-Dec-11	WB2	FGRD	M	56	2.4510	3	0.5463	4009.04	893.19
12-Dec-11	WB2	PLAT	F	39	1.0635	6	0.2590	4404.94	1056.53
12-Dec-11	WB2	PLAT	M	44	1.1684	4	0.2909	4409.64	1032.05
12-Dec-11	WB3	FGRD	NA	50	1.6935	9	0.4088	4292.03	4292.03
12-Dec-11	WB3	PLAT	NA	42	1.3097	10	0.3341	4328.58	1084.06
12-Dec-11	WB4	FGRD	F	57	2.3690	1	0.5310	4083.63	915.33
14-Dec-11	EB1	PLAT	F	36	0.8013	7	0.2056	4597.52	1158.02
14-Dec-11	EB1	PLAT	M	45	1.5388	3	0.4153	4621.36	1211.89
14-Dec-11	EB2	FGRD	I	40	0.6370	1	0.1382	4243.27	920.60
14-Dec-11	EB2	PLAT	F	37	0.8080	7	0.1931	4431.78	1052.47
14-Dec-11	EB2	PLAT	M	35	0.7386	3	0.1733	4441.81	1007.48

14-Dec-11	EB3	FGRD	F	61	3.0501	3	0.7103	4566.40	1069.24
14-Dec-11	EB3	FGRD	I	45	1.1120	3	0.2456	4306.60	953.58
14-Dec-11	EB3	FGRD	M	72	5.5652	4	1.2790	4230.30	975.27
14-Dec-11	EB3	PLAT	F	44	1.3164	3	0.3221	4497.55	1103.39
14-Dec-11	SQB1	FGRD	F	78	7.0163	3	1.6898	4131.61	968.64
14-Dec-11	SQB1	FGRD	I	49	1.3886	3	0.3339	4190.80	10009.44
14-Dec-11	SQB1	FGRD	M	66	3.7509	4	0.8803	4169.18	978.46
14-Dec-11	SQB1	PLAT	F	44	1.2672	6	0.3269	4677.99	1204.55
14-Dec-11	SQB1	PLAT	M	50	1.9802	4	0.5357	4500.58	1211.17
14-Dec-11	SQB2	FGRD	F	76	7.4400	4	1.7983	4210.03	1003.43
14-Dec-11	SQB2	FGRD	I	52	1.6609	2	0.3921	4246.85	1000.64
14-Dec-11	SQB2	FGRD	M	81	8.4974	4	2.1317	4089.14	1006.40
14-Dec-11	SQB2	PLAT	F	56	2.8049	5	0.7183	4376.14	1147.48
14-Dec-11	SQB2	PLAT	M	57	3.1226	5	0.8101	4394.39	1138.09
14-Dec-11	SQB3	FGRD	F	71	6.9547	4	1.6619	4322.75	1013.99
14-Dec-11	SQB3	FGRD	I	42	0.8025	2	0.1833	4419.89	1009.22
14-Dec-11	SQB3	FGRD	M	65	3.9910	4	0.9426	4242.17	1002.98
14-Dec-11	SQB4	FGRD	F	77	7.5159	3	1.8790	4113.05	989.73
14-Dec-11	SQB4	FGRD	I	44	1.0588	4	0.2527	4214.85	996.79
14-Dec-11	SQB4	FGRD	M	76	6.0536	3	1.4895	4199.01	1031.32
14-Dec-11	SQB4	PLAT	F	45	1.3986	6	0.3754	4486.70	1207.74
14-Dec-11	SQB4	PLAT	M	39	0.8482	4	0.2216	4457.21	1157.48
15-Dec-11	GC2	FGRD	I	35 SL	0.7978	1	0.1884	4193.08	990.19
15-Dec-11	GC2	FGRD	M	55	2.1030	1	0.4763	3952.68	895.23
15-Dec-11	GC2	PLAT	F	34	0.6018	3	0.1539	4727.26	1211.32
15-Dec-11	GC4	FGRD	F	65	3.6972	1	0.9113	4428.70	1091.60
15-Dec-11	GC4	FGRD	M	64	3.0305	1	0.7462	4197.37	1033.52
15-Dec-11	GC4	PLAT	F	36	0.7474	5	0.1993	4915.06	1301.70
15-Dec-11	GC4	PLAT	M	32	0.5348	3	0.1417	5037.76	1334.72
15-Dec-11	LB1	FGRD	F	77	6.0428	1	1.5089	4531.40	1131.50
15-Dec-11	LB1	FGRD	I	40	0.7768	1	0.1929	4729.75	1174.52

15-Dec-11	LB1	FGRD	M	110	18.7886	1	4.9568	4331.54	1142.74
15-Dec-11	LB1	PLAT	F	42	1.3238	6	0.3888	4930.58	1413.94
15-Dec-11	LB1	PLAT	M	41	1.1371	4	0.3214	4988.48	1393.42
15-Dec-11	LB2	FGRD	F	63	3.0043	3	0.7619	4362.51	1106.82
15-Dec-11	LB2	FGRD	I	57	1.9902	1	0.5207	4362.76	1141.44
15-Dec-11	LB3	FGRD	F	86	10.1200	4	2.5454	4431.03	1114.20
15-Dec-11	LB3	FGRD	I	50	1.6473	2	0.3854	4574.40	1075.23
15-Dec-11	LB3	FGRD	M	84	10.0073	4	2.5303	4273.36	1073.17
15-Dec-11	LB4	FGRD	F	74	6.6626	5	1.7030	4259.93	1055.49
15-Dec-11	LB4	FGRD	M	77	7.8086	5	1.9768	4149.97	1034.39
9-Mar-12	GB1	FGRD	F	72	6.1951	5	1.3593	4373.45	963.45
9-Mar-12	GB1	FGRD	M	75	6.9791	5	1.5440	4383.08	971.15
9-Mar-12	GB1	PLAT	F	42	1.2076	7	0.2554	4573.25	961.27
9-Mar-12	GB1	PLAT	M	34	0.6167	2	0.1129	4616.75	839.51
9-Mar-12	GB2	FGRD	F	75	6.2645	5	1.3545	4325.23	931.98
9-Mar-12	GB2	FGRD	I	50	1.3473	1	0.2944	4378.19	956.68
9-Mar-12	GB2	FGRD	M	83	8.5734	4	1.8257	4184.95	896.71
9-Mar-12	GB2	PLAT	F	37	0.9022	1	0.1981	5250.79	1152.94
9-Mar-12	GB3	FGRD	F	85	9.9276	5	2.2085	4435.08	992.84
9-Mar-12	GB3	FGRD	M	79	7.3909	5	1.6148	4366.24	957.87
9-Mar-12	GB3	PLAT	F	36	0.7149	1	0.1343	4395.72	825.77
9-Mar-12	GB4	FGRD	F	78	8.3075	5	1.6858	4249.40	918.26
9-Mar-12	GB4	FGRD	M	86	9.7472	5	2.1183	4024.48	877.45
9-Mar-12	WB1	FGRD	F	103	14.6506	4	3.2556	4354.69	976.33
9-Mar-12	WB1	FGRD	M	93	14.2022	4	3.2034	4347.11	980.52
9-Mar-12	WB2	FGRD	F	67	8.0626	5	1.8151	4302.88	943.79
9-Mar-12	WB2	FGRD	I	45	1.2577	1	0.2473	4376.01	860.45
9-Mar-12	WB2	FGRD	M	77	7.7601	4	1.7180	4163.30	931.80
9-Mar-12	WB2	PLAT	F	47	1.6772	1	0.3550	3933.38	832.55
9-Mar-12	WB2	PLAT	M	43	1.4653	5	0.3189	4532.23	968.98
9-Mar-12	WB3	FGRD	F	76	7.3758	4	1.6969	4270.42	989.33

