TEMPORAL AND SPATIAL DISTRIBUTION OF NATIVE AND INVASIVE BIVALVES IN BAYOU LAFOURCHE, LOUISIANA

A Thesis

Submitted to the Graduate Faculty
of Nicholls State University
in Partial Fulfillment
of the Requirements for the Degree
Master of Science in Marine and Environmental Biology

By
Kelsey Lynn Adkisson
B. S., Western Washington University, 2006

Spring 2010

CERTIFICATE

This is to certify that the thesis entitled "The temporal and spatial distribution of native and invasive bivalves in Bayou Lafourche, Louisiana" submitted for the award of Master of Science to Nicholls State University is a record of authentic, original research conducted by Ms. Kelsey Lynn Adkisson under our supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship, or other similar titles.

APPROVED:	SIGNATURE:	DATE:
Allyse Ferrara, Ph.D. Associate Professor of Biological Sciences Committee Chair	______________________	____________
Quenton Fontenot, Ph.D. Associate Professor of Biological Sciences Committee Member	______________________	____________
Gary LaFleur, Ph.D. Associate Professor of Biological Sciences Committee Member	______________________	____________
Paul Hartfield Endangered Species Biologist U.S. Fish and Wildlife Service Committee Member	______________________	____________
Michael Massimi Invasive Species Coordinator Barataria-Terrebonne National Estuary Program Committee Member	______________________	____________

ABSTRACT

The zebra mussel *Dreissena polymorpha* and the Asian clam *Corbicula fluminea* are invasive, bio-fouling species that were introduced into North America during the last century. Invasive bivalve introductions may result in a loss of biodiversity, particularly among vulnerable native freshwater mussel populations. The goal of this project was to investigate the temporal and spatial distribution of native and invasive freshwater bivalves in Bayou Lafourche, a controlled distributary of the Mississippi River. This study also addressed the temperature tolerance of zebra mussels collected from a warm water (31ºC), high sediment environment.

Native and invasive bivalves were sampled during ten sampling trips from 2007 to 2010, using a ponar sampler and bridge scrapings. Zebra mussel thermal tolerance was assessed in a laboratory study. High densities (6,070 clams/m^2) of Asian clams were found in the upper part of Bayou Lafourche (Donaldsonville to Thibodaux) accounting for 94% of the bivalves collected. Mean benthic zebra mussel densities were low (< 60 mussel/m^2) in Bayou Lafourche, with 1.8% of ponar samples (19 of 1,050 ponar grabs) containing live zebra mussels. During the summers, cooler water temperatures that may have served as thermal refugia for zebra mussels (< 31ºC) occurred closest to the Donaldsonville pumping station, and temperature increased by 0.1ºC for each kilometer downstream. Few (N=46) native freshwater mussels were collected during this study, although five previously undocumented species were identified from Bayou Lafourche. Native freshwater mussels of southeastern Louisiana are poorly studied and the impacts and distribution of invasive species in the Lower Mississippi River Basin should be determined if native species are to be managed and conserved.

ACKNOWLEDGEMENTS

This research would not have been possible without the support of many people. First, I express deepest gratitude to my committee advisor, Dr. Allyse Ferrara for her enthusiasm, support, guidance and for providing so many valuable opportunities both in and out of the classroom. Her understood confidence in my potential forced me to realize my abilities. Sincere appreciation goes to my committee members, Dr. Quenton Fontenot and Dr. Gary LaFleur, for their insight and support; Mr. Paul Hartfield, for his help with bivalve identification and for his contagious enthusiasm for freshwater mussels; and Michael Massimi, for his insight on invasive species and environmental issues in Louisiana. Additionally, I would also like to thank Dr. Earl Melancon for his wealth of knowledge on bivalves and Mr. Archie Chaisson for introducing me to southern Louisiana history and politics.

Special thanks go to all the wonderful graduate students at Nicholls State University who have provided support, valuable insight and friendship throughout this experience: Jeremy Dunn, Billy Finney, Cynthia Fox, Saori Mine, Rachel Ianni, Justin Merrifield, Sam Wise and Mark Suchy. A very special thank you goes to Tim Clay for all his help with ponar sampling, and to Sara Shields for all her support, and incredible mussel hunting abilities.

Sincere gratitude goes to my family for their inspiration, support, patience and understanding throughout my academic career: Kathy, Larry, Cathy, Doug, Lindsey and Hailey. I would not have had this opportunity without them. Finally, I would like to thank Patrick Mirick for all of his support and creative methods of mussel collection.

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LIST OF ABBREVIATIONS

AC= Asian clam
ANOVA= analysis of variance
BTES= Barataria-Terrebonne Estuary System
cfs= cubic feet per second
DO= dissolved oxygen
F= fall
GIWW= Gulf Intracoastal Waterway
m= meter
mm= millimeter
m^2= square meter
m^3= cubic meter
PCA= principal component analysis
ppt= parts per thousand
RKM= river kilometer
SAS= Statistical Analysis Software
SE= standard error
SP= spring
SU= summer
Temp= temperature
W= winter
ZM= zebra mussel

INTRODUCTION

Non-native, invasive species can cause a shift in community composition, potentially displacing native species. The zebra mussel *Dreissena polymorpha* is one of the most well-known non-native, invasive species introduced to North America (Strayer 2009). The Asian clam *Corbicula fluminea*, has become the most widespread and persistent non-native, invasive bivalve in North America (McMahon 1999). In contrast, North American native freshwater bivalve (family: Unionidae; Figure 1) diversity is rapidly declining. Native bivalves are an extremely vulnerable group of organisms, with nearly 6% of modern species considered extinct and 25% listed as federally endangered (Neves 1993; Williams et al. 1993; Neves et al. 1997; Williams et al. 2008). Historically restricted to separate continents, the ranges of the non-native zebra mussel and Asian clams now overlap with the ranges of native unionid populations in North America. The direct impact of non-native, invasive bivalves on unionids is controversial (McMahon 1999). Although, physical interaction (Mackie 1993) combined with interspecific competition for habitat (Yeager et al. 2000) and food (Strayer and Smith 1996), have caused further decline in native freshwater mussel populations.

Native Freshwater Mussels and Clams

North America has the most diverse mussel assemblages in the world, with nearly 300 species (Williams et al. 1993). The southeastern U.S. contains a wealth of mussel diversity, with 91% of the nation’s native freshwater mussels occurring in this region (Neves et al. 1997). Unfortunately, over half (55%) of North American native freshwater mussel species are imperiled (Williams et al. 1993) with at least 19 taxa assumed to be

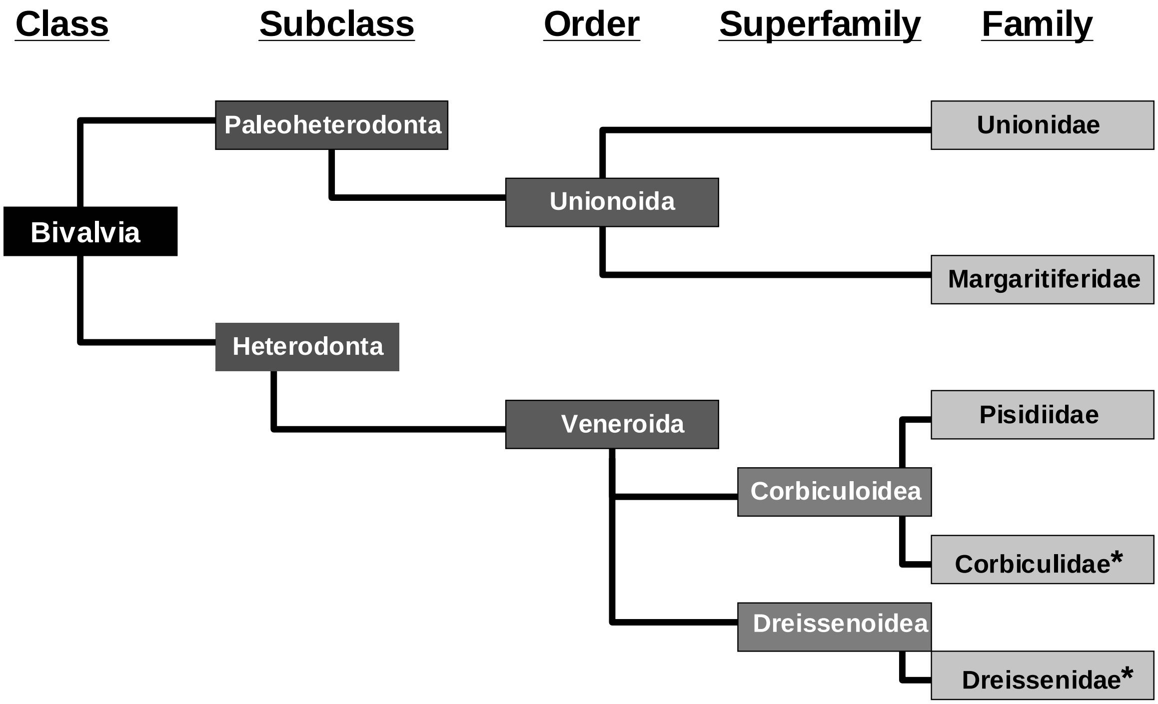

Figure 1. Taxonomic tree for the lineages of native and non-native, invasive (*) freshwater mussels and clams in Louisiana (modified from Integrated Taxonomic Information System on-line database 2010).

extinct (Bogan 1993), 70 (23%) taxa are federally listed as endangered or threatened and 40 (14%) taxa are candidates for federal protection (Neves 2004). The majority (95%) of federally endangered freshwater mussels occur in the southeastern U.S. (Williams et al. 2008). Freshwater mussel decline has been linked to impoundments, loss of host-fish populations, pollution and invasive species introductions (Bogan 1993; Williams et al. 1993; Williams et al. 2008). At least 67 species of freshwater mussels are found in Louisiana (Vidrine 1993). Mussels of the order Unionoida are ovoviviparous and produce bivalve larvae called glochidia. Glochidia are a unique life stage that is parasitic on the gills or fins of fish, which are used for dispersal (Figure 2; Williams et al. 2008).

Dams and weirs alter hydrologic patterns and often act as barriers to fish passage (Watters 1996). Vaughn and Taylor (1999) found a decline in mussel diversity below a dam, and mussel abundance was positively correlated with distance downstream of the impoundment. Watters (1996) found that unionid distribution was limited by small dams, which prevent fish-host movement and ultimately, glochidia attachment and dispersal.

Water pollution is another potential factor contributing to freshwater mussel decline. The glochidial and juvenile life stages are most sensitive to aquatic contaminants (Bringolf et al. 2007), such as copper and ammonia (Wang et al. 2007). According to Bringolf et al. (2007) juvenile *Lampsilis siliquoidea* were sensitive to fungicides and exhibited repressed growth with chronic concentrations (>3.8 mg/L) of the herbicide atrazine.

Zebra mussel invasions have been linked to declines in native freshwater mussel and clam populations (Unionidae and Sphaeriidae; Vidrine 1993; Neves et al 1997;

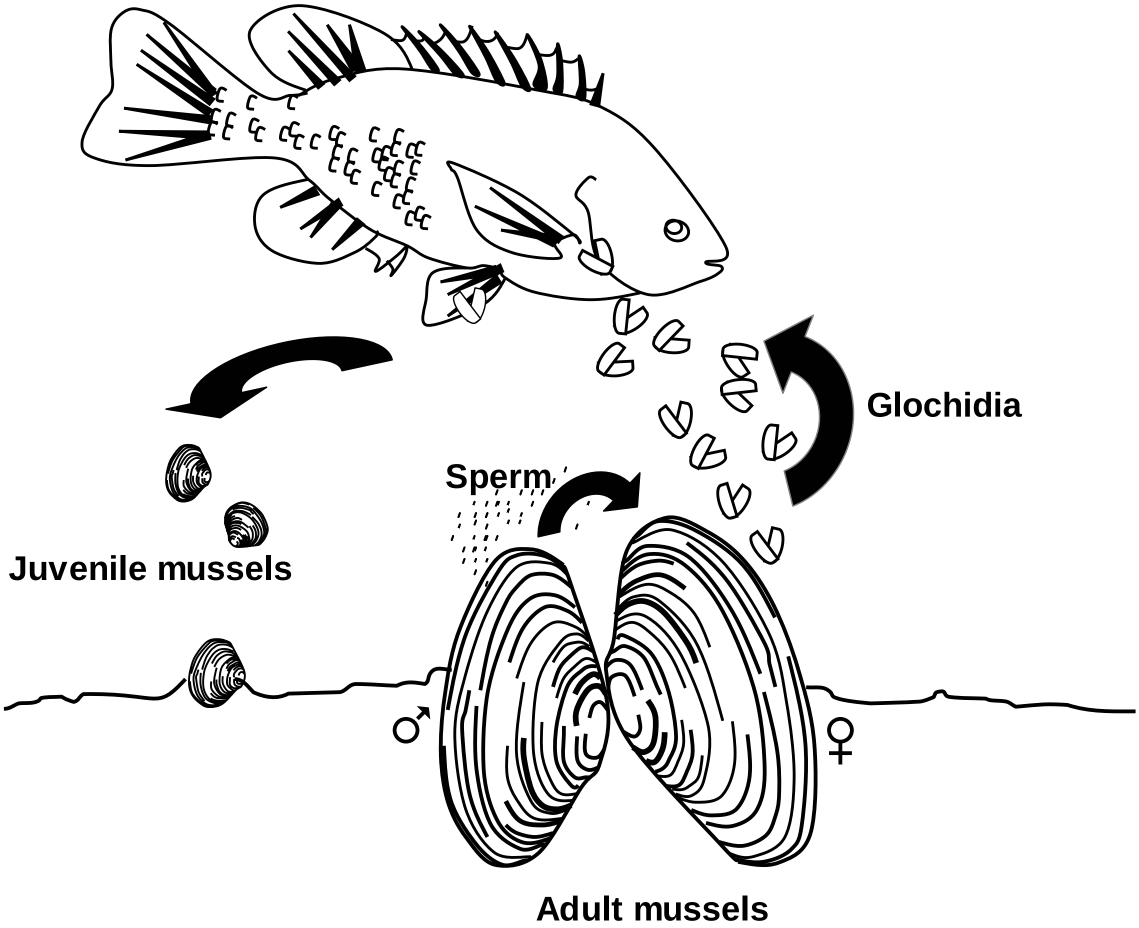

Figure 2. Life cycle of freshwater mussels (modified from Williams et al. 2008). Sperm are taken up by the female via the incurrent siphon and eggs are fertilized internally in the suprabranchial chamber. The female broods the fertilized eggs in the gills (brooding time varies with species) until glochidial development is complete. The female then releases the glochidia via the excurrent siphon, to attach to the gills or fins of a host-fish. Once attached, the glochidia mature into juvenile mussels and drop off of the fish-host to begin the independent, benthic life stages.