9-Mar-12	WB3	FGRD	I	44	0.9807	1	0.2117	4149.14	895.66
9-Mar-12	WB3	FGRD	M	70	5.5044	5	1.2562	4143.19	955.33
9-Mar-12	WB3	PLAT	F	43	1.3458	6	0.3165	4449.56	1018.29
9-Mar-12	WB3	PLAT	M	52	2.1226	4	0.4956	4196.77	988.07
9-Mar-12	WB4	FGRD	F	80	9.6172	4	2.2204	4198.13	975.18
9-Mar-12	WB4	FGRD	M	71	6.6756	6	1.5353	4222.16	965.26
9-Mar-12	WB4	PLAT	F	39	1.0012	6	0.2307	4758.89	1077.91
9-Mar-12	WB4	PLAT	M	53	2.5796	4	0.6155	4225.85	1009.30
10-Mar-12	GC1	FGRD	F	84	10.0636	5	2.2761	4258.55	954.33
10-Mar-12	GC1	FGRD	M	77	7.9297	5	1.7941	4285.30	961.62
10-Mar-12	GC1	PLAT	M	40	1.0025	1	0.2123	4255.59	901.21
10-Mar-12	GC2	FGRD	F	82	9.0396	5	2.0728	4342.64	992.58
10-Mar-12	GC2	FGRD	M	85	9.0495	5	2.0502	4191.08	951.71
10-Mar-12	GC2	PLAT	F	51	2.1072	1	0.5041	4659.64	1114.71
10-Mar-12	GC3	FGRD	F	81	8.8258	6	2.0638	4390.99	1021.42
10-Mar-12	GC3	FGRD	M	90	11.4100	4	2.6190	4102.50	940.57
10-Mar-12	GC3	PLAT	F	35	0.6623	1	0.1495	4955.52	1118.60
10-Mar-12	GC3	PLAT	M	39	0.9316	3	0.2078	4393.53	1006.95
10-Mar-12	GC4	FGRD	F	75	6.8626	6	1.5434	4290.20	958.44
10-Mar-12	GC4	FGRD	M	74	6.0327	4	1.3274	4127.02	906.67
10-Mar-12	GC4	PLAT	F	46	1.6932	5	0.3986	4747.52	1120.97
10-Mar-12	GC4	PLAT	M	49	1.7364	2	0.3920	4757.72	1073.12
10-Mar-12	LB1	FGRD	F	83	9.6422	5	2.2464	4256.35	984.73
10-Mar-12	LB1	FGRD	M	80	8.6768	5	1.8221	4100.44	865.61
10-Mar-12	LB2	FGRD	F	90	11.6466	4	2.6809	4151.18	955.96
10-Mar-12	LB2	FGRD	I	45	1.1415	1	0.2168	4511.05	856.76
10-Mar-12	LB2	FGRD	M	82	8.6066	5	1.9546	4026.21	898.94
10-Mar-12	LB3	FGRD	F	79	8.5243	5	1.9741	4270.47	994.12
10-Mar-12	LB3	FGRD	M	79	8.4794	5	2.0089	4169.18	983.55
10-Mar-12	LB4	FGRD	F	91	11.8238	4	2.7395	4076.83	941.70
10-Mar-12	LB4	FGRD	I	44	0.9762	1	0.1963	4429.02	890.61

10-Mar-12	LB4	FGRD	M	87	10.5844	5	2.4407	4009.46	944.48
11-Mar-12	EB1	FGRD	F	73	7.2304	4	1.6356	4414.20	997.06
11-Mar-12	EB1	FGRD	I	38	0.7173	1	0.1459	4456.30	906.42
11-Mar-12	EB1	FGRD	M	69	6.2899	5	1.4523	4256.67	959.42
11-Mar-12	EB1	PLAT	F	42	1.3494	6	0.2921	4556.17	943.96
11-Mar-12	EB1	PLAT	M	45	1.5936	4	0.3388	4065.85	855.40
11-Mar-12	EB2	FGRD	F	84	11.2070	4	2.5469	4283.92	956.90
11-Mar-12	EB2	FGRD	I	47	1.3747	1	0.3049	4325.33	959.33
11-Mar-12	EB2	FGRD	M	77	7.9352	5	1.8006	4131.50	908.59
11-Mar-12	EB3	FGRD	F	86	11.7406	5	2.8341	4461.92	1043.48
11-Mar-12	EB3	FGRD	I	41	0.7935	1	0.1584	4467.97	891.90
11-Mar-12	EB3	FGRD	M	81	9.7399	4	2.2565	4294.90	986.10
11-Mar-12	EB3	PLAT	F	42	1.2013	1	0.2738	4682.16	1067.16
11-Mar-12	EB3	PLAT	M	43	1.3388	1	0.2930	4349.58	951.92
11-Mar-12	SQB1	FGRD	F	84	11.3037	4	2.6437	4347.22	1019.03
11-Mar-12	SQB1	FGRD	I	42	0.8592	1	0.1891	4883.65	1074.83
11-Mar-12	SQB1	FGRD	M	78	8.0589	5	1.9131	4211.66	988.16
11-Mar-12	SQB1	PLAT	F	38	0.8533	1	0.2066	4541.32	1099.54
11-Mar-12	SQB2	FGRD	F	77	8.3252	5	1.9867	4370.04	1026.59
11-Mar-12	SQB2	FGRD	M	78	8.6268	5	2.0793	4243.07	1007.25
11-Mar-12	SQB2	PLAT	M	64	4.0046	2	0.9038	4164.34	943.82
11-Mar-12	SQB3	FGRD	F	76	7.9631	5	1.8673	4388.35	1010.49
11-Mar-12	SQB3	FGRD	M	80	8.3231	5	1.9391	4154.24	966.35
11-Mar-12	SQB4	FGRD	F	81	9.2719	5	2.1113	4310.08	987.80
11-Mar-12	SQB4	FGRD	M	83	9.4132	5	2.1732	4190.89	965.97
17-Jul-12	GB1	FGRD	F	70	5.4034	4	1.3412	4264.74	1028.38
17-Jul-12	GB1	FGRD	M	63	3.5393	3	0.8375	4456.92	1053.79
17-Jul-12	GB2	FGRD	F	76	7.1843	6	1.6454	4283.99	966.18
17-Jul-12	GB2	FGRD	M	65	3.8477	4	0.9092	4311.26	1004.36
17-Jul-12	GB3	FGRD	F	63	3.2558	1	0.8000	4646.75	1141.78
17-Jul-12	GB4	FGRD	F	87	10.0643	4	2.3809	4292.47	1018.16

17-Jul-12	GB4	FGRD	I	48	1.2932	1	0.2844	4224.93	929.14
17-Jul-12	GB4	FGRD	M	84	9.8540	5	2.7440	4261.11	1165.45
17-Jul-12	WB1	FGRD	F	67	4.4509	6	1.0051	6587.13	1470.46
17-Jul-12	WB1	FGRD	I	43	1.0045	2	0.1869	4683.75	868.15
17-Jul-12	WB1	FGRD	M	56	2.4962	2	0.5163	4657.98	965.36
17-Jul-12	WB1	PLAT	F	39	1.0450	7	0.2129	5150.22	1033.92
17-Jul-12	WB1	PLAT	M	41	1.0099	3	0.2194	4765.92	1036.53
17-Jul-12	WB2	FGRD	F	68	5.1357	4	1.1901	4648.45	1056.77
17-Jul-12	WB2	FGRD	I	43	0.8821	2	0.1835	4797.03	978.29
17-Jul-12	WB2	FGRD	M	65	4.3829	4	1.0049	4688.75	1055.43
17-Jul-12	WB3	FGRD	F	69	5.9640	4	1.4165	4739.54	1071.02
17-Jul-12	WB3	FGRD	I	41	0.9080	2	0.1774	4531.15	884.74
17-Jul-12	WB3	FGRD	M	78	9.0262	4	2.0841	4503.09	1026.70
17-Jul-12	WB3	PLAT	F	44	1.6167	5	0.3496	4549.44	943.58
17-Jul-12	WB3	PLAT	M	40	0.9122	5	0.1996	4382.07	952.61
17-Jul-12	WB4	FGRD	F	77	8.0900	4	2.0061	4662.19	1102.83
17-Jul-12	WB4	FGRD	I	45	1.3023	2	0.2721	4486.46	929.37
17-Jul-12	WB4	FGRD	M	81	8.2518	4	1.9407	4451.75	1026.57
17-Jul-12	WB4	PLAT	M	45	1.2769	3	0.2789	4046.03	883.91
18-Jul-12	LB1	FGRD	F	80	8.9419	4	2.1482	4412.52	1037.87
18-Jul-12	LB1	FGRD	I	45	1.0627	1	0.2399	4388.80	990.75
18-Jul-12	LB1	FGRD	M	75	7.6385	5	1.8360	4340.47	1023.77
18-Jul-12	LB1	PLAT	F	41	1.2491	2	0.2676	4964.95	1065.46
18-Jul-12	LB2	FGRD	F	84	9.3239	4	2.2024	4256.82	979.89
18-Jul-12	LB2	FGRD	I	44	1.0388	1	0.2296	4140.02	915.04
18-Jul-12	LB2	FGRD	M	82	8.6822	5	2.1271	4263.84	1024.76
18-Jul-12	LB3	FGRD	F	86	11.1213	4	2.6515	4484.47	1082.66
18-Jul-12	LB3	FGRD	I	45	1.1852	2	0.2603	4267.16	938.40
18-Jul-12	LB3	FGRD	M	81	9.2017	4	2.1589	4467.37	1049.58
18-Jul-12	LB4	FGRD	F	86	10.0875	4	2.4239	4013.31	946.52
18-Jul-12	LB4	FGRD	I	43	1.0214	1	0.2094	4403.71	902.82

18-Jul-12	LB4	FGRD	M	78	7.8158	5	1.8796	4229.63	980.01
18-Jul-12	LB4	PLAT	F	44	1.4043	3	0.3022	4366.13	918.69
18-Jul-12	LB4	PLAT	M	52	1.8705	2	0.4228	4117.26	926.71
19-Jul-12	EB1	FGRD	F	55	2.1361	3	0.4775	4460.19	998.22
19-Jul-12	EB1	FGRD	I	41	0.9176	6	0.1965	4489.40	960.11
19-Jul-12	EB1	FGRD	M	55	2.3980	1	0.5441	4626.08	1049.64
19-Jul-12	EB1	PLAT	F	40	0.9072	1	0.2002	4632.60	1022.32
19-Jul-12	EB2	FGRD	F	73	6.6604	4	1.5072	4080.11	900.95
19-Jul-12	EB2	FGRD	I	44	0.9551	2	0.2070	4262.63	923.98
19-Jul-12	EB2	FGRD	M	77	7.6294	4	1.7791	4203.58	970.46
19-Jul-12	EB2	PLAT	M	38 SL	1.3838	1	0.3220	4147.39	965.07
19-Jul-12	EB3	FGRD	F	83	9.7088	5	2.3522	4354.88	1031.88
19-Jul-12	EB3	FGRD	I	47	1.2054	1	0.2685	4066.88	905.89
19-Jul-12	EB3	FGRD	M	86	9.4541	4	2.1742	4234.42	970.40
19-Jul-12	SQB1	FGRD	F	82	8.6686	4	1.9913	4292.78	960.56
19-Jul-12	SQB1	FGRD	I	48	1.3090	2	0.2777	4421.42	942.56
19-Jul-12	SQB1	FGRD	M	80	8.5604	4	2.0480	4590.13	1083.64
19-Jul-12	SQB1	PLAT	F	45	1.5761	8	0.3432	4569.72	961.95
19-Jul-12	SQB1	PLAT	M	46	1.2954	2	0.2847	4067.63	891.25
19-Jul-12	SQB2	FGRD	F	85	9.4067	4	2.2474	4431.70	1054.33
19-Jul-12	SQB2	FGRD	I	47	1.1825	1	0.2609	4342.28	958.06
19-Jul-12	SQB2	FGRD	M	83	9.3282	5	2.2659	4307.63	1009.40
19-Jul-12	SQB3	FGRD	F	86	10.9933	4	2.5906	4249.27	992.20
19-Jul-12	SQB3	FGRD	I	48	1.3232	2	0.2833	4321.43	928.71
19-Jul-12	SQB3	FGRD	M	82	8.8776	4	2.1033	4298.54	999.85
19-Jul-12	SQB3	PLAT	F	40	1.1111	4	0.2359	4681.20	965.90
19-Jul-12	SQB3	PLAT	M	48	1.6456	2	0.3539	4431.96	943.45
19-Jul-12	SQB4	FGRD	F	83	9.3099	4	2.1624	4145.78	951.31
19-Jul-12	SQB4	FGRD	I	45	1.1740	2	0.2434	4513.72	930.67
19-Jul-12	SQB4	FGRD	M	71	5.4081	4	1.2282	4184.34	921.30
29-Jul-12	GC2	FGRD	F	67	4.7616	5	1.1836	4443.90	1082.95

29-Jul-12	GC2	FGRD	M	68	4.4341	3	1.1041	4547.65	1132.45
29-Jul-12	GC2	PLAT	M	38	0.8485	3	0.2180	4565.97	1173.84
29-Jul-12	GC3	FGRD	F	80	7.1631	3	1.8244	4330.49	1101.09
29-Jul-12	GC3	FGRD	M	71	5.9994	7	1.5183	4571.52	1159.25
29-Jul-12	GC3	PLAT	F	40	1.0659	3	0.2662	5117.67	1206.53
29-Jul-12	GC3	PLAT	M	36	0.6107	5	0.1479	4430.04	1069.47
29-Jul-12	GC4	FGRD	F	82	8.6849	4	2.1834	4496.04	1115.85
29-Jul-12	GC4	FGRD	I	57	2.3471	1	0.5695	4774.19	1158.41
29-Jul-12	GC4	FGRD	M	76	6.8573	5	1.6677	4373.65	1065.16
29-Jul-12	GC4	PLAT	M	40	0.7033	2	0.1717	4292.02	1040.62
7-Sep-12	GC3	PLAT	F	30 SL	0.6990	1	0.1374	4870.92	957.46
7-Sep-12	GC3	PLAT	M	46	1.3968	1	0.3143	4390.77	987.99
7-Sep-12	GC4	FGRD	F	82	8.3033	8	1.9491	4399.88	1039.05
7-Sep-12	GC4	FGRD	M	78	7.3112	2	1.7794	4641.11	1130.28
7-Sep-12	GC4	PLAT	F	40	1.1832	6	0.2565	4742.27	1015.19
7-Sep-12	GC4	PLAT	M	39	1.1040	2	0.2528	4433.02	951.24
7-Sep-12	LB1	FGRD	F	77	6.5781	5	2.0611	4525.38	1242.78
7-Sep-12	LB1	FGRD	M	84	10.2000	5	2.4739	4466.65	1053.80
7-Sep-12	LB1	PLAT	F	42	1.2695	6	0.3127	4920.22	1274.38
7-Sep-12	LB1	PLAT	M	48	1.7785	4	0.4471	4797.73	1156.81
7-Sep-12	LB2	FGRD	F	79	7.6817	5	1.8325	4269.99	990.78
7-Sep-12	LB2	FGRD	M	81	9.1561	5	2.2167	4161.12	1004.10
7-Sep-12	LB2	PLAT	F	54	2.8835	2	0.6769	4826.61	1119.65
7-Sep-12	LB2	PLAT	M	57	3.1791	2	0.8389	5094.71	1318.42
7-Sep-12	LB3	FGRD	F	83	9.2457	4	2.2871	4338.92	1014.27
7-Sep-12	LB3	FGRD	I	41	0.8985	1	0.1825	4595.16	933.35
7-Sep-12	LB3	FGRD	M	80	8.9894	5	2.1846	4304.23	1012.31
7-Sep-12	LB3	PLAT	F	50	2.4700	3	0.5466	4419.60	991.49
7-Sep-12	LB3	PLAT	I	22 SL	0.2748	1	0.0489	4370.87	777.79
7-Sep-12	LB4	FGRD	F	82	9.6566	4	2.3761	4216.43	1017.71
7-Sep-12	LB4	FGRD	I	42	0.8233	1	0.1810	4430.83	974.10