Williams et al. 2008). Although, permanent and temporary effects of the zebra mussel invasions are not fully understood (Strayer 2009). In Lake Michigan, zebra mussel invasion was correlated with a decline in native fingernail clam populations (Family Sphaeriidae; Lauer and McComish 2001). According to Strayer and Malcom (2007), in the decade following zebra mussel colonization, the Hudson River experienced at least a 65% to 100% decline in densities of populations of four species of native bivalves. From 2000 to 2005, the native mussel populations stabilized or increased, and were predicted to remain between 4 and 22% of densities prior to zebra mussel invasion.

Asian Clam

The non-native Asian clam is the most widespread, invasive freshwater bivalve in North America (McMahon and Bogan 2001). This species is euryoecious (McMahon 1999); tolerating a wide range of habitats. Asian clams are found in a variety of sediment substrates, can exhibit hermaphroditic reproduction (Kraemer et al. 1986), are highly fecund, have a free-living larval stage and are able to rapidly colonize disturbed habitats (McMahon and Bogan 2001). The Asian clam may be found in high densities (250,000 clams/m^2; Cherry et al. 1986) and is considered to be one of the most invasive bivalve species in North America (McMahon and Bogan 2001).

Historically, Asian clams (family Corbiculidae; Figure 1) were consumed by humans in parts of their native range (Southeast Asia) and were introduced to the western hemisphere by Asian immigrants (Counts 1981). Two populations of the Asian clam were initially introduced into the United States, in the Pacific Northwest and in Kentucky. In 1924, shells of the Asian clam were first collected in North America on

Vancouver Island, British Columbia (Counts 1981). In 1938, the first live Asian clam specimens were found in the Columbia River, Washington (Burch 1944). During the following three decades, the Asian clam dispersed following connected waterways and irrigation canals, eventually reaching the Colorado River and Rio Grande drainage basins (McMahon 1982; Dundee and Dundee 1958). In 1957, the second population was introduced into the Ohio River, near Paducah, Kentucky and dispersed throughout the Mississippi River drainage basin (Sinclair and Isom 1961). In 1963, the first live Asian clams were collected in Louisiana (McMahon 1982). The Asian clam has since spread to 44 continental states, Hawaii and Puerto Rico (USGS 2010).

Like zebra mussels, the Asian clam is a biofouling species, particularly in water and power plants (McMahon 1999), although the method of fouling is different. Due to the high densities (>20,000 clams/m^2; McMahon 1999) in which Asian clams can occur, juvenile clams and empty shells are passively transported downstream often settling out in lower velocity areas, such as pipes. The estimated cost associated with Asian clam damage is about $1 billion per year (Pimental 2005).

The Asian clam is a short-lived, highly fecund bivalve with a life span that ranges from 1-4 years (McMahon 1999). Juveniles are able to reproduce within 3-12 months of hatching (McMahon and Bogan 2001) at shell lengths of 6-10 mm (McMahon 1999). In southern populations, reproduction typically occurs twice per year (McMahon and Bogan 2001) and begins when water temperatures reach or drop to 17-19ºC for at least seven days during the spring and fall. Reproduction ceases when water temperatures reach 28ºC or higher (Kramer et al. 1986; Morgan et al. 2003). Asian clams are periodic hermaphrodites that most frequently cross-fertilize (Kraemer et al. 1986). Asian clam populations are often dominated by juveniles due to high fecundity with high mortality rates throughout the lifespan. McMahon (1999) suggested that first, second, and third year mortality rates were 74-98%, 59-69% and 93-97%, respectively.

Although able to survive a wider temperature and dissolved oxygen range than zebra mussels, Mathews and McMahon (1999) suggested that the Asian clam is more commonly associated with lotic environments and is not tolerant of warm water habitats (25ºC), that remain oxygen depleted (<2 mg/L DO) for 12 days. Temperatures below 2ºC (Mattice and Dye 1976) caused mortality and limit the range of Asian clams in northern latitudes (Mathews and McMahon 1999; Morgan et al. 2003). The insipient upper lethal temperature limit for the Asian clam is 34ºC (Mattice and Dye 1976), although the clams survived temperatures up to 37ºC in heated power plant discharge in the Connecticut River (Morgan et al. 2003). Growth occurs at temperatures between 10-36ºC, and is most rapid between 24-30ºC (Morgan et al. 2003).

Zebra Mussel

The family Dreissenidae contains at least three genera and 200 species, including *Dreissena polymorpha* (Figure 1; Kinzelbach 1992). Zebra mussels are indigenous to fresh and brackish waters of the Black and Caspian Sea drainage basins in Europe (Kinzelbach 1992; Strayer and Smith 1993; May et al. 2006). Although historically isolated to the Black and Caspian Sea drainages, the range of the zebra mussels in Europe expanded in the last two centuries due to increased canal and pipeline construction (Kinzelbach 1992; Aldridge et al. 2004). For the past century in Europe, zebra mussels have been associated with fouling boat hulls and pipes in hydroelectric, nuclear and water treatment plants (Lyakhov 1964; Mackie et al. 1989). Ultimately, European experiences foreshadowed economic and environmental losses connected to zebra mussel introduction and colonization in the U.S. (Mackie et al. 1989; Mackie and Schloesser 1996; Strayer 2009).

Zebra mussels first arrived in North America via ship ballast water and were discovered in northern Lake St. Claire in 1986 (Hebert et al. 1989; Carlton 2008). By 1994, zebra mussels were found along the length of the Mississippi River and in the Atchafalaya River, a major distributary of the Mississippi River (Allen et al. 1999; USGS 2010). Since then, the mussels have colonized most major waterways in the eastern half of the United States (USGS 2010).

Zebra mussel densities vary with habitat and latitude. Densities are lower in high sediment, riverine habitats, like the lower Mississippi River, than in lentic, low sediment habitats, such as the Great Lakes (Mihuc et al. 1999). Maximum densities in the Great Lakes can reach 700,000-800,000 mussels/m^2 (Kovalak et al. 1993), compared with 400,000 mussels/m^2 in the Mississippi River at Baton Rouge, Louisiana (Kraft 1995). Mihuc et al. (1999) found lower densities (1,200 mussels/m^2) in the Atchafalaya River.

Zebra mussels use temporary and permanent (Eckroat et al. 1993) byssal threads to attach to hard substrates, sand, mud, vegetation, shells and each other (Berkman et al. 1998). Ackerman et al. (1996) examined zebra mussel attachment strength on natural (wood-plywood, concrete, rock-dolomite/limestone), metallic (aluminum, copper/nickel alloy, steel) and polymeric (tar coated steel, acrylic, teflon and polyvinylchloride) substrates. Attachment strength varied with substrate type and was strongest on rock (dolomite/limestone) and steel, and was weakest on polymers and aluminum (Ackerman et al. 1996). Voluntary detachment occurs during stressful environmental conditions, such as turbulent water (Eckroat et al. 1993). Zebra mussels have a preference for sheltered microhabitats, such as the interior of pipes (Kilgour and Mackie 1993) and this preferential settlement makes removal difficult and costly.

Current zebra mussel removal strategies in closed environments, such as power plants, water plants and isolated quarries, involve mechanical, thermal and chemical treatments that target larval or adult life stages (Crosier and Molloy 2002). Treatment options include various methods of mechanical removal, high pressure water jetting, heat, freezing, biocides, dewatering, pipe coatings, oxides and the use of flocculants (Crosier and Molloy 2002). Currently, no open water treatments for zebra mussel removal exist (Strayer 2009).

Over the past twenty years, costs associated with zebra mussel damage and control in the U.S. have been estimated at up to $1 billion per year (Pimentel 2005). Although, more recent research suggests that the initial estimates were overvalued. Connelly et al. (2007) reviewed costs of zebra mussel damage from 1989 through 2004 to water treatment and power plants. An estimated total of $267 million was spent by power plants, with an average of $500,000 being spent per facility (Connelly et al. 2007). Strayer (2009) suggested that further research is needed to determine economic losses to recreational and commercial fisheries and shipping and tourism, due to zebra mussel introduction.

Ecologically, zebra mussels alter trophic food webs (Caraco et al. 1997) and have been linked to initial (Strayer and Malcom 2007) and permanent declines in native mussel and clam biodiversity (Strayer and Smith 1996; Lauer and McComish 2001).

Riccardi et al. (1998) estimated an extinction rate of about 60 unionid species native to the Great Lakes and Mississippi River drainage basin due to zebra mussel invasion. Benthic filter feeding bivalves play a key role in controlling phytoplankton levels in aquatic environments (Cloern 1982) and high levels of water phytoplankton filtration can negatively affect planktivourous fish, possibly altering fisheries (MacIsaac 1996).

Zebra mussel growth and development varies regionally and with water temperature (McMahon 1996). Zebra mussels in the Great Lakes have a shorter life span and are smaller than European zebra mussels (Mackie et al. 1989; Mackie 1993). In Europe, the average life span ranges from 3-7 years (Stanczykowska 1977) versus two years in the Great Lakes (Mackie 1993). Stanczykowska (1977) suggested that warmer water temperatures decrease mussel life span.

Sexual development is size dependant and occurs when mussels reach 5 mm shell length in the Great Lakes (Mackie 1993) and 7-8 mm shell length in Europe (Sprung 1992). In the Great Lakes, the spawning season begins in the spring when water temperatures reach 10 to 18°C (Mackie 1993; McMahon 1996). In the lower Mississippi River, zebra mussels spawn from April to June (Allen et al. 1999). Females can produce 30,000 to 1 million eggs per spawn and reproduction takes place via external fertilization (Figure 3; Mackie et al. 1989; Sprung 1993). Eggs must be fertilized within 2 to 4.75 hours, although sperm can remain viable in the water column for up to 22 hours (Sprung 1993). Larval development rate varies with temperature. Larvae can swim between 6-20 hours post fertilization, depending on temperature. When the larvae begin to develop shells, they enter the veliger stage and may remain in this phase for two weeks to a month