7-Sep-12	LB4	FGRD	M	76	7.2609	5	1.7868	4192.22	1002.02
7-Sep-12	LB4	PLAT	F	44	1.2812	4	0.2898	4688.47	1062.48
7-Sep-12	LB4	PLAT	M	51	2.2871	3	0.6008	4664.59	1204.47
8-Sep-12	EB1	FGRD	F	57	2.3566	4	0.4915	4235.59	884.69
8-Sep-12	EB1	FGRD	I	46	1.1428	2	0.2347	4073.25	836.99
8-Sep-12	EB1	FGRD	M	65	3.9316	4	0.8458	4265.13	917.36
8-Sep-12	EB1	PLAT	F	44	1.1462	2	0.2278	4400.79	878.58
8-Sep-12	EB1	PLAT	M	39	0.9523	3	0.2011	4631.50	969.25
8-Sep-12	EB2	FGRD	F	56	2.4287	2	0.5217	4209.26	904.28
8-Sep-12	EB2	FGRD	I	44	1.0753	3	0.2233	4255.03	877.67
8-Sep-12	EB2	PLAT	F	33	0.5730	5	0.1047	4198.46	729.34
8-Sep-12	EB2	PLAT	I	20	0.1077	1	0.0164	4431.53	674.81
8-Sep-12	EB2	PLAT	M	45	1.4870	1	0.3329	4454.72	997.29
8-Sep-12	EB3	FGRD	F	81	9.3666	4	2.1396	4207.37	938.37
8-Sep-12	EB3	FGRD	I	45	0.9789	1	0.1945	4221.09	838.70
8-Sep-12	EB3	FGRD	M	77	8.1446	5	1.9410	4169.87	961.88
8-Sep-12	EB3	PLAT	F	54	2.7962	2	0.5997	4184.38	920.57
8-Sep-12	SQB1	FGRD	F	80	8.0409	4	1.8943	4172.82	964.41
8-Sep-12	SQB1	FGRD	I	47	1.2042	1	0.2704	4440.95	997.20
8-Sep-12	SQB1	FGRD	M	78	7.9018	5	1.9091	4133.89	992.49
8-Sep-12	SQB1	PLAT	F	46	1.9143	5	0.4387	4298.19	984.32
8-Sep-12	SQB1	PLAT	M	48	1.7909	5	0.4375	4408.13	1064.49
8-Sep-12	SQB2	FGRD	F	83	9.3884	4	2.2968	4274.16	1013.73
8-Sep-12	SQB2	FGRD	I	48	1.3226	1	0.2988	4288.03	968.75
8-Sep-12	SQB2	FGRD	M	73	8.5208	5	1.5338	4083.96	786.43
8-Sep-12	SQB2	PLAT	F	45	1.5487	5	0.3621	4358.98	1025.06
8-Sep-12	SQB2	PLAT	M	50	2.1875	5	0.5255	4384.24	1022.12
8-Sep-12	SQB3	FGRD	F	79	8.0346	4	1.8486	4189.88	940.57
8-Sep-12	SQB3	FGRD	I	48	1.2427	1	0.2681	4356.47	939.86
8-Sep-12	SQB3	FGRD	M	73	6.5207	5	1.5536	4220.32	967.32
8-Sep-12	SQB3	PLAT	F	49	1.8371	8	0.3958	4481.54	1011.03

8-Sep-12	SQB3	PLAT	M	50	1.7317	2	0.3810	4100.40	904.40
8-Sep-12	SQB4	FGRD	F	78	7.8176	5	1.7597	4155.60	933.96
8-Sep-12	SQB4	FGRD	M	76	7.3749	5	1.7495	4123.63	935.12
8-Sep-12	SQB4	PLAT	F	47	1.8510	5	0.4529	4687.94	1158.52
8-Sep-12	SQB4	PLAT	M	51	2.2406	5	0.5376	4407.14	1062.11
9-Sep-12	GB1	FGRD	F	101	15.8983	4	4.0515	4466.45	1145.23
9-Sep-12	GB1	FGRD	M	91	11.7630	3	2.9142	4376.74	1082.54
9-Sep-12	GB2	FGRD	F	76	6.6403	4	1.4425	4328.81	947.33
9-Sep-12	GB2	FGRD	M	73	5.5972	1	1.1931	4310.06	918.73
9-Sep-12	GB4	FGRD	F	100	13.6345	3	3.2866	4188.70	1006.03
9-Sep-12	GB4	FGRD	M	98	14.6309	5	3.4712	4208.20	996.65
10-Sep-12	WB1	FGRD	F	71	5.5568	5	1.3495	4578.41	1101.41
10-Sep-12	WB1	FGRD	M	64	3.6679	5	0.8850	4528.63	1090.39
10-Sep-12	WB1	PLAT	F	45	1.7171	5	0.4061	5143.76	1200.09
10-Sep-12	WB1	PLAT	I	22	0.1699	1	0.0289	5057.95	860.36
10-Sep-12	WB1	PLAT	M	43	1.3794	4	0.3339	5003.07	1158.84
10-Sep-12	WB2	FGRD	F	70	6.2416	5	1.4268	4315.25	962.03
10-Sep-12	WB2	FGRD	M	70	6.0775	5	1.3662	4451.58	981.40
10-Sep-12	WB2	PLAT	F	43	1.4025	4	0.2989	4847.22	1034.50
10-Sep-12	WB2	PLAT	M	48	1.8499	6	0.4257	4832.11	1069.29
10-Sep-12	WB3	FGRD	F	80	7.9254	5	1.7903	4308.66	960.09
10-Sep-12	WB3	FGRD	I	44	0.9939	1	0.2053	4296.91	887.57
10-Sep-12	WB3	FGRD	M	76	7.4782	4	1.6343	4273.62	960.22
10-Sep-12	WB3	PLAT	F	40	1.0889	4	0.2324	4767.75	1024.76
10-Sep-12	WB3	PLAT	M	39	0.9023	2	0.1913	4657.15	990.35
10-Sep-12	WB4	FGRD	F	75	5.9938	4	2.0862	4221.40	1522.64
10-Sep-12	WB4	FGRD	I	45	1.0709	1	0.2193	3827.15	783.73
10-Sep-12	WB4	FGRD	M	85	11.5098	5	2.0824	4362.89	802.93
10-Sep-12	WB4	PLAT	F	49	1.9637	1	0.4028	4327.71	887.71
10-Sep-12	WB4	PLAT	M	51	2.0795	1	0.4614	4611.14	1023.12

Table 9. Species measures averaged for each sampling event at each marsh. All lengths are total length unless indicated with an SL for standard length. See Fig. 2.13 for species abbreviations.

Date	Site	Species	Length (mm)	Weight (g)	Sex	N
12/14/2011	EB1	FCON	33	0.3965	F	1
12/14/2011	EB1	PLAT	36	0.7818	F	17
12/14/2011	EB1	PLAT	42	1.1311	M	5
12/14/2011	EB2	FGRD	40	0.6370	I	1
12/14/2011	EB2	PLAT	37	0.7971	F	13
12/14/2011	EB2	PLAT	37	0.8423	M	4
12/14/2011	EB3	AXEN	31	0.4575	I	1
12/14/2011	EB3	FCON	46	1.3868	M	1
12/14/2011	EB3	FGRD	61	2.9167	F	10
12/14/2011	EB3	FGRD	66	4.1612	M	8
12/14/2011	EB3	FGRD	47	1.1890	I	6
12/14/2011	EB3	PLAT	44	1.3164	F	3
12/12/2011	GB1	FGRD	71	5.1968	M	6
12/12/2011	GB1	FGRD	65	4.2385	F	4
12/12/2011	GB1	FCON	44	1.0151	F	1
12/12/2011	GB2	PLAT	58	3.0024	M	1
12/12/2011	GB2	FGRD	36	1.1805	M	10
12/12/2011	GB2	FGRD	45	1.2854	F	13
12/12/2011	GB2	FGRD	45	1.0081	I	1
12/12/2011	GB2	AXEN	38	0.8866	M	1
12/12/2011	GB2	AXEN	33	0.6511	F	1
12/12/2011	GB3	NO FISH				0
12/12/2011	GB4	FGRD	55	1.9377	M	1
12/12/2011	GB4	FGRD	61	2.8438	F	1
12/12/2011	GB4	PLAT	37	1.3499	M	2
12/12/2011	GB4	PLAT	35	1.1615	F	7

12/12/2011	GB4	FCON	42	0.9007	F	1
12/12/2011	GB4	AXEN	36	1.1463	M	17
12/12/2011	GB4	AXEN	35	0.9909	F	7
12/12/2011	GB4	AXEN	22	0.1489	I	1
12/15/2011	GC1	NO FISH				0
12/15/2011	GC2	CVAR	35	0.9068	F	28
12/15/2011	GC2	CVAR	45	2.0602	M	3
12/15/2011	GC2	CVAR	39	1.2160	I	13
12/15/2011	GC2	FCON	44	1.1017	F	1
12/15/2011	GC2	FCON	40	0.8398	M	1
12/15/2011	GC2	FGRD	55	2.1030	M	1
12/15/2011	GC2	FGRD	35	0.7978	I	1
12/15/2011	GC2	PLAT	31	0.6018	F	3
12/15/2011	GC3	FGRD	71	5.1468		8
12/15/2011	GC3	PLAT	43	1.3608		28
12/15/2011	GC3	CVAR	37	1.2092		85
12/15/2011	GC3	FCON	41	0.9191		7
12/15/2011	GC4	CVAR	37	1.1449	F	6
12/15/2011	GC4	FGRD	65	3.6972	F	1
12/15/2011	GC4	FGRD	64	3.0305	M	1
12/15/2011	GC4	FPUL	39	0.7446	M	1
12/15/2011	GC4	PLAT	35	0.7114	F	6
12/15/2011	GC4	PLAT	34	0.5996	M	5
12/15/2011	LB1	CVAR	34	0.7338	F	2
12/15/2011	LB1	CVAR	28	0.4215	I	2
12/15/2011	LB1	FCON	36	0.6057	F	1
12/15/2011	LB1	FCON	42	0.9860	M	2
12/15/2011	LB1	FGRD	77	6.0428	F	1
12/15/2011	LB1	FGRD	110	18.7886	M	1
12/15/2011	LB1	FGRD	40	0.7768	I	1

12/15/2011	LB1	FPUL	39	0.7951	F	1
12/15/2011	LB1	FPUL	36	0.4809	M	1
12/15/2011	LB1	PLAT	39	1.0365	F	15
12/15/2011	LB1	PLAT	37	0.8763	M	8
12/15/2011	LB2	FGRD	63	3.0043	F	3
12/15/2011	LB2	FGRD	57	1.9902	I	1
12/15/2011	LB3	FGRD	80	8.5213	M	11
12/15/2011	LB3	FGRD	85	10.5555	F	9
12/15/2011	LB3	FGRD	53	2.0008	I	3
12/15/2011	LB3	AXEN	29	0.4291	I	1
12/15/2011	LB3	CVAR	30	0.5282	I	1
12/15/2011	LB4	FGRD	72	5.9331	M	31
12/15/2011	LB4	FGRD	68	4.9330	F	55
12/15/2011	LB4	FGRD	51	1.7364	I	10
12/15/2011	LB4	CVAR	54	3.9204	M	2
12/15/2011	LB4	CVAR	48	2.6448	F	1
12/14/2011	SQB1	AXEN	31	0.4825	I	5
12/14/2011	SQB1	FCON	46	1.1877	F	9
12/14/2011	SQB1	FCON	44	0.9377	M	1
12/14/2011	SQB1	FGRD	63	3.5123	F	13
12/14/2011	SQB1	FGRD	49	1.4274	I	17
12/14/2011	SQB1	FGRD	61	3.0241	M	15
12/14/2011	SQB1	PLAT	45	1.3768	F	11
12/14/2011	SQB1	PLAT	50	1.9803	M	4
12/14/2011	SQB2	FCON	56	2.3820	F	2
12/14/2011	SQB2	FCON	42	0.8587	M	1
12/14/2011	SQB2	FGRD	73	6.5054	F	8
12/14/2011	SQB2	FGRD	52	1.6609	I	2
12/14/2011	SQB2	FGRD	82	9.2868	M	7
12/14/2011	SQB2	PLAT	55	2.7147	F	21
12/14/2011	SQB2	PLAT	55	2.7891	M	11

12/14/2011	SQB3	AXEN	30	0.5334	F	5
12/14/2011	SQB3	AXEN	34	0.7767	M	6
12/14/2011	SQB3	CVAR	45	1.9282	F	1
12/14/2011	SQB3	FCON	43	0.9013	F	2
12/14/2011	SQB3	FGRD	60	3.7787	F	28
12/14/2011	SQB3	FGRD	46	1.1899	I	8
12/14/2011	SQB3	FGRD	58	2.6460	M	17
12/14/2011	SQB3	FPUL	46	1.2087	M	2
12/14/2011	SQB4	FGRD	66	3.9083	F	21
12/14/2011	SQB4	FGRD	65	3.6027	M	26
12/14/2011	SQB4	FGRD	50	1.4646	I	21
12/14/2011	SQB4	AXEN	34	0.5961	I	3
12/14/2011	SQB4	CVAR	56	3.9688	M	2
12/14/2011	SQB4	FCON	43	0.9842	F	4
12/14/2011	SQB4	FCON	37 SL	1.0764	M	1
12/14/2011	SQB4	FSIM	48	0.9939	I	3
12/14/2011	SQB4	PLAT	45	1.3721	F	9
12/14/2011	SQB4	PLAT	39	0.8709	M	6
12/12/2011	WB1	PLAT	34	0.5063	F	1
12/12/2011	WB2	FGRD	37	1.1082	M	3
12/12/2011	WB2	FGRD	43	1.8210	F	5
12/12/2011	WB2	FGRD	41	1.5091	I	2
12/12/2011	WB2	PLAT	37	1.1124	M	4
12/12/2011	WB2	PLAT	38	1.2408	F	29
12/12/2011	WB2	FCON	38	0.6651	M	1
12/12/2011	WB2	FCON	50	1.6587	F	7
12/12/2011	WB2	AXEN	56	2.2719	M	3
12/12/2011	WB2	AXEN	58	2.0859	F	8
12/12/2011	WB2	CVAR	56	2.0362	F	5
12/12/2011	WB3	FGRD	43	1.3504		24
12/12/2011	WB3	PLAT	40	1.0758		53

12/12/2011	WB3	CVAR	40	1.4480		11
12/12/2011	WB3	AXEN	32	0.6587		30
12/12/2011	WB3	FCON	44	1.0948		42
12/12/2011	WB4	AXEN	29	0.4550	F	2
12/12/2011	WB4	AXEN	31	0.5732	M	2
12/12/2011	WB4	FCON	38	0.7440	F	5
12/12/2011	WB4	FCON	41	0.8628	M	2
12/12/2011	WB4	FGRD	57	2.3690	F	1
12/12/2011	WB4	GHOL	22	0.0966	I	1
3/9/2012	GB1	AXEN	31	0.5602	F	1
3/9/2012	GB1	CVAR	37	1.0535	F	1
3/9/2012	GB1	CVAR	30	0.5279	I	1
3/9/2012	GB1	FCON	44	1.2470	F	8
3/9/2012	GB1	FGRD	72	5.6770	F	8
3/9/2012	GB1	FGRD	72	5..8484	M	8
3/9/2012	GB1	PLAT	42	1.2076	F	7
3/9/2012	GB1	PLAT	34	0.6167	M	2
3/9/2012	GB2	FCON	50	1.9214	F	6
3/9/2012	GB2	FGRD	78	6.6301	F	15
3/9/2012	GB2	FGRD	50	1.3473	I	1
3/9/2012	GB2	FGRD	76	6.6176	M	12
3/9/2012	GB2	PLAT	37	0.9022	F	1
3/9/2012	GB3	CVAR	47	2.4690	F	2
3/9/2012	GB3	FCON	59	3.0863	F	3
3/9/2012	GB3	FGRD	84	9.3899	F	7
3/9/2012	GB3	FGRD	76	6.5037	M	9
3/9/2012	GB3	PLAT	36	0.7149	F	1
3/9/2012	GB4	AXEN	34	0.6429	F	3
3/9/2012	GB4	AXEN	34	0.8014	M	1
3/9/2012	GB4	FCON	58	2.4563	F	1
3/9/2012	GB4	FGRD	75	6.6138	F	41

3/9/2012	GB4	FGRD	78	7.2512	M	41
3/9/2012	WB1	CVAR	49	2.7054	M	3
3/9/2012	WB1	FGRD	103	14.6506	F	4
3/9/2012	WB1	FGRD	93	14.2022	M	4
3/9/2012	WB2	AXEN	29	0.4618	F	1
3/9/2012	WB2	AXEN	31	0.5498	M	2
3/9/2012	WB2	CVAR	40	1.5533	F	11
3/9/2012	WB2	CVAR	32	0.7119	I	3
3/9/2012	WB2	CVAR	40	1.4038	M	4
3/9/2012	WB2	FCON	46	1.4454	F	3
3/9/2012	WB2	FCON	46	1.6110	M	3
3/9/2012	WB2	FGRD	65	7.4022	F	7
3/9/2012	WB2	FGRD	45	1.2577	I	1
3/9/2012	WB2	FGRD	71	6.5114	M	5
3/9/2012	WB2	PLAT	47	1.6772	F	1
3/9/2012	WB2	PLAT	43	1.4653	M	5
3/9/2012	WB3	AXEN	31	0.5640	F	7
3/9/2012	WB3	AXEN	33	0.6478	M	10
3/9/2012	WB3	CVAR	45	2.4058	F	27
3/9/2012	WB3	CVAR	34	0.8665	I	5
3/9/2012	WB3	CVAR	45	2.3324	M	30
3/9/2012	WB3	FCON	48	1.6059	F	11
3/9/2012	WB3	FCON	46	1.1031	M	1
3/9/2012	WB3	FGRD	64	4.0688	F	19
3/9/2012	WB3	FGRD	44	0.9807	I	1
3/9/2012	WB3	FGRD	66	4.3399	M	25
3/9/2012	WB3	GHOL	40	0.6543	F	2
3/9/2012	WB3	PLAT	44	1.4143	F	17
3/9/2012	WB3	PLAT	53	2.1812	M	8
3/9/2012	WB4	AXEN	31	0.5693	F	17
3/9/2012	WB4	AXEN	21	0.1860	I	1