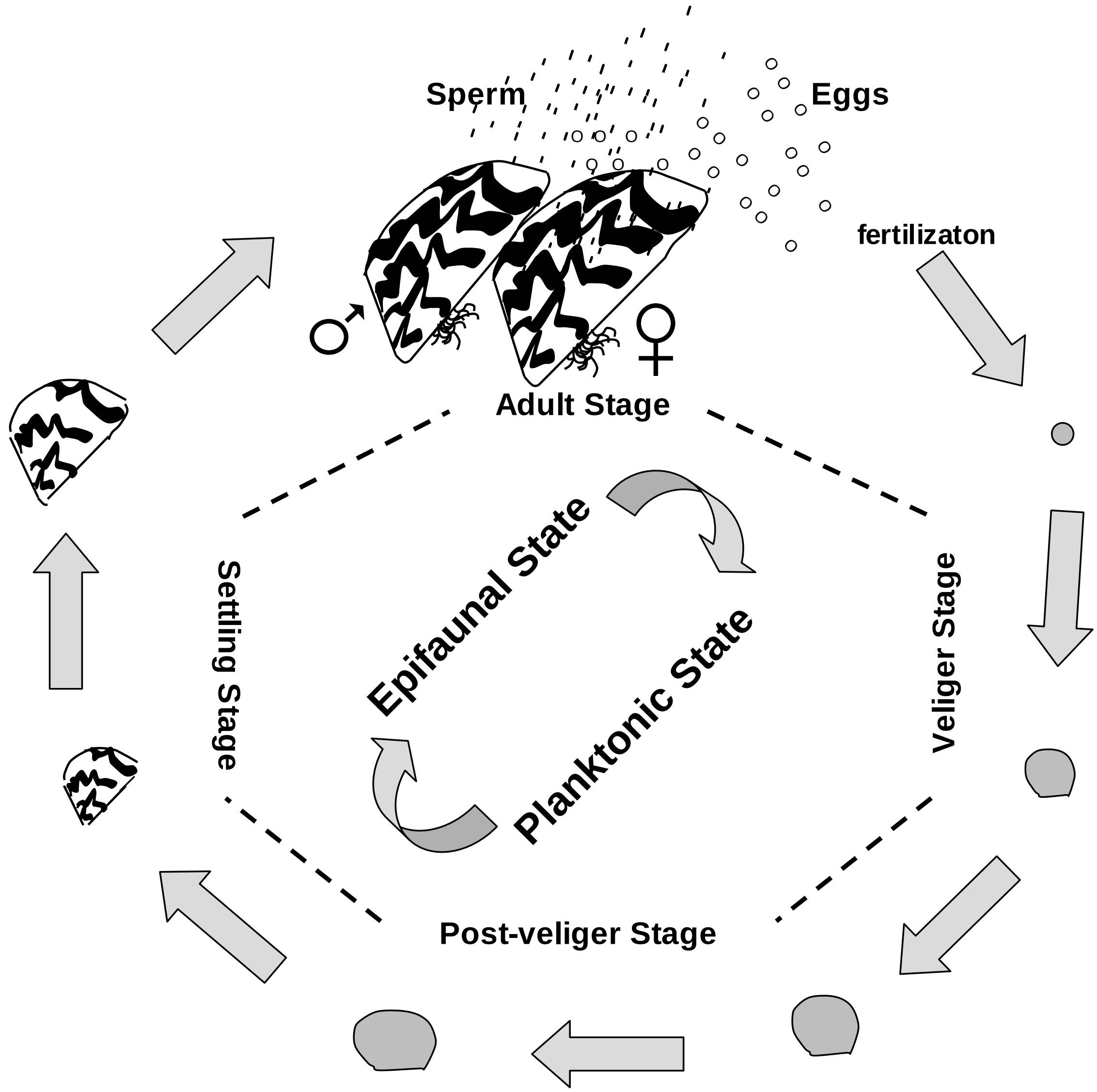

Figure 3. Life cycle of the zebra mussel *Dreissena polymorpha* (modified from Mackie 1999). Fertilization occurs externally, producing free-swimming planktonic veligers. The veligers mature into the post-veliger stage, and then settle and attach to substrate and grow into the adult stage.

(Sprung 1993). Zebra mussel larvae grow in water temperatures ranging from 12-24 °C, with maximum development occurring at 18 °C (Sprung 1987; Sprung 1993).

Environmental and physiochemical parameters such as temperature, suspended sediment, dissolved oxygen, salinity, and calcium concentration influence adult and larval zebra mussel distribution. Larval development only occurs at pH between 7.4-9.4; and calcium concentration must be between 40-60 mg/L (Sprung 1993). Dissolved oxygen must be above 20% saturation at 18ºC (Sprung 1993).

For adult zebra mussels, growth rates are correlated with temperature and vary throughout the United States. In Lake Erie, growth rates were at least 10 mm per year (Griffiths et al. 1991). In the lower Mississippi River, near Baton Rouge, Allen et al. (1999) determined that zebra mussel growth rates fluctuate seasonally and vary with population size structure. The highest growth rates occurred in the spring (12-21°C) and in the fall (16-28ºC) and ranged from 2.5 to 6.8 mm/year, although no growth occurs during the summer months due to high water temperatures. Additionally, larger mussels (>15 mm) were more susceptible to mortality events due to high (>29-30ºC) summer water temperatures (Allen et al. 1999; Elderkin and Klerks 2005). Elderkin and Klerks (2005) found that zebra mussel populations from the lower Mississippi River had a higher temperature tolerance than did mussels from the upper Mississippi River, although, this variation was most likely due to selective pressure, not adaptation. The upper thermal lethal limit for zebra mussels ranges from 30ºC (Iwanyzki and McCauley 1993) to 35ºC (Alexander and McMahon 2004).

Suspended sediment also affects adult zebra mussel growth. Although bivalves selectively sort organic and inorganic particles from the water column (Newell and

Langdon 1996), large amounts of suspended inorganic sediment, dilute the quantity of food consumed (Bricelj and Malouf 1984; Madon et al. 1998). Bricelj and Malouf (1984) found that the clearance rate of the hard clam *Mercenaria mercenaria* declined 1.3% for every 1 mg/L increase in suspended sediment. Madon et al. (1998) determined that metabolic processes of zebra mussels begin to decline when inorganic suspended sediment levels surpass 1 mg/L at 20°C in a controlled environment (Madon et al. 1998). In the lower Mississippi River (St. Francisville, Louisiana) the mean annual suspended sediment concentration during 1993-2007 was 150 mg/L (Horowitz 2009), although fluctuations occurred seasonally and reached 450 mg/L (Baton Rouge, Louisiana; Allen et al. 1999) during the spring. Ultimately, large amounts of suspended inorganic sediments suppress zebra mussel growth in lotic, turbid environments (Madon et al. 1998). Zebra mussels are further stressed by the combined effects of high sediment loads and warm water temperatures (Alexander et al. 1994). Zebra mussels are intolerant of low dissolved oxygen (DO) conditions and mortality increases with increased temperature. Mathews and McMahon (1999) determined that 100% mortality occured after 3.5 days at hypoxic (<2 mg/L DO) conditions in warm water (25ºC).

Zebra mussels in Europe have been found in brackish water systems with salinities up to 12 ppt (Strayer and Smith 1993). For zebra mussels in North America, salinity tolerance varied with temperature and life stage (Kilgour et al. 1994), although reproduction declined in warm water temperatures (>20ºC) at salinities greater than 1 ppt (Kilgour et al. 1994). Acclimated mussels can survive salinities between 2-4 ppt (Wilcox and Dietz 1998) and veligers were able to tolerate salinities up to 4.5 ppt (Kilgour et al. 1994).

Other physiochemical parameters that influence zebra mussel distribution are calcium and magnesium availability. All bivalves require calcium for successful growth and shell development (Dietz et al. 1994). Jones and Riccardi (2005) suggested that calcium levels below 8-10 mgCa/L limit zebra mussel distribution. Furthermore, Dietz et al. (1994) determined that zebra mussels were unable to survive in magnesium depleted water and required minimal concentrations of chlorine and potassium.

More than twenty years ago, zebra mussels were introduced into the U.S. (Hebert et al. 1989; Carlton 2008; Strayer 2009). Since that time, zebra mussels have rapidly invaded most major waterways in the eastern U.S. (USGS 2010). Originally, the spread of zebra mussels was predicted to be restricted to temperate climates, based on European distributions (Strayer 1991). Summer water temperatures in the southern U.S. often exceed the upper lethal limit for zebra mussels (>31ºC) although in 1992, the first zebra mussels were observed in southeastern Louisiana in the Mississippi River (USGS 2010) and have since spread outside of the main channel to the floodplain. In these regions, warm summer water temperatures combined with high sediment loads and low dissolved oxygen levels (<1.0 mg/L), create unfavorable habitat for zebra mussel survival (Mihuc et al. 1999). In April 2006, adult zebra mussels were found attached to the subsurface root system of the non-indigenous invasive plant, wild taro, *Colocasia esculenta,* in Bayou Lafourche, Louisiana (Michael Massimi, BTNEP, personal communication).

The purpose of this study was to examine the temporal and spatial distribution of zebra mussels, Asian clams and native freshwater mussels in Bayou Lafourche. I predicted that seasonal water temperatures and river kilometer will influence zebra mussel distribution.

The objectives of this study were to:

1) determine seasonal (winter, spring, summer, fall) adult zebra mussel distribution in Bayou Lafourche;
2) determine the temperature tolerance of zebra mussels collected from a high temperature, high sediment, low dissolved oxygen environment;
3) determine seasonal Asian clam distribution in Bayou Lafourche;
4) document native freshwater mussel species in Bayou Lafourche, and;
5) determine the influences of water quality on bivalve distribution and abundance.

METHODS

Study Area

The Barataria-Terrebonne Estuary System (BTES), located in southeastern Louisiana, is bordered by the Atchafalaya River Basin to the west and the Mississippi River to the east. The estuary encompasses an area of 16,835 km^2 and is divided by Bayou Lafourche, which extends 174 kilometers from the Mississippi River to the Gulf of Mexico (Figure 4; McKensie et al. 1995). Historically, Bayou Lafourche was a major distributary of the Mississippi River, but was leveed at the confluence in 1904 to eliminate spring flooding (CH2M HILL 2005). The elimination of a freshwater input combined with lack of flow resulted in poor water quality. In 1955, the Walter Leeman Pumping station was built at the head of Bayou Lafourche in Donaldsonville, reconnecting the bayou to the Mississippi River. Four pumps siphon water 300 m over the levee into the head of Bayou Lafourche at a rate of approximately 5 m^3 per second (Archie Chaisson, Bayou Lafourche Freshwater District, personal communication).

My study area included the upper 110 river kilometers (RKM) of Bayou Lafourche, from the city of Donaldsonville (RKM 1) to the Gulf Intracoastal Waterway (GIWW; RKM 110). This stretch exhibits three different zones, each of which has unique physical characteristics. The upper third of the study area (RKM 1-40) is closest to the Walter Leeman pumping station and receives high sediment input creating a shallow, turbid habitat, surrounded by urban and agricultural areas. This area has the highest velocity and the bank vegetation primarily consists of wild taro *Colocasia esculenta* during the growing season. The middle zone (RKM 40-80) has high densities of submerged aquatic vegetation (hydrilla *Hydrilla verticillata*) and floating vegetation.

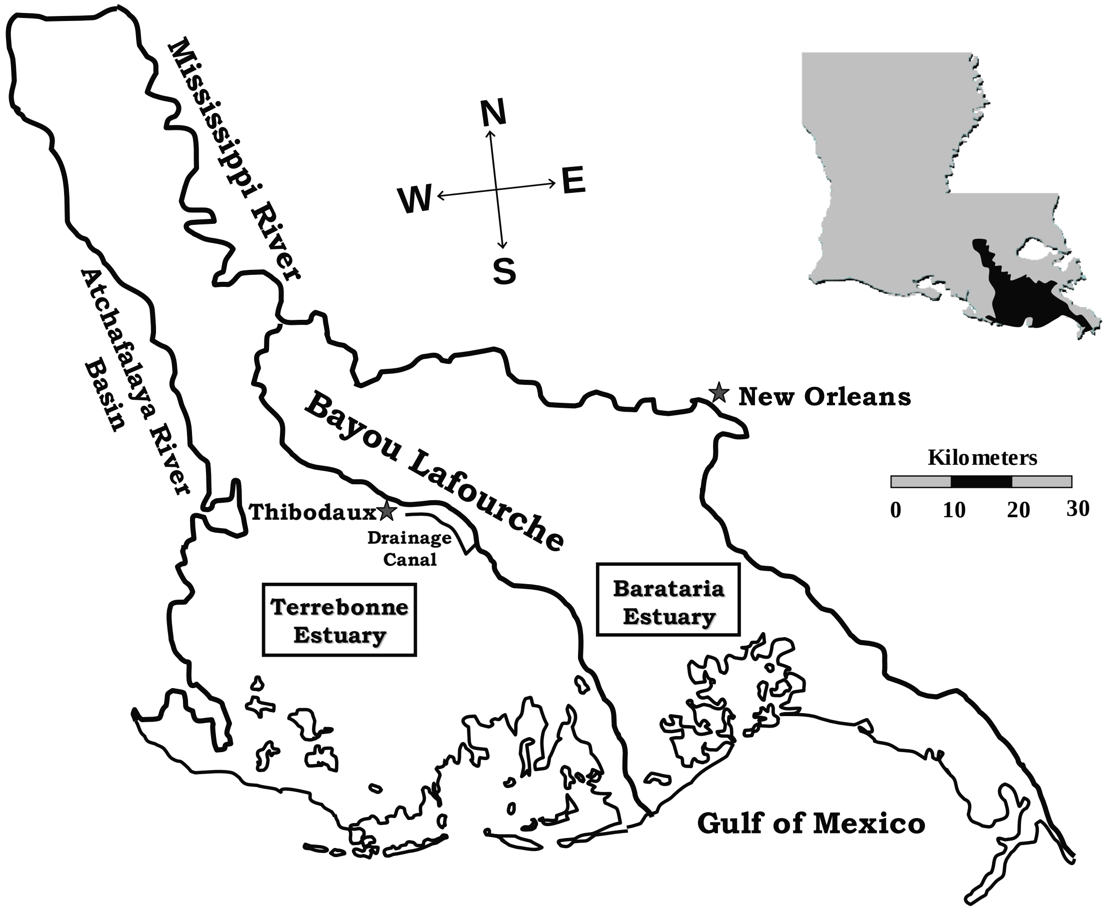

Figure 4. Bayou Lafourche extends 174 kilometers from the Mississippi River to the Gulf of Mexico, dividing the Barataria and Terrebonne Estuaries.

(water hyacinth *Eichhornia crassipes*) throughout the spring, summer and fall months. In 1969, a weir was constructed in the city of Thibodaux (RKM 54) to provide a reliable source of drinking water (CH2M HILL 2005). The weir creates a barrier to upstream fish passage except during high flows when the weir is overtopped (>15 cm precipitation/24 hours; Archie Chaisson, Bayou Lafourche Freshwater District, personal communication). The lower zone (RKM 80-110) is tidally influenced, and has a navigation channel maintained for shipping.

Physicochemical Data

Temperature (ºC), dissolved oxygen (mg/L), salinity (ppt) and conductivity (μS) were measured using a handheld YSI meter (model 85) and Secchi disk depth (cm) was measured at all sampling sites during each sampling trip from June 2007 to January 2010. Temperature was measured at the top and bottom of the water column from June 2009 to January 2010. A temperature logger (Onset Hobo© pendant) was placed in Bayou Lafourche (RKM 52; Mr. Harry Shields, 960 Bayou Road, Thibodaux, 70301) from 1 July 2009 to 10 April 2010.

Adult Zebra Mussel Distribution

Adult zebra mussels (>3 mm total length; TL) were collected during ten sampling trips from 2007 to 2010. Sampling seasons were defined as spring-March through May; summer-June through August; fall-September through November; and winter-December through February. The upper section (RKM 1-110) of Bayou Lafourche, from Donaldsonville to the GIWW was sampled during each trip. This stretch was divided into three zones. In each zone, five randomly selected transects were sampled for zebra mussels. At each transect, the bayou cross section was divided into nine evenly spaced sample locations (Figure 5). In the outer two locations, emergent aquatic vegetation was sampled using a posthole digger. Benthic samples were taken from the other seven locations using a petit ponar (0.023 m^2) grab. Each posthole and ponar grab sample was washed over a screen (1 mm x 1 mm mesh), rinsed, place in individual labeled plastic bags and held on ice for later processing in the laboratory. In the laboratory, all samples were refrigerated (4°C) until processed. During processing, samples were rinsed over a mesh screen (1 mm x 1 mm mesh) to remove mud. Samples were placed into enameled sorting trays and examined for the presence of adult zebra mussels. All mussels were preserved in a 70% ethyl alcohol solution. Zebra mussel total length was measured to the nearest 0.1 mm (±0.2mm) using digital calipers.

In addition to benthic sampling, accessible bridges and hard vertical surfaces were scraped using a long handled dip net (1 mm x 1 mm mesh). Bayou Lafourche contains 17 bridges between Donaldsonville (RKM 1) and the Thibodaux weir (RKM 54). Five of the bridges are constructed of creosote-coated wood, are inaccessible, or do not have pilings below the waterline. Twelve of the bridges are constructed of concrete with pilings below the waterline, providing suitable substrate for zebra mussel colonization (Figure 6). The twelve concrete bridges were seasonally examined for zebra mussel presence from June 2007 to January 2010. Access to bridges and hard vertical surfaces was frequently blocked, particularly in the spring and summer, due to mats of floating vegetation or debris or by low water levels and bridge crossbars.

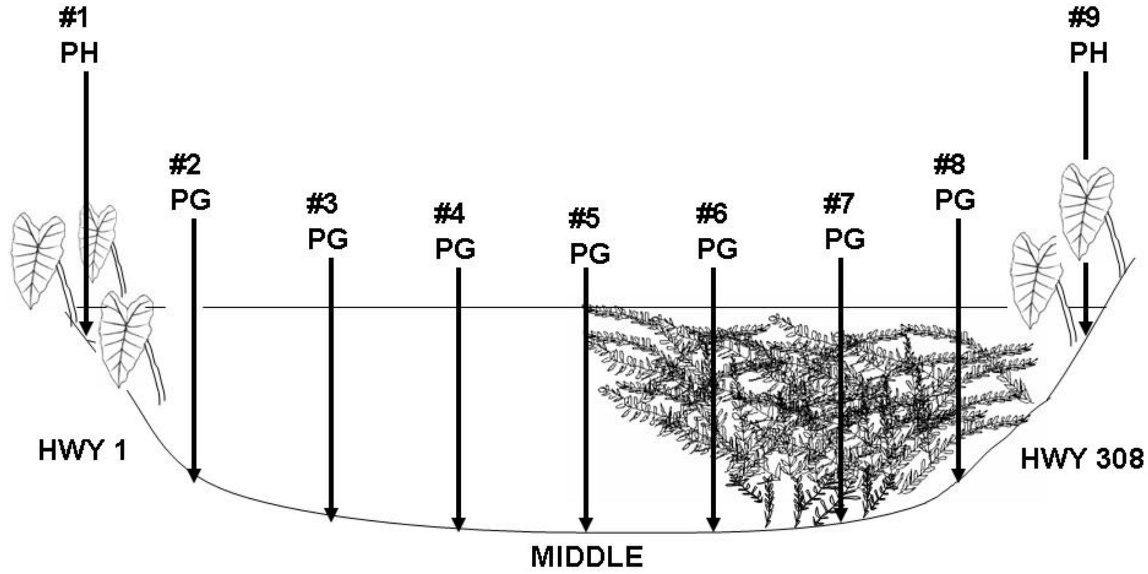

Figure 5. Sample locations for each randomly selected transect. Fifteen randomly selected river kilometers were divided into bayou cross-sections, with each cross-section containing seven ponar grabs (PG #2-8) and two post-hole grabs (PH #1 and 9).

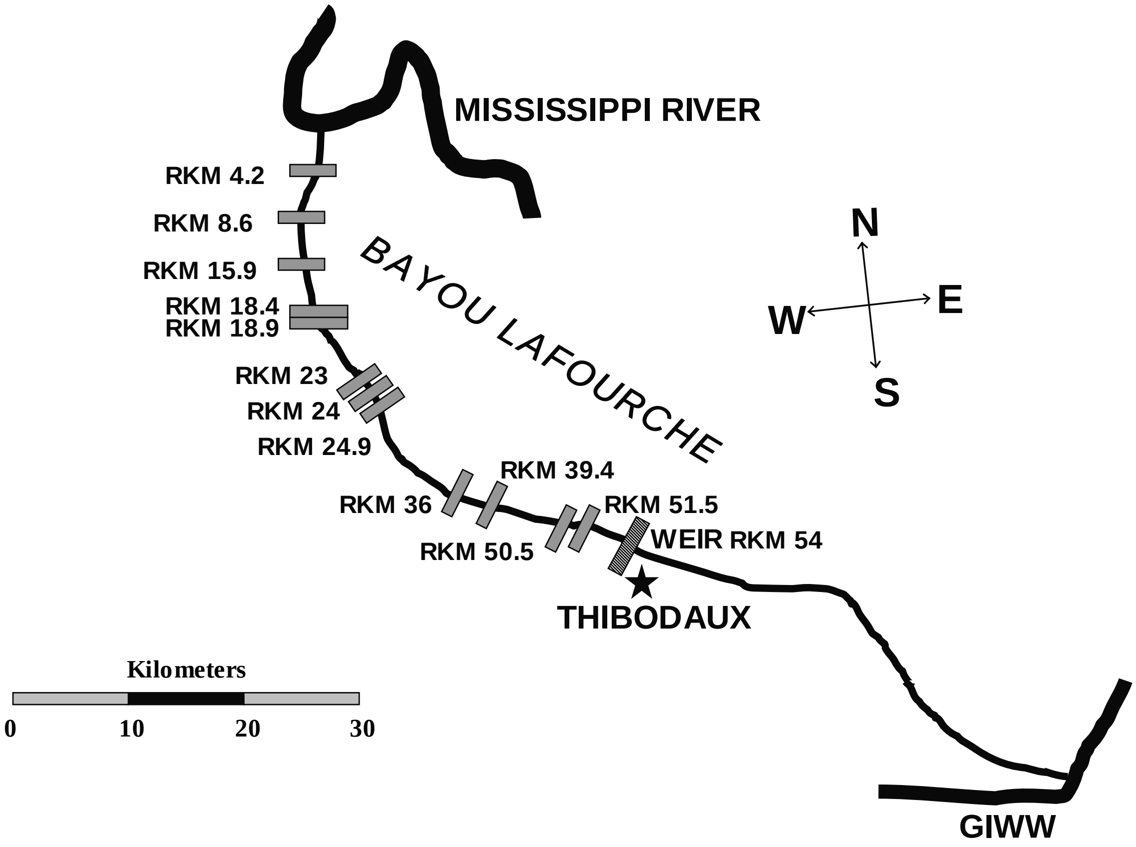

Figure 6. Twelve concrete bridges (extending from Donaldsonville, RKM 1, to Thibodaux, RKM 51.5) were scraped seasonally for zebra mussels to assess presence from June 2007 to January 2010.

Zebra Mussel Temperature Tolerance

Live zebra mussels were collected on 1 August 2009, in Napoleonville, Louisiana (RKM 25) from bridge pilings at a depth of 1 m and a temperature of 30.6ºC. The mussels were immediately transported back to the laboratory and placed in 27 ±1°C aerated, dechlorinated, Lafourche Parish municipal water. Mussels were divided into groups and mean total shell lengths per tank ranged from 12.2 to 13.5mm. Mussels were placed in six 19L glass aquaria and acclimated to the laboratory with a 12:12 hour light:dark cycle for 16 days at 27 ± 1°C. The acclimation period allowed mussels to recover from stresses associated with collection and for byssal thread attachment. Temperatures were maintained via a circulating water bath with an immersed electric heater controlled by a thermostat (Figure 7). The mussels were not fed during the experiment and were used within 37 days of collection (Chase and McMahon 1995). Two treatments were used to determine temperature tolerance, a control treatment maintained at 28.5 ± 1ºC and a treatment with gradually increasing temperature. Each treatment included two separate water baths with three tanks, each tank contained twenty mussels with byssal threads attached to the aquarium wall or tiles (120 mussels total). Six unglazed quarry tiles were stacked in each tank as substrate for attachment. Byssal thread formation demonstrated lack of stress and only attached mussels or clumps of mussels were used in the experiment (Spidle et al. 1995). The experimental temperature was increased 1 ± 1ºC every five days and the control temperature was maintained at 28.5 ± 1ºC. Death was determined when valves gaped or when mussels did not exhibit a response after gentle probing (Iwanyzki and McCauley 1993). Dead mussels were immediately removed from tanks and measured to the nearest 0.1 mm with digital

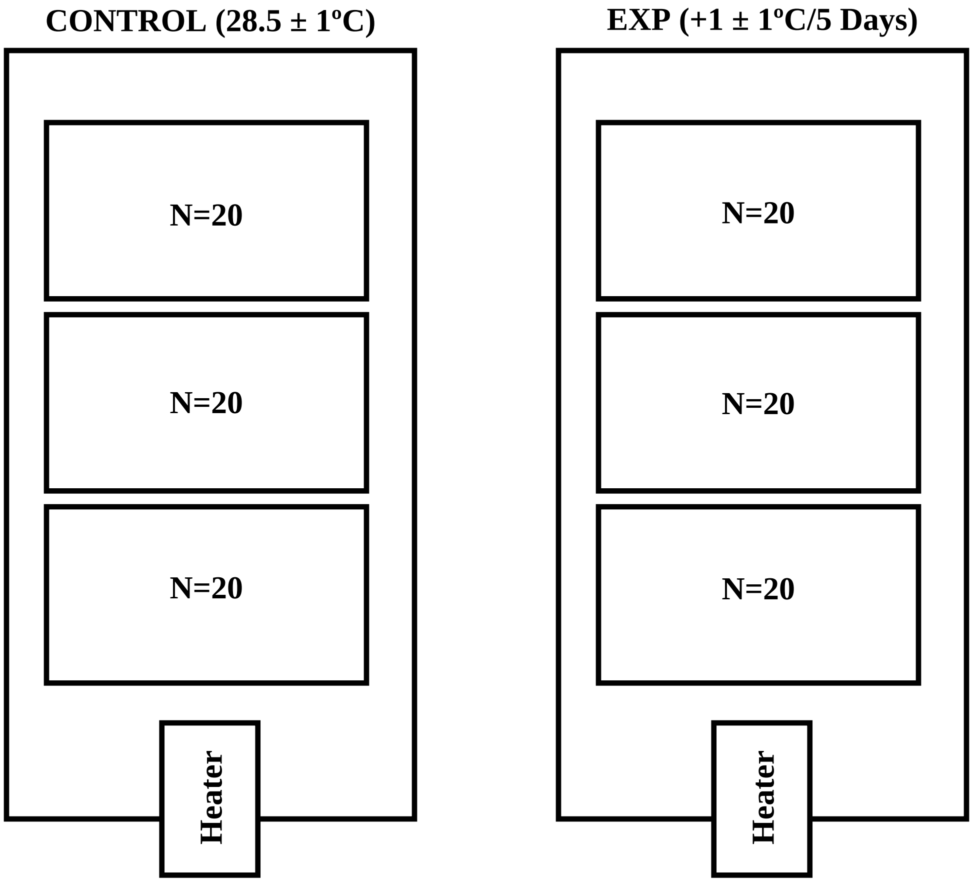

Figure 7. Schematic diagram of the circulating water baths used to determine zebra mussel temperature tolerance. Each treatment included two separate water baths with three tanks, each tank contained twenty zebra mussels with byssal threads attached. The control treatment temperature was maintained at 28.5 ± 1ºC and the experimental (EXP) treatment temperature was increased 1 ± 1ºC every five days.

calipers. Throughout the experiment temperature, dissolved oxygen, salinity and specific conductance were measured daily. Total ammonia-N (TAN; mg/L) was measured using the Nesslerization method, nitrite-N (mg/L) was measured using the AZO dye method, and pH was measured using a Hannah Instruments pH meter. Ammonia, nitrite and pH levels were measured every 2 days and partial water changes occurred every three days. Dissolved oxygen did not differ between treatments and was always above 6.0 mg/L. The mean dissolved oxygen for both treatments combined was 7.29 ± 0.67 mg/L. For both treatments, the pH remained above 7.5 and the salinity remained below 0.5 ppt.