3/9/2012	WB4	AXEN	32	0.6578	M	13
3/9/2012	WB4	CVAR	51	3.3973	F	3
3/9/2012	WB4	FCON	45	1.3075	F	17
3/9/2012	WB4	FCON	43	1.1190	M	10
3/9/2012	WB4	FGRD	73	6.8138	F	14
3/9/2012	WB4	FGRD	69	5.4914	M	16
3/9/2012	WB4	PLAT	39	0.9810	F	7
3/9/2012	WB4	PLAT	53	2.5796	M	4
3/10/2012	GC1	FCON	50	1.8270	F	1
3/10/2012	GC1	FGRD	83	9.5194	F	8
3/10/2012	GC1	FGRD	79	8.6337	M	6
3/10/2012	GC1	LPAR	40	0.9039	F	1
3/10/2012	GC1	PLAT	40	1.0025	M	1
3/10/2012	GC2	AXEN	33	0.5849	F	1
3/10/2012	GC2	CVAR	47	2.4814	F	19
3/10/2012	GC2	CVAR	50	2.7617	M	2
3/10/2012	GC2	FCON	55	2.1464	M	1
3/10/2012	GC2	FGRD	82	8.5432	F	32
3/10/2012	GC2	FGRD	81	8.0208	M	23
3/10/2012	GC2	PLAT	51	2.1072	F	1
3/10/2012	GC3	CVAR	42	1.6188	F	1
3/10/2012	GC3	FCON	45	1.3125	F	1
3/10/2012	GC3	FCON	61	3.2785	M	1
3/10/2012	GC3	FGRD	81	9.0298	F	11
3/10/2012	GC3	FGRD	84	9.7316	M	9
3/10/2012	GC3	LPAR	40	0.7822	M	1
3/10/2012	GC3	PLAT	35	0.6623	F	1
3/10/2012	GC3	PLAT	39	0.9316	M	3
3/10/2012	GC4	AXEN	35	0.8216	M	1
3/10/2012	GC4	CVAR	48	2.7479	F	3
3/10/2012	GC4	CVAR	48	2.5178	M	2

3/10/2012	GC4	FCON	44	1.2334	F	2
3/10/2012	GC4	FGRD	74	6.5156	F	31
3/10/2012	GC4	FGRD	74	6.1924	M	23
3/10/2012	GC4	PLAT	46	1.6932	F	5
3/10/2012	GC4	PLAT	49	1.7364	M	2
3/10/2012	LB1	CVAR	42	1.6128	F	1
3/10/2012	LB1	CVAR	36	0.9337	M	1
3/10/2012	LB1	FGRD	84	9.4429	F	54
3/10/2012	LB1	FGRD	82	8.7087	M	52
3/10/2012	LB2	CVAR	44	1.8385	F	1
3/10/2012	LB2	CVAR	53	3.5619	M	2
3/10/2012	LB2	FGRD	81	8.8829	F	61
3/10/2012	LB2	FGRD	45	1.1415	I	1
3/10/2012	LB2	FGRD	81	8.4831	M	46
3/10/2012	LB3	CVAR	50	2.9926	F	3
3/10/2012	LB3	CVAR	54	3.8181	M	2
3/10/2012	LB3	FGRD	82	8.8018	F	54
3/10/2012	LB3	FGRD	83	8.9153	M	56
3/10/2012	LB4	CVAR	52	3.5234	F	6
3/10/2012	LB4	CVAR	54	3.9249	M	4
3/10/2012	LB4	FGRD	85	9.6360	F	63
3/10/2012	LB4	FGRD	44	0.9762	I	1
3/10/2012	LB4	FGRD	89	10.6472	M	83
3/10/2012	LB4	FSIM	95	10.3313	M	1
3/11/2012	EB1	CVAR	40	1.6292	F	5
3/11/2012	EB1	CVAR	39	1.5035	M	5
3/11/2012	EB1	FCON	46	1.4667	F	11
3/11/2012	EB1	FCON	44	1.2565	M	3
3/11/2012	EB1	FGRD	68	5.6761	F	14
3/11/2012	EB1	FGRD	44	1.1617	I	9
3/11/2012	EB1	FGRD	66	5.1577	M	16

3/11/2012	EB1	PLAT	42	1.2309	F	34
3/11/2012	EB1	PLAT	43	1.4098	M	10
3/11/2012	EB2	FCON	43	1.1736	F	9
3/11/2012	EB2	FGRD	78	8.4622	F	16
3/11/2012	EB2	FGRD	47	1.3747	I	1
3/11/2012	EB2	FGRD	74	6.5648	M	27
3/11/2012	EB3	AXEN	32	0.5629	F	5
3/11/2012	EB3	AXEN	34	0.8192	M	2
3/11/2012	EB3	FCON	47	1.4806	F	1
3/11/2012	EB3	FGRD	81	9.4681	F	19
3/11/2012	EB3	FGRD	44	1.0754	I	3
3/11/2012	EB3	FGRD	74	7.2140	M	19
3/11/2012	EB3	PLAT	42	1.2013	F	1
3/11/2012	EB3	PLAT	43	1.3388	M	1
3/11/2012	SQB1	AXEN	36	0.9236	F	10
3/11/2012	SQB1	CVAR	50	2.6988	F	1
3/11/2012	SQB1	CVAR	52	3.3395	M	1
3/11/2012	SQB1	FCON	49	1.8163	F	1
3/11/2012	SQB1	FCON	46	1.2004	M	1
3/11/2012	SQB1	FGRD	73	6.5092	F	48
3/11/2012	SQB1	FGRD	42	0.8592	I	1
3/11/2012	SQB1	FGRD	80	8.1999	M	41
3/11/2012	SQB1	PLAT	38	0.8553	F	1
3/11/2012	SQB2	AXEN	37	0.8987	F	5
3/11/2012	SQB2	AXEN	35	0.7803	M	2
3/11/2012	SQB2	CVAR	53	3.9201	M	3
3/11/2012	SQB2	FCON	52	2.0342	F	3
3/11/2012	SQB2	FGRD	75	7.1529	F	52
3/11/2012	SQB2	FGRD	77	7.0387	M	45
3/11/2012	SQB2	PLAT	64	4.0046	M	2
3/11/2012	SQB3	AXEN	37	0.9394	F	4

3/11/2012	SQB3	CVAR	52	3.5891	F	12
3/11/2012	SQB3	CVAR	50	3.0822	M	2
3/11/2012	SQB3	FGRD	72	6.0598	F	47
3/11/2012	SQB3	FGRD	76	6.8796	M	34
3/11/2012	SQB4	AXEN	35	0.8269	F	5
3/11/2012	SQB4	AXEN	37	0.9766	M	1
3/11/2012	SQB4	CVAR	58	4.7500	F	1
3/11/2012	SQB4	FCON	51	1.7832	-	1
3/11/2012	SQB4	FGRD	81	9.1892	F	44
3/11/2012	SQB4	FGRD	77	7.0646	M	18
7/17/2012	GB1	FCON	50	1.6515	F	1
7/17/2012	GB1	FCON	43	1.0460	M	1
7/17/2012	GB1	FGRD	70	5.4034	F	4
7/17/2012	GB1	FGRD	63	3.5393	M	3
7/17/2012	GB2	CVAR	47	2.1321	F	1
7/17/2012	GB2	FGRD	67	4.4909	F	26
7/17/2012	GB2	FGRD	59	2.8113	M	27
7/17/2012	GB3	FGRD	63	3.2558	F	1
7/17/2012	GB4	CVAR	47	2.4601	F	1
7/17/2012	GB4	FCON	58	2.5401	F	1
7/17/2012	GB4	FGRD	75	6.5446	F	17
7/17/2012	GB4	FGRD	51	1.7512	I	9
7/17/2012	GB4	FGRD	79	8.2784	M	79
7/17/2012	WB1	FCON	52	1.8565	F	7
7/17/2012	WB1	FCON	53	1.8216	M	2
7/17/2012	WB1	FGRD	58	2.7164	F	22
7/17/2012	WB1	FGRD	45	1.0792	I	8
7/17/2012	WB1	FGRD	56	2.4328	M	3
7/17/2012	WB1	GHOL	44	0.9692	F	2
7/17/2012	WB1	PLAT	40	1.0412	F	23
7/17/2012	WB1	PLAT	41	1.0099	M	3