Asian Clam Distribution

Asian clam sampling was conducted concurrently with adult zebra mussel benthic sampling from January 2009 to January 2010. Six sampling trips occurred seasonally. All live Asian clams were measured and checked for attached zebra mussels.

Unionid Distribution

Adult benthic unionid sampling was conducted concurrently with the adult zebra mussel and Asian clam benthic sampling. Benthic sampling occurred seasonally from June 2007 to January 2010. All unionids were identified to species, measured and checked for attached zebra mussels. Additionally, dredge spoils from a drainage canal (Figure 4; 29º 45’ 36.41 N, 90º 46’ 49.29 W), which is connected to Bayou Lafourche, were examined for mussel shells in March 2008.

Zebra mussel and Asian clam analyses

Principal component analysis (PCA) was used to compare physicochemical parameters with bivalve abundance. PCA was conducted on zebra mussel abundance data collected from October 2007 to January 2010, and for Asian clam abundance data collected from January 2009 to January 2010. Zebra mussel and Asian clam abundance data were pooled by season. Only loadings > 4.0 were used in the analyses of both species. Multiple regression analysis was used to assess the relationship between river kilometer and zebra mussel abundance. Regression analysis was used to estimate summer water temperatures in Donaldsonville, based on data collected in June 2007, June 2009 and August 2009.

RESULTS

A total of 2,760 freshwater bivalves, comprising ten species and four families, were collected during ten sampling trips between June 2007 and January 2010. Two invasive bivalve species and eight native bivalve species were collected using a petit ponar, scraping hard vertical surfaces and from dredge spoils (Table 1). Post-hole digger sampling collected no live zebra mussels and only nine live Asian clams, therefore these samples were removed from the analyses. Five native freshwater mussel species were collected that were not previously identified from the BTES (Vidrine 1993; Table 2). Invasive bivalves dominated the benthic and bridge piling samples, comprising 76.2% of the total mussel abundance. The Asian clam was the most common benthic bivalve species found in Bayou Lafourche, followed by the zebra mussel (Table 1). Few (N=46) native mussels were collected, with *Toxilasma parvum* being the most common unionid in ponar samples (0.4% of samples; Figure 8). No live T. *parvum* were collected where Asian clams (> 1 clam/m^2) occurred.

Physicochemical Results

Bayou Lafourche, a shallow waterbody, did not stratify. A maximum of 0.4ºC temperature difference was found between surface and bottom temperatures. A continuous temperature logger in Thibodaux (RKM 52) recorded the highest water temperatures in July 2009 (35.0°C) and the coldest in January 2010 (2.0°C; Figure 9). However, mean temperatures ranged from 12.5 to 30.9°C for the seasonal ponar sampling (Figure 10). Based on regression analysis (Figure 11), water temperatures increased 0.1ºC per RKM downstream from Donaldsonville (RKM 1) to the Thibodaux weir

Table 1. Species, common name and number collected for 2,760 native and invasive (*) freshwater mussels and clams collected from Bayou Lafourche and an adjacent drainage canal (29º 45’ 36.41 N, 90º 46’ 49.29 W) from June 2007 to January 2010. Bivalves were collected with a petit ponar, post-hole digger, bridge scrapings and dredge spoil surveys. Five species of mussels were collected when recently dead (**) and all other bivalves were collected live.

SPECIES	**COMMON NAME**	**NUMBER COLLECTED**		
		Ponar	**Scrape**	**Spoils**
*Corbicula fluminea**	Asian clam	2,099	1	0
Sphaeriidae spp.	Fingernail clam	120	27	0
*Dreissena polymorpha**	Zebra mussel	39	422	0
Toxolasma parvum	Lilliput	9	2	0
Toxolasma texasensis	Texas lilliput	1**	0	0
Rangia cuneata	Surf clam	4	0	0
Pyganodon grandis	Giant floater	1**	0	8**
Quadrula apiculata	Southern mapleleaf	1**	0	5**
Glebula rotundata	Round pearlshell	2**	0	17**
Mytilopsis leucophaeta	Conrad’s false mussel	2**	0	0
TOTAL		2,278	452	30

Table 2. Five native freshwater mussel species not previously documented (Vidrine 1993) in the Barataria-Terrebonne Estuary System. The mussels were collected from Bayou Lafourche using a petit ponar, post-hole digger and from the dredge spoils of an adjacent drainage canal (29º 45’ 36.41 N, 90º 46’ 49.29 W).

SPECIES	**COMMON NAME**	**NUMBER COLLECTED**	
		Bayou Lafourche	**Drainage Canal**
Toxolasma parvum	Lilliput	9	0
Toxolasma texasensis	Texas lilliput	1	0
Pyganodon grandis	Giant floater	1	8
Quadrula apiculata	Southern mapleleaf	1	5
Glebula rotundata	Round pearlshell	2	17

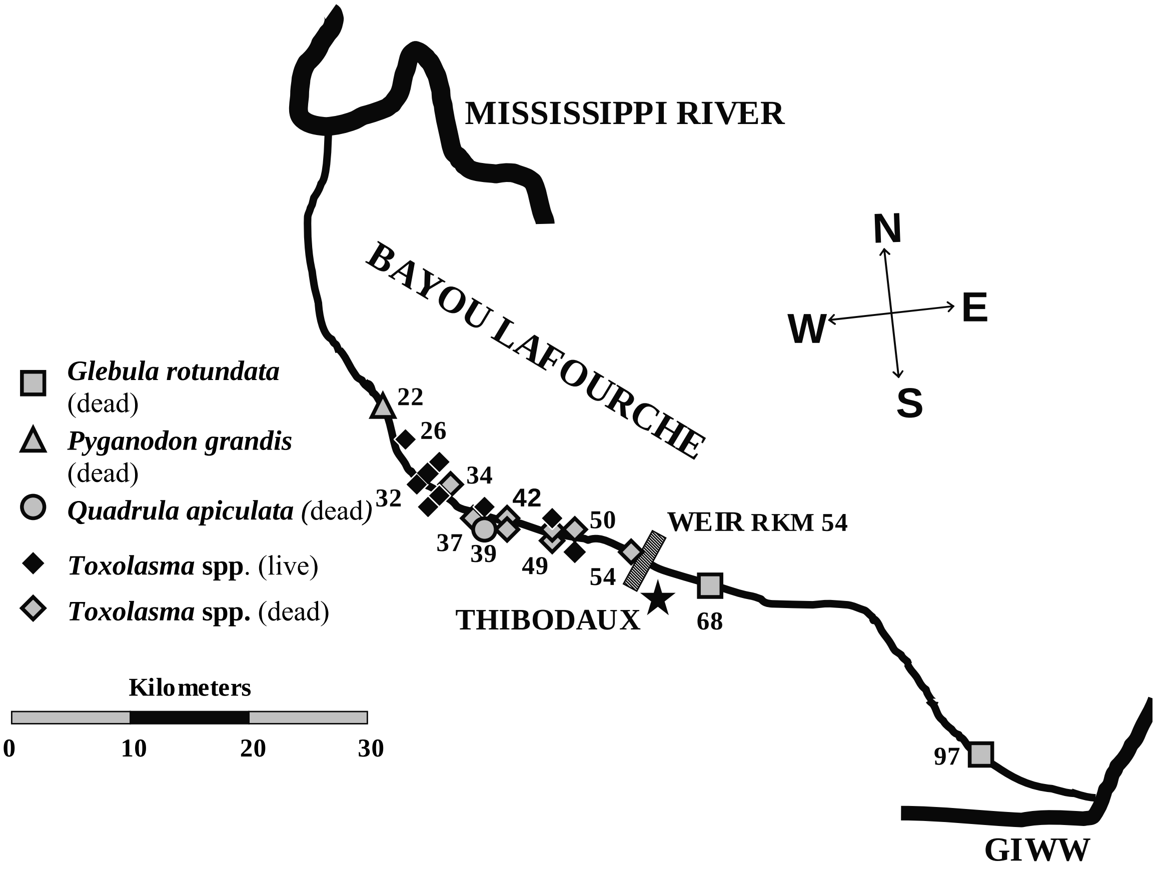

Figure 8. At least four unionid genera were collected in Bayou Lafourche between June 2007 and January 2010. The only live unionids collected during this study were *Toxolasma* spp. All *Toxolasma* spp. were collected above the Thibodaux weir (RKM < 54).

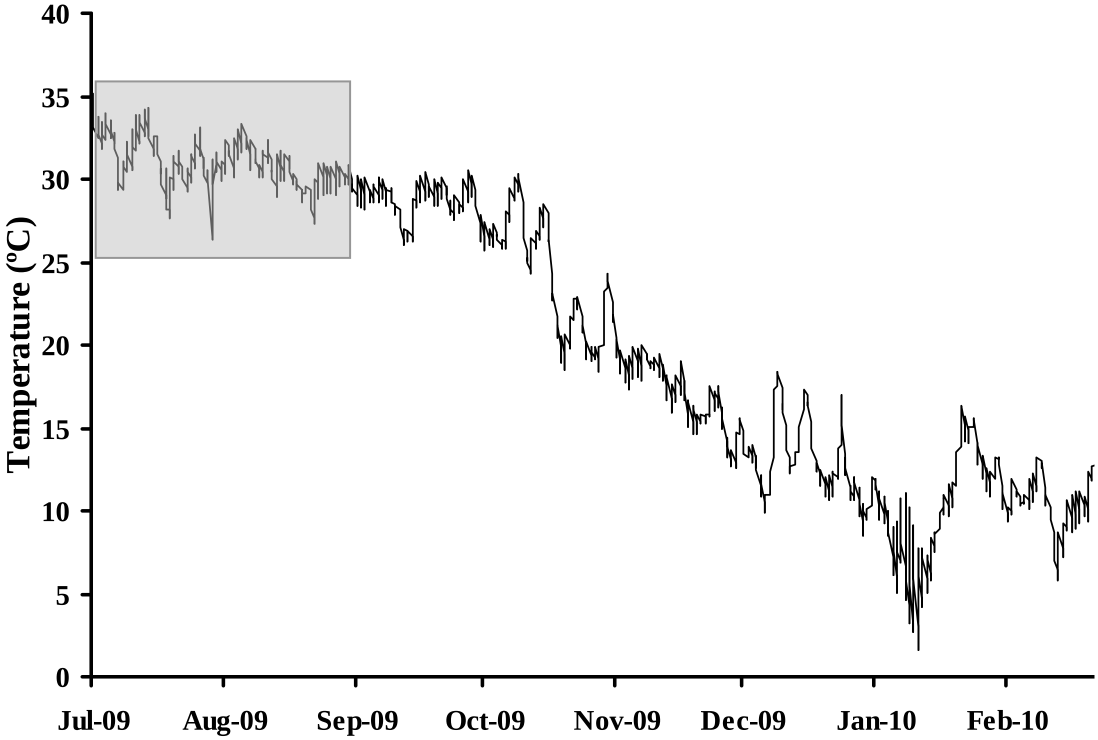

Figure 9. Water temperatures recorded every 6 hours in Bayou Lafourche (RKM 52) from 1 July 2009 to 22 February 2010. Temperatures recorded from 1 July 2009 to 31 August 2009 (highlighted gray) were used to predict temperatures in Donaldsonville (RKM 1; Figure 11)

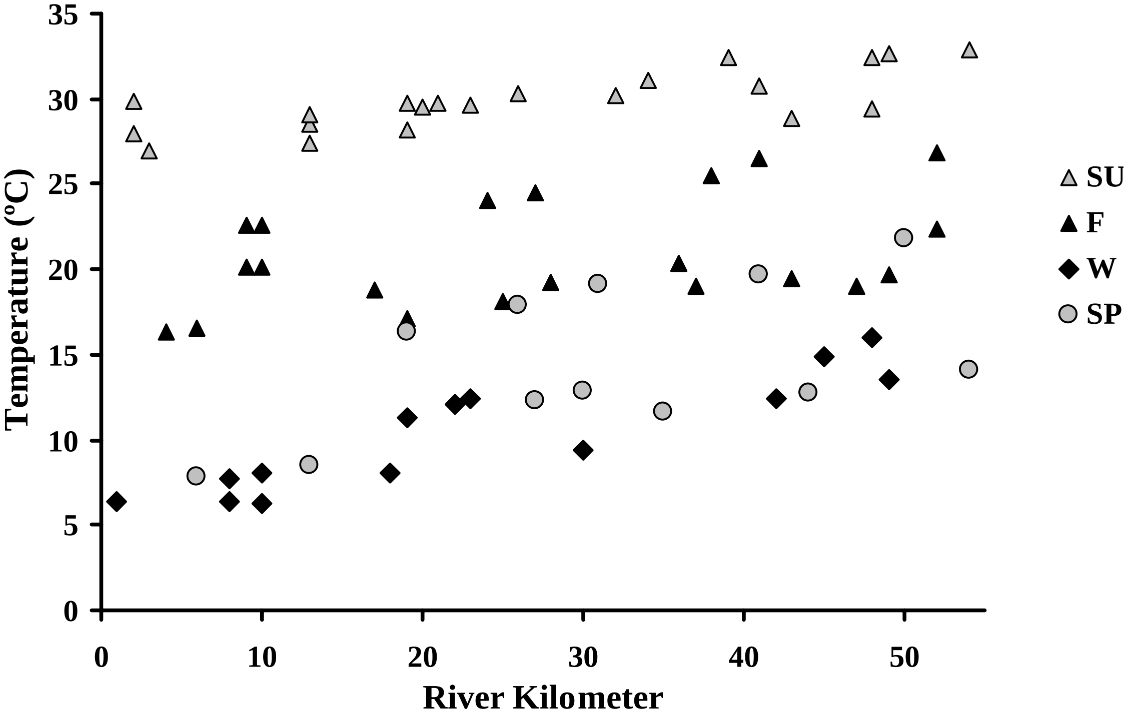

Figure 10. Summer (SU), fall (F), winter (W) and spring (SP) water temperatures in upper Bayou Lafourche (RKM ≤ 54) from June 2007 to January 2010, by river kilometer.

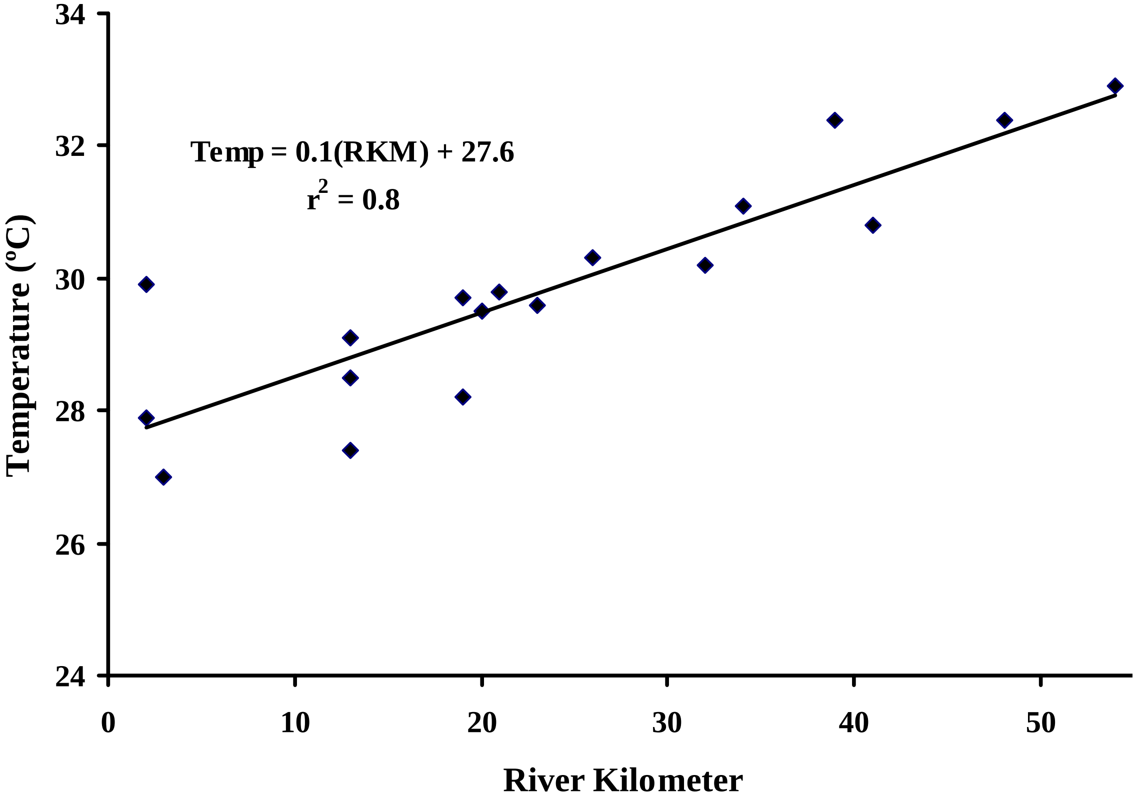

Figure 11. Summer water temperatures for the upper 54 RKM of Bayou Lafourche in June 2007, June 2009 and August 2009. Water temperatures increased 0.1ºC per RKM downstream from Donaldsonville (RKM 1) to the Thibodaux weir (RKM 54).

(RKM 54) during the summer and estimated water temperature was never greater than 30ºC in Donaldsonville (RKM 1; Figure 12).

During 2008 and 2009, the mean daily discharge of Bayou Lafourche ranged from 0 to 8.6 m^3/sec (Figure 13). No discharge occurred between 2 September and 4 September 2008, due to loss of electrical power from Hurricane Gustav (landfall on 1 September 2008). Mean DO ranged from 2.7 to 9.6 mg/L, however anoxic conditions (0.17 mg/L), were recorded (10 September 2008; LADEQ 2010) in upper Bayou Lafourche (RKM 25) following Hurricane Gustav. Mean salinity for all sample periods combined, remained below 0.2 ppt, with the exception of a 0.4 ppt measurement on 5 October 2008 at RKM 95. Mean Secchi disk depth ranged from 27.5 to 69.2 cm.

Zebra Mussels

Benthic Sampling

A total of 1,050 petit ponar samples and 300 post-hole digger samples were collected during ten sampling trips from June 2007 to January 2010 (Table 3). A total of 39 live zebra mussels were collected with the petit ponar from upper Bayou Lafourche above RKM 34 and no live zebra mussels were collected with the post-hole digger therefore post-hole digger samples were not used in the analyses. Mean benthic zebra mussel densities were low (< 60 mussel/m^2) in Bayou Lafourche, with 1.8% of ponar samples (19 of 1,050 ponar grabs) containing live zebra mussels. However, zebra mussels did exhibit seasonal and spatial trends in abundance (Figures 14, 15 and 16). Mean zebra mussel abundance decreased (0.00176 mussels/RKM) downstream ($P < 0.05$). The highest zebra mussel abundances occurred during the spring and fall and

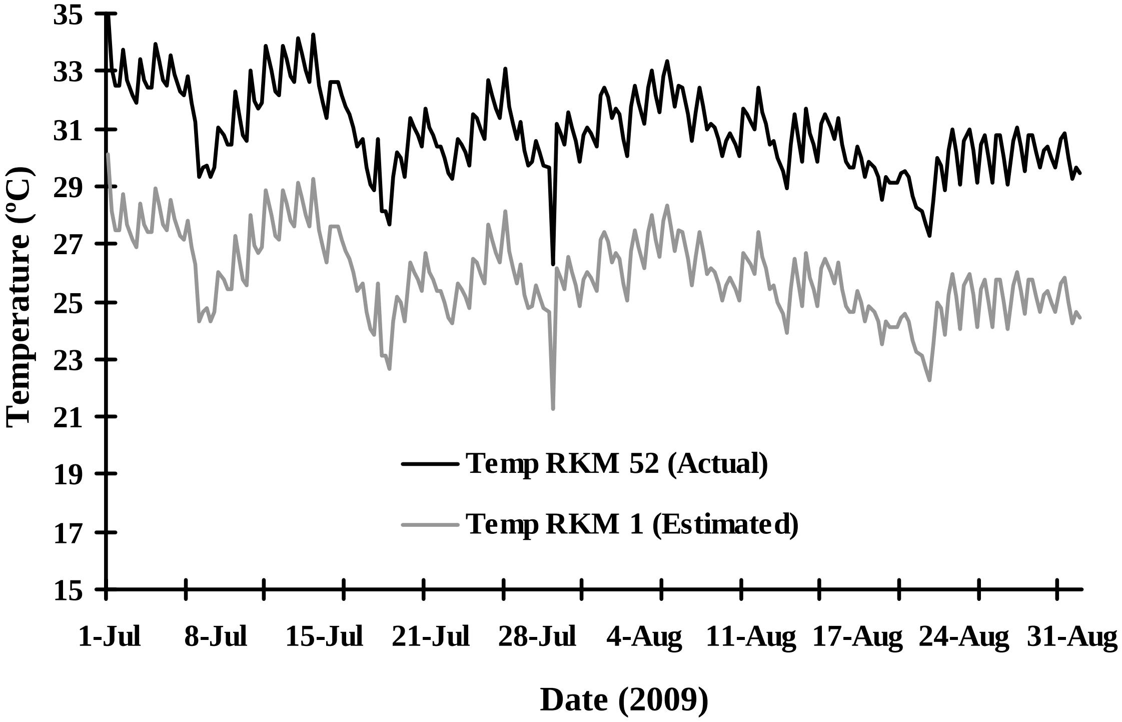

Figure 12. Summer water temperatures recorded every six hours at RKM 52 from 1 July 2009 to 31 August 2009, and estimated water temperatures at the Donaldsonville pumping station (RKM1) based on regression analysis (Figure 11). Summer water temperatures increased 0.1ºC/RKM downstream from RKM 1 to RKM 54.

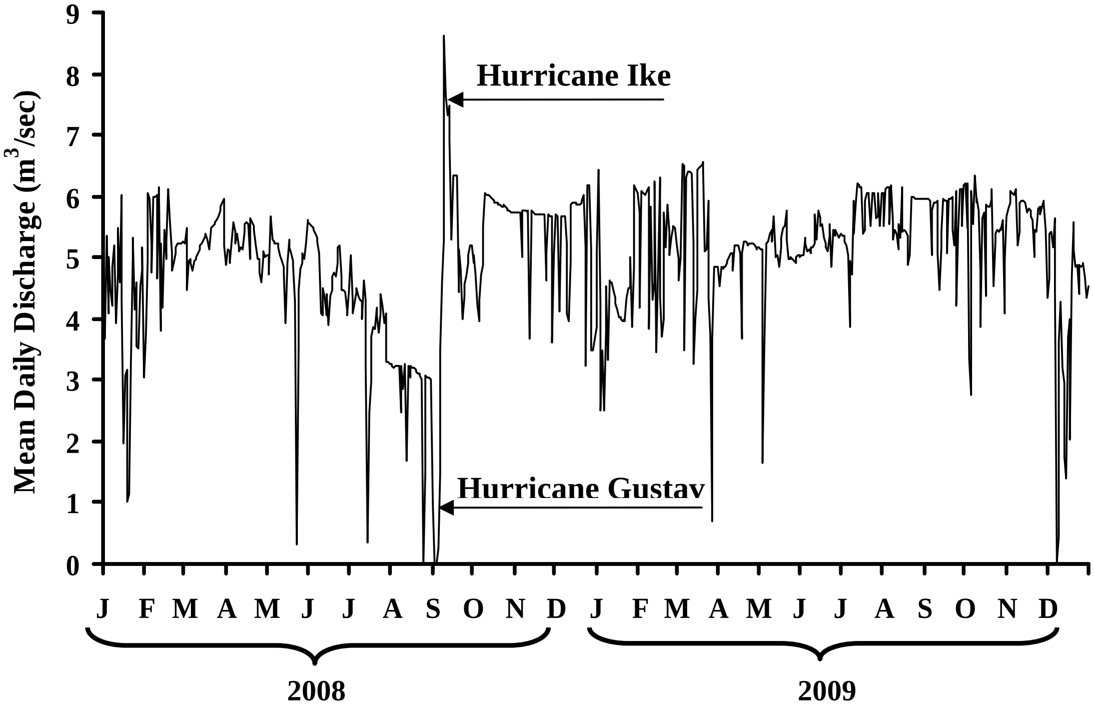

Figure 13. Daily discharge (m^3/sec) of Bayou Lafourche at the Donaldsonville pumping station in 2008 and 2009. In September 2008 the pumps were not running due to a power outage from Hurricane Gustav, which made landfall on 1 September 2008. The high discharge during September 2008, was due to Hurricane Ike, which made landfall on 14 September 2008.