7/17/2012	WB2	CVAR	42	1.6449	F	2
7/17/2012	WB2	CVAR	43	1.7358	M	5
7/17/2012	WB2	FCON	50	1.7995	F	17
7/17/2012	WB2	FCON	51	1.8949	M	5
7/17/2012	WB2	FGRD	65	4.4644	F	9
7/17/2012	WB2	FGRD	46	1.2899	I	6
7/17/2012	WB2	FGRD	73	6.0247	M	6
7/17/2012	WB2	LPAR	42	0.8973	F	1
7/17/2012	WB2	PLAT	41	1.1791	F	36
7/17/2012	WB2	PLAT	40	0.9231	M	5
7/17/2012	WB3	AXEN	35	0.7520	F	7
7/17/2012	WB3	AXEN	40	1.2908	M	1
7/17/2012	WB3	CVAR	41	1.5324	F	6
7/17/2012	WB3	CVAR	30	0.5213	I	1
7/17/2012	WB3	CVAR	42	1.7566	M	4
7/17/2012	WB3	FCON	51	1.9374	F	33
7/17/2012	WB3	FGRD	60	3.5815	F	21
7/17/2012	WB3	FGRD	44	1.1011	I	31
7/17/2012	WB3	FGRD	65	4.8605	M	18
7/17/2012	WB3	GHOL	43	0.8105	F	1
7/17/2012	WB3	PLAT	40	1.0531	F	55
7/17/2012	WB3	PLAT	41	0.9267	M	8
7/17/2012	WB4	AXEN	35	0.8487	F	1
7/17/2012	WB4	CVAR	42	1.8814	F	6
7/17/2012	WB4	CVAR	39	1.5777	M	5
7/17/2012	WB4	FCON	50	1.8892	F	13
7/17/2012	WB4	FCON	45	1.2701	M	5
7/17/2012	WB4	FGRD	63	4.0968	F	33
7/17/2012	WB4	FGRD	47	1.4866	I	19
7/17/2012	WB4	FGRD	71	6.5606	M	27
7/17/2012	WB4	GHOL	32	0.3474	F	1

7/17/2012	WB4	PLAT	45	1.2769	M	3
7/18/2012	LB1	FGRD	82	9.4508	F	20
7/18/2012	LB1	FGRD	45	1.1604	I	13
7/18/2012	LB1	FGRD	72	6.3435	M	19
7/18/2012	LB1	PLAT	41	1.2491	F	2
7/18/2012	LB2	AXEN	36	0.8302	F	1
7/18/2012	LB2	FCON	63	3.4776	F	1
7/18/2012	LB2	FGRD	70	5.9037	F	84
7/18/2012	LB2	FGRD	49	1.5204	I	14
7/18/2012	LB2	FGRD	72	5.9994	M	69
7/18/2012	LB3	FCON	60	3.2989	F	1
7/18/2012	LB3	FGRD	70	5.5485	F	57
7/18/2012	LB3	FGRD	46	1.2340	I	22
7/18/2012	LB3	FGRD	74	6.6688	M	38
7/18/2012	LB4	AXEN	40	1.2591	F	1
7/18/2012	LB4	AXEN	39	1.2363	M	2
7/18/2012	LB4	FGRD	73	5.8919	F	92
7/18/2012	LB4	FGRD	46	1.2110	I	3
7/18/2012	LB4	FGRD	77	7.0939	M	49
7/18/2012	LB4	PLAT	44	1.4043	F	3
7/18/2012	LB4	PLAT	52	1.8705	M	2
7/19/2012	EB1	AXEN	35	0.7270	F	3
7/19/2012	EB1	CVAR	46	2.0172	M	1
7/19/2012	EB1	FCON	48	1.3619	F	1
7/19/2012	EB1	FGRD	55	2.1361	F	3
7/19/2012	EB1	FGRD	41	1.0604	I	7
7/19/2012	EB1	FGRD	55	2.3980	M	1
7/19/2012	EB1	PLAT	40	0.9072	F	1
7/19/2012	EB2	FCON	55	2.3298	F	1
7/19/2012	EB2	FGRD	69	5.6957	F	10
7/19/2012	EB2	FGRD	44	1.0622	I	6

7/19/2012	EB2	FGRD	79	7.5297	M	7
7/19/2012	EB2	PLAT	38 SL	1.3838	M	1
7/19/2012	EB3	FCON	56	2.3655	F	1
7/19/2012	EB3	FGRD	78	7.7769	F	18
7/19/2012	EB3	FGRD	47	1.2901	I	9
7/19/2012	EB3	FGRD	89	10.1399	M	14
7/19/2012	SQB1	AXEN	35	0.7942	F	2
7/19/2012	SQB1	CVAR	59	5.0400	F	1
7/19/2012	SQB1	FGRD	70	5.3847	F	24
7/19/2012	SQB1	FGRD	49	1.4491	I	17
7/19/2012	SQB1	FGRD	79	7.8501	M	21
7/19/2012	SQB1	PLAT	44	1.6224	F	15
7/19/2012	SQB1	PLAT	46	1.2954	M	2
7/19/2012	SQB2	FCON	56	2.4103	F	1
7/19/2012	SQB2	FGRD	77	7.5750	F	36
7/19/2012	SQB2	FGRD	46	1.1819	I	5
7/19/2012	SQB2	FGRD	84	9.5612	M	15
7/19/2012	SQB2	GHOL	51	1.4505	F	1
7/19/2012	SQB3	AXEN	31	0.4454	F	2
7/19/2012	SQB3	FGRD	75	7.4283	F	19
7/19/2012	SQB3	FGRD	48	1.3615	I	10
7/19/2012	SQB3	FGRD	77	7.6657	M	13
7/19/2012	SQB3	GHOL	37	0.5238	F	1
7/19/2012	SQB3	PLAT	40	1.1111	F	4
7/19/2012	SQB3	PLAT	48	1.6456	M	2
7/19/2012	SQB4	FGRD	75	7.5071	F	36
7/19/2012	SQB4	FGRD	48	1.5062	I	3
7/19/2012	SQB4	FGRD	67	4.4679	M	7
7/29/2012	GC1	NO FISH				0
7/29/2012	GC2	CVAR	48	3.3891	F	1

7/29/2012	GC2	CVAR	44	2.1212	M	1
7/29/2012	GC2	FGRD	67	4.7616	F	5
7/29/2012	GC2	FGRD	68	4.4341	M	3
7/29/2012	GC2	PLAT	38	0.8485	M	3
7/29/2012	GC3	CVAR	52	3.4117	F	1
7/29/2012	GC3	CVAR	43	1.8186	M	1
7/29/2012	GC3	FCON	47	1.5468	F	1
7/29/2012	GC3	FGRD	73	5.4210	F	9
7/29/2012	GC3	FGRD	55	1.9425	I	1
7/29/2012	GC3	FGRD	71	5.8830	M	11
7/29/2012	GC3	PLAT	40	1.0659	F	3
7/29/2012	GC3	PLAT	36	0.6107	M	5
7/29/2012	GC4	FGRD	81	8.3037	F	11
7/29/2012	GC4	FGRD	57	2.2915	I	2
7/29/2012	GC4	FGRD	74	5.7898	M	15
7/29/2012	GC4	PLAT	40	0.7033	M	2
9/7/2012	GC1	GHOL	32	0.4769	F	21
9/7/2012	GC1	GHOL	22	0.1066	M	2
9/7/2012	GC2	GHOL	38	0.6108	F	13
9/7/2012	GC2	GHOL	19 SL	0.1497	I (M)	1
9/7/2012	GC2	GHOL	21 SL	0.2119	M	1
9/7/2012	GC3	AXEN	34	0.6870	F	1
9/7/2012	GC3	GHOL	38	0.6259	F	21
9/7/2012	GC3	GHOL	17 SL	0.0954	I	2
9/7/2012	GC3	GHOL	21 SL	0.1353	M	1
9/7/2012	GC3	PLAT	30 SL	0.6690	F	1
9/7/2012	GC3	PLAT	46	1.3968	M	1
9/7/2012	GC4	FGRD	84	8.9276	F	13
9/7/2012	GC4	FGRD	78	6.8679	M	4
9/7/2012	GC4	GHOL	43	0.9296	F	3
9/7/2012	GC4	PLAT	40	1.1832	F	6