Table 3. Ten seasonal sampling trips were made from 21 June 2007 to 26 January 2010. Each sample was sampled at least twice from June 2007 to January 2010.

YEAR	**DATE**	**SEASON**
2007	21, 22, 23 June	Summer
	23, 26 October	Fall
2008	9, 10 March	Spring
	4, 5 October	Fall
2009	11, 12 January	Winter
	4, 5 April	Spring
	23, 27 June	Summer
	14, 19 August	Summer
	27 October, 23 November	Fall
2010	25, 26 January	Winter

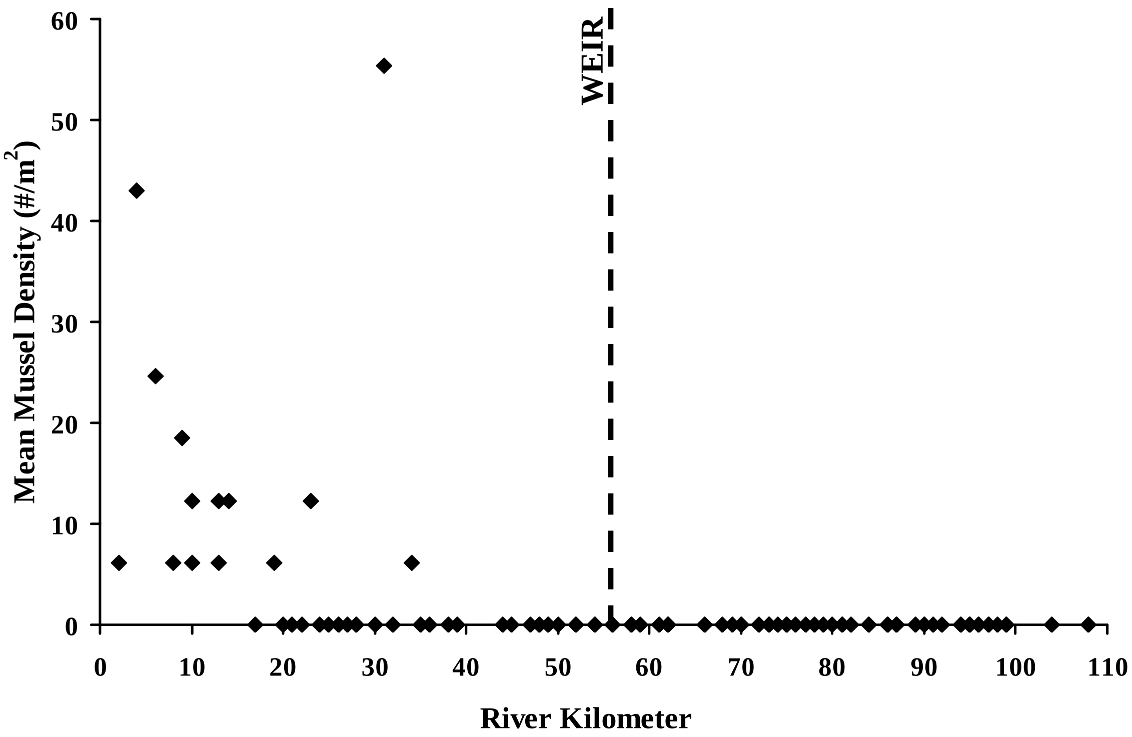

Figure 14. Mean live zebra mussel density from ponar grab samples by river kilometer from June 2007 to January 2010 from Donaldsonville (RKM 1) to the GIWW (RKM 110). Live zebra mussels were only collected above the Thibodaux weir (RKM 54; denoted by the dashed black line).

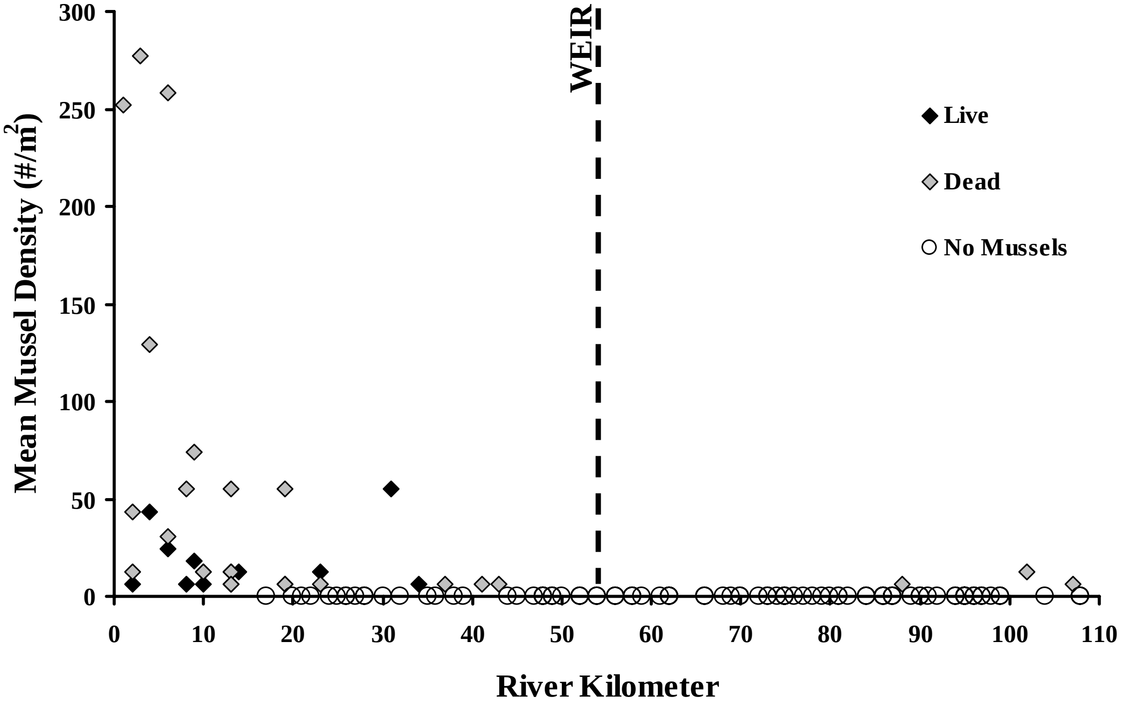

Figure 15. Mean densities of live and dead zebra mussels from ponar grab samples by river kilometer from June 2007 to January 2010 from Donaldsonville (RKM 1) to the GIWW (RKM 110). No live zebra mussels were collected below the Thibodaux weir (RKM 54). The open circles on the x-axis represent samples containing no live or dead zebra mussels.

the lowest occurred in the winter and summer months. During the fall, the highest zebra mussel abundance occurred in the uppermost reach of Bayou Lafourche (RKM 1 to 10). Zebra mussels were more widely dispersed during the winter and spring, although no live mussels were collected from the benthos downstream of RKM 34 (Figures 14, 15 and 16).

Principal Component Analysis

Principal component analysis (PCA) produced two principal components that accounted for 73.7% of the variation. Principal component 1 (PC1) accounted for 50.7 % of the variation and principal component 2 (PC2) accounted for 23% of the variation. On PC1, temperature and specific conductance were negatively loaded and DO was positively loaded (Figure 17; Table 4). Zebra mussel abundance was positively loaded on PC2. Bayou Lafourche exhibited seasonal variation in physicochemical parameters, but measured parameters did not predict zebra mussel abundance. In summer, water temperatures and specific conductivity were high and DO was low. In contrast, winter water temperatures and specific conductivity were low and DO was high. Spring and fall months were transitional between summer and winter water conditions. Zebra mussel abundance was highest in spring and fall, respectively and was lowest in winter and summer.

Regression analysis

Although temperature and DO were thought to limit zebra mussel distribution in south Louisiana, no water quality variable was related to mussel abundance in Bayou

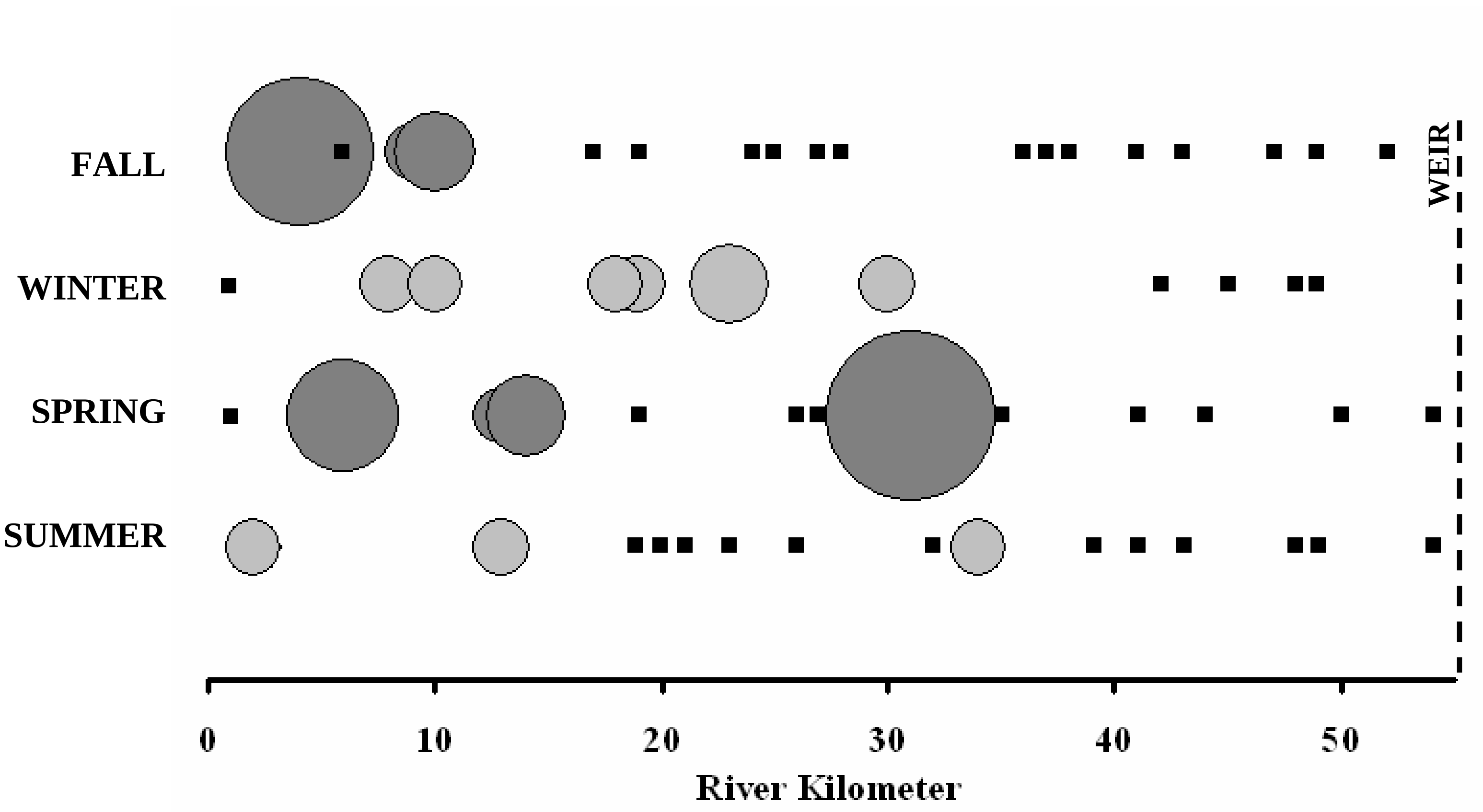

Figure 16. Seasonal zebra mussel abundance by river kilometer above the Thibodaux weir (RKM 54) from June 2007 to January 2010. Circle diameter represents total number of live zebra mussels at each transect site. The black squares represent transects where no live zebra mussels were collected. In the summer, live zebra mussels were only collected by benthic sampling in June 2009 (N=3).