9/7/2012	GC4	PLAT	39	1.1040	M	2
9/7/2012	LB1	AXEN	35	0.6907	F	2
9/7/2012	LB1	AXEN	33	0.6906	M	3
9/7/2012	LB1	FCON	46	1.3988	F	1
9/7/2012	LB1	FGRD	69	5.7363	F	30
9/7/2012	LB1	FGRD	83	10.1628	M	25
9/7/2012	LB1	GHOL	38	0.7658	F	1
9/7/2012	LB1	PLAT	42	1.2764	F	28
9/7/2012	LB1	PLAT	48	1.7785	M	4
9/7/2012	LB2	AXEN	28 SL	0.5918	M	1
9/7/2012	LB2	CVAR	51	3.0050	F	2
9/7/2012	LB2	CVAR	54	4.0935	M	1
9/7/2012	LB2	FCON	44	1.5220	M	1
9/7/2012	LB2	FGRD	76	6.9159	F	54
9/7/2012	LB2	FGRD	81	8.5629	M	66
9/7/2012	LB2	FSIM	95	10.0680	F	1
9/7/2012	LB2	PLAT	54	2.8835	F	2
9/7/2012	LB2	PLAT	57	3.1781	M	2
9/7/2012	LB3	AXEN	30	0.5045	F	1
9/7/2012	LB3	FGRD	68	5.3270	F	43
9/7/2012	LB3	FGRD	46	1.2310	I	3
9/7/2012	LB3	FGRD	74	7.0438	M	24
9/7/2012	LB3	GHOL	44	1.1562	F	1
9/7/2012	LB3	GHOL	23	0.1166	I	1
9/7/2012	LB3	PLAT	50	2.4700	F	3
9/7/2012	LB3	PLAT	22 SL	0.2748	I	1
9/7/2012	LB4	AXEN	38	1.0346	F	4
9/7/2012	LB4	AXEN	34	0.7007	M	3
9/7/2012	LB4	FGRD	73	6.0985	F	79
9/7/2012	LB4	FGRD	45	1.2210	I	4
9/7/2012	LB4	FGRD	76	6.9543	M	48

9/7/2012	LB4	PLAT	44	1.2812	F	4
9/7/2012	LB4	PLAT	51	2.2871	M	3
9/8/2012	EB1	FCON	52	1.6574	F	1
9/8/2012	EB1	FGRD	57	2.1906	F	5
9/8/2012	EB1	FGRD	46	1.1428	I	2
9/8/2012	EB1	FGRD	65	3.9609	M	4
9/8/2012	EB1	GHOL	37	0.5408	F	6
9/8/2012	EB1	PLAT	44	1.1462	F	2
9/8/2012	EB1	PLAT	39	0.9253	M	3
9/8/2012	EB2	FGRD	56	2.4287	F	2
9/8/2012	EB2	FGRD	44	1.0753	I	3
9/8/2012	EB2	GHOL	29	0.2493	F	19
9/8/2012	EB2	GHOL	21	0.0902	I	4
9/8/2012	EB2	GHOL	26	0.1439	M	3
9/8/2012	EB2	PLAT	34	0.5730	F	5
9/8/2012	EB2	PLAT	20	0.1077	I	1
9/8/2012	EB2	PLAT	45	1.4870	M	1
9/8/2012	EB3	FGRD	68	5.3772	F	45
9/8/2012	EB3	FGRD	48	1.2555	I	7
9/8/2012	EB3	FGRD	77	7.6718	M	28
9/8/2012	EB3	GHOL	31	0.3227	F	2
9/8/2012	EB3	GHOL	27	0.1887	M	1
9/8/2012	EB3	PLAT	54	2.7962	F	2
9/8/2012	SQB1	AXEN	38	1.0472	F	1
9/8/2012	SQB1	FCON	56	2.5562	F	3
9/8/2012	SQB1	FGRD	69	5.3886	F	24
9/8/2012	SQB1	FGRD	48	1.2162	I	2
9/8/2012	SQB1	FGRD	75	6.7086	M	22
9/8/2012	SQB1	PLAT	44	1.3576	F	23
9/8/2012	SQB1	PLAT	49	1.8128	M	7
9/8/2012	SQB2	FGRD	71	5.7053	F	21

9/8/2012	SQB2	FGRD	48	1.4093	I	2
9/8/2012	SQB2	FGRD	72	5.8272	M	14
9/8/2012	SQB2	GHOL	50	1.3464	F	1
9/8/2012	SQB2	PLAT	45	1.5085	F	10
9/8/2012	SQB2	PLAT	50	2.1381	M	11
9/8/2012	SQB3	AXEN	31	0.5054	F	2
9/8/2012	SQB3	FGRD	73	6.4388	F	16
9/8/2012	SQB3	FGRD	48	1.3162	I	2
9/8/2012	SQB3	FGRD	71	6.3089	M	9
9/8/2012	SQB3	PLAT	48	1.8372	F	14
9/8/2012	SQB3	PLAT	50	1.7317	M	2
9/8/2012	SQB4	AXEN	34	0.7009	F	5
9/8/2012	SQB4	AXEN	35	0.7697	M	3
9/8/2012	SQB4	FGRD	71	6.0947	F	28
9/8/2012	SQB4	FGRD	73	6.3692	M	11
9/8/2012	SQB4	PLAT	47	1.7317	F	21
9/8/2012	SQB4	PLAT	55	2.7710	M	15
9/9/2012	GB1	AXEN	35	0.6915	F	1
9/9/2012	GB1	FGRD	101	15.8983	F	4
9/9/2012	GB1	FGRD	91	11.7633	M	3
9/9/2012	GB1	GHOL	23	0.1133	I	1
9/9/2012	GB2	AXEN	41	1.2482	F	1
9/9/2012	GB2	FGRD	76	6.6403	F	4
9/9/2012	GB2	FGRD	73	5.5972	M	1
9/9/2012	GB2	GHOL	33	0.4241	F	7
9/9/2012	GB2	GHOL	22	0.1099	I	2
9/9/2012	GB2	GHOL	26	0.1839	M	1
9/9/2012	GB4	FGRD	100	13.6345	F	3
9/9/2012	GB4	FGRD	98	14.6309	M	5
9/9/2012	WB1	FGRD	66	4.1326	F	13
9/9/2012	WB1	FGRD	41 SL	1.2416	I	1

9/9/2012	WB1	FGRD	64	3.6767	M	7
9/9/2012	WB1	GHOL	32	0.3852	F	16
9/9/2012	WB1	GHOL	22	0.0950	I	3
9/9/2012	WB1	GHOL	24	0.1120	M	1
9/9/2012	WB1	PLAT	44	1.4926	F	46
9/9/2012	WB1	PLAT	22	0.1699	I	1
9/9/2012	WB1	PLAT	43	1.3710	M	20
9/9/2012	WB2	FCON	55	2.3112	F	3
9/9/2012	WB2	FCON	49	1.6459	M	2
9/9/2012	WB2	FGRD	66	5.0367	F	10
9/9/2012	WB2	FGRD	70	6.0775	M	5
9/9/2012	WB2	FPUL	54	2.0634	M	1
9/9/2012	WB2	GHOL	35	0.4404	F	28
9/9/2012	WB2	PLAT	44	1.4901	F	7
9/9/2012	WB2	PLAT	47	1.7718	M	11
9/9/2012	WB3	AXEN	35	0.8403	M	1
9/9/2012	WB3	FCON	49	1.8879	F	10
9/9/2012	WB3	FCON	41	0.8448	M	1
9/9/2012	WB3	FGRD	63	3.9674	F	17
9/9/2012	WB3	FGRD	47	1.2902	I	10
9/9/2012	WB3	FGRD	72	6.1451	M	12
9/9/2012	WB3	GHOL	32	0.4030	F	25
9/9/2012	WB3	PLAT	40	1.0889	F	4
9/9/2012	WB3	PLAT	39	0.9023	M	2
9/9/2012	WB4	AXEN	32	0.5686	F	1
9/9/2012	WB4	FGRD	71	5.7226	F	22
9/9/2012	WB4	FGRD	47	1.2324	I	3
9/9/2012	WB4	FGRD	72	6.0938	M	23
9/9/2012	WB4	GHOL	23	0.1165	I	1
9/9/2012	WB4	PLAT	49	1.9637	F	1
9/9/2012	WB4	PLAT	51	2.0795	M	1