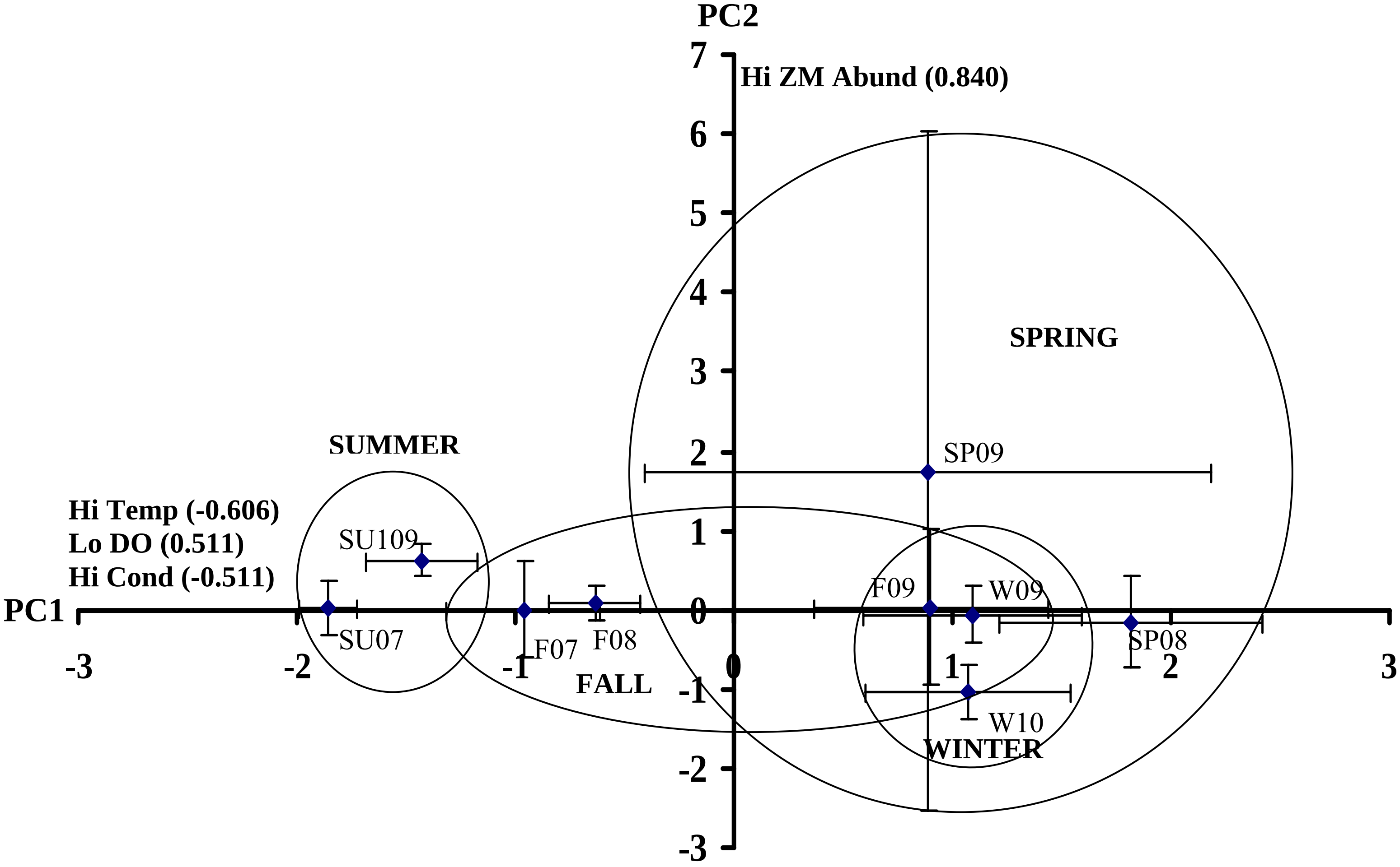

Figure 17. Seasonal associations between principal components 1 and 2 (PC1 and PC2). PC1 accounted for 50.7% of the variation and PC2 accounted for 23% of the variation among temperature (Temp), dissolved oxygen (DO), conductivity (Cond) and zebra mussel abundance (ZM abund). Loadings (>0.4) are listed to describe each parameter and the error bars represent the 95% confidence intervals.

Table 4. Zebra mussel abundance and water quality PCA loadings with PC1 explaining 50.3% of the variation and PC2 explaining 23% of the variation. Loadings > 0.4 were used in analyses (bold).

VARIABLE	**PC1**	**PC2**
Mean ZM Abundance	0.33	**0.84**
Temperature (ºC)	**-0.606**	0.305
Dissolved Oxygen (mg L^{-1})	**0.511**	0.214
Specific Conductance (μS)	**-0.511**	0.395

Lafourche. There was no relationship between physiochemical parameters and zebra mussel abundance. However, mean zebra mussel abundance decreased (0.00176 mussels/RKM) downstream ($P < 0.05$).

Hard Surface Scrapings

Zebra mussel presence on bridge pilings extended as far as RKM 39.4 (Figure 18). No live mussels were collected below this point, although two concrete bridges were available for colonization at RKM 50.5 and 51.5.

Temperature Tolerance

Acclimated adult zebra mussels survived temperatures up to 32 ±1ºC, although 100% mortality occurred at 33 ±1ºC with 50% mortality occurring at 31.1 ± 1ºC (Figure 19). Mean (± SE) daily mortality rates for the control treatment was 0.52 ± 0.11 mussels per day.

Seasonal Growth Patterns

Zebra mussels collected from Bayou Lafourche with the petit ponar and bridge scrapings exhibited seasonal growth from spring 2008 to winter 2010 (Figures 20 and 21). Mean (±SE) total shell length ranged from 7.7 ± 0.37 in winter (January) 2009 to 14.9 ± 0.33 in early summer (June) and 14.2 ± 0.17 in late summer (August) 2009. Mean zebra mussel total shell length from winter 2009 was smaller than the mean total shell length in summer 2009 ($P < 0.05$; Figure 22).

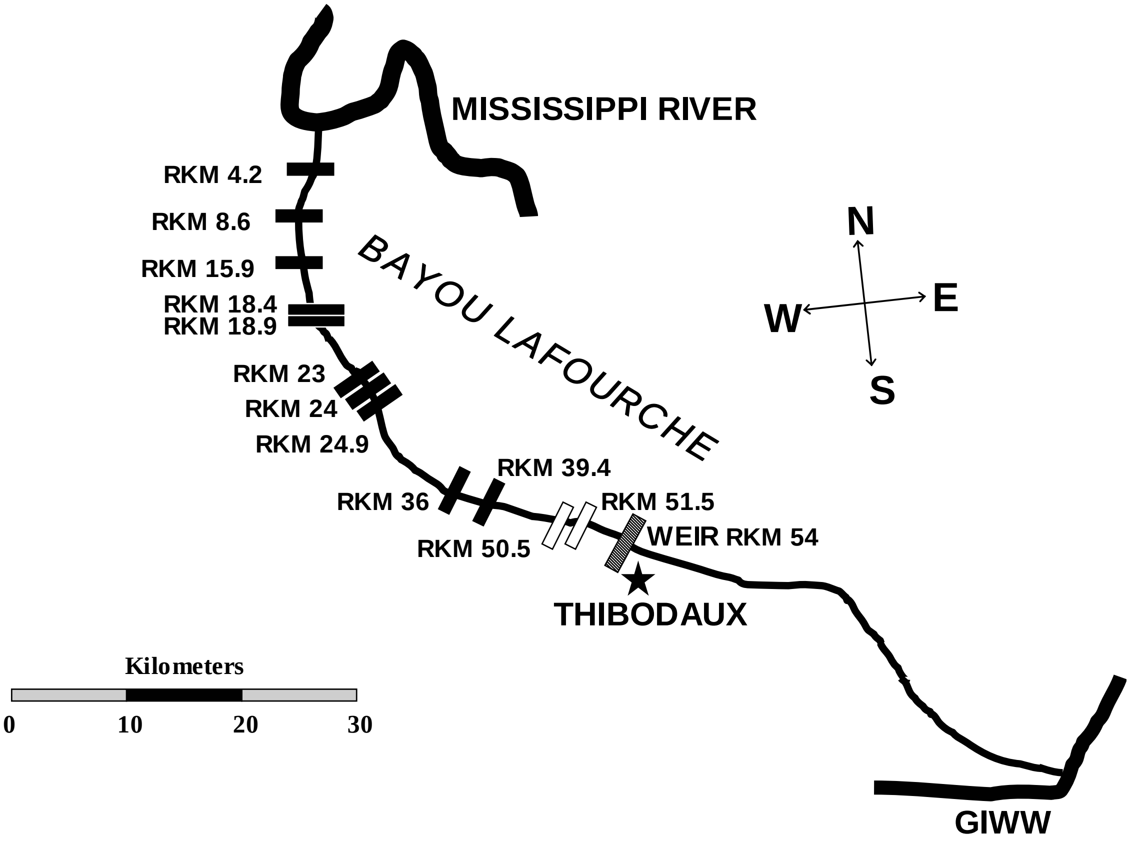

Figure 18. Twelve concrete bridges (extending from Donaldsonville, RKM 1, to Thibodaux, RKM 51.5) were scraped seasonally for zebra mussels to assess presence from June 2007 to January 2010. Zebra mussels were collected from all bridges shaded black. No zebra mussels were collected at, or below, bridges represented by white bars (RKMs >50.5).

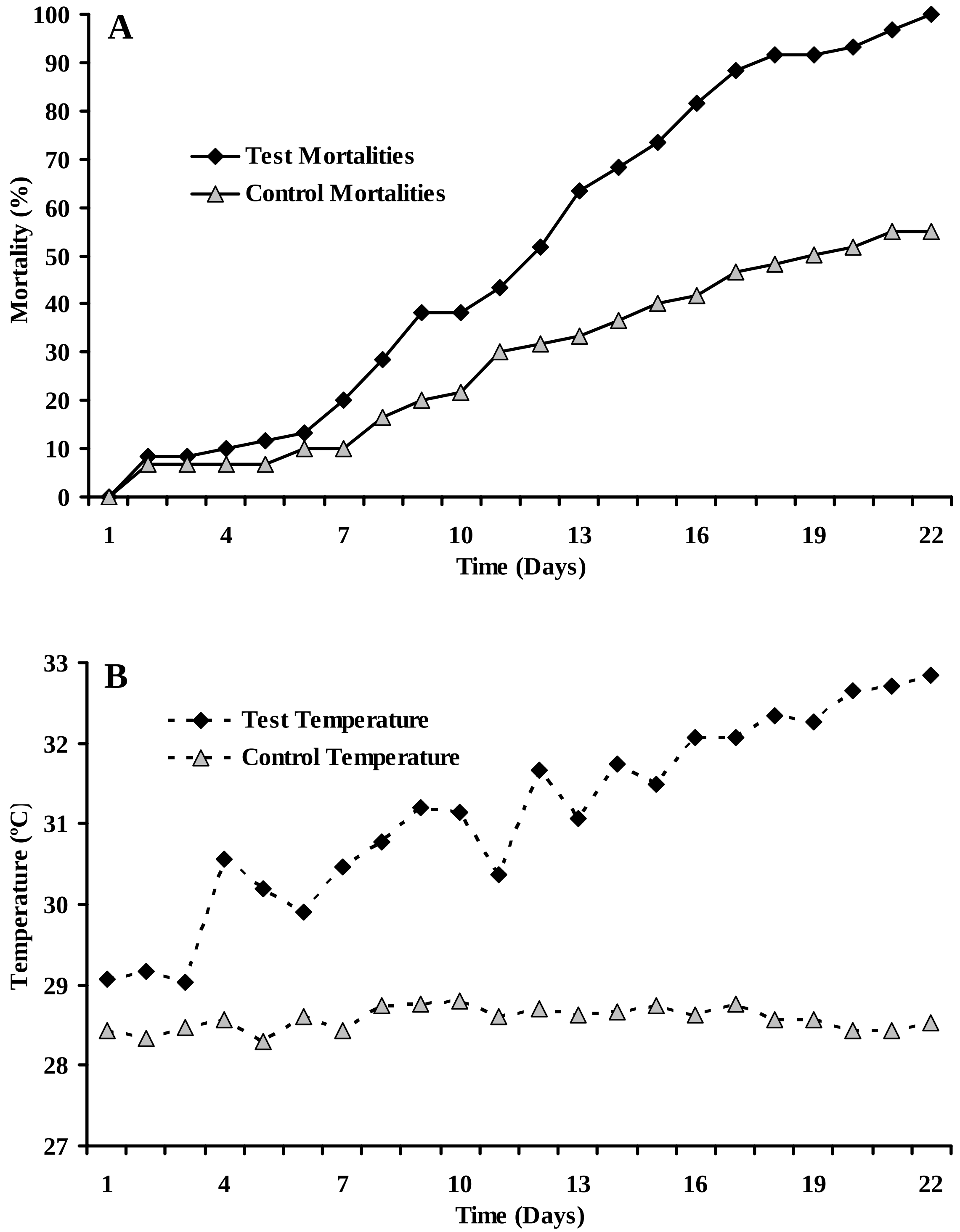

Figure 19. Zebra mussel temperature tolerance mortality (A) and water temperature (B) per day. Acclimated adult zebra mussels survived temperatures up to 33 ±1ºC, with 50% mortality occurring at 31.1 ± 1ºC. The experimental temperature was increased 1 ± 1ºC every five days and the control temperature was maintained at 28.5 ± 1ºC.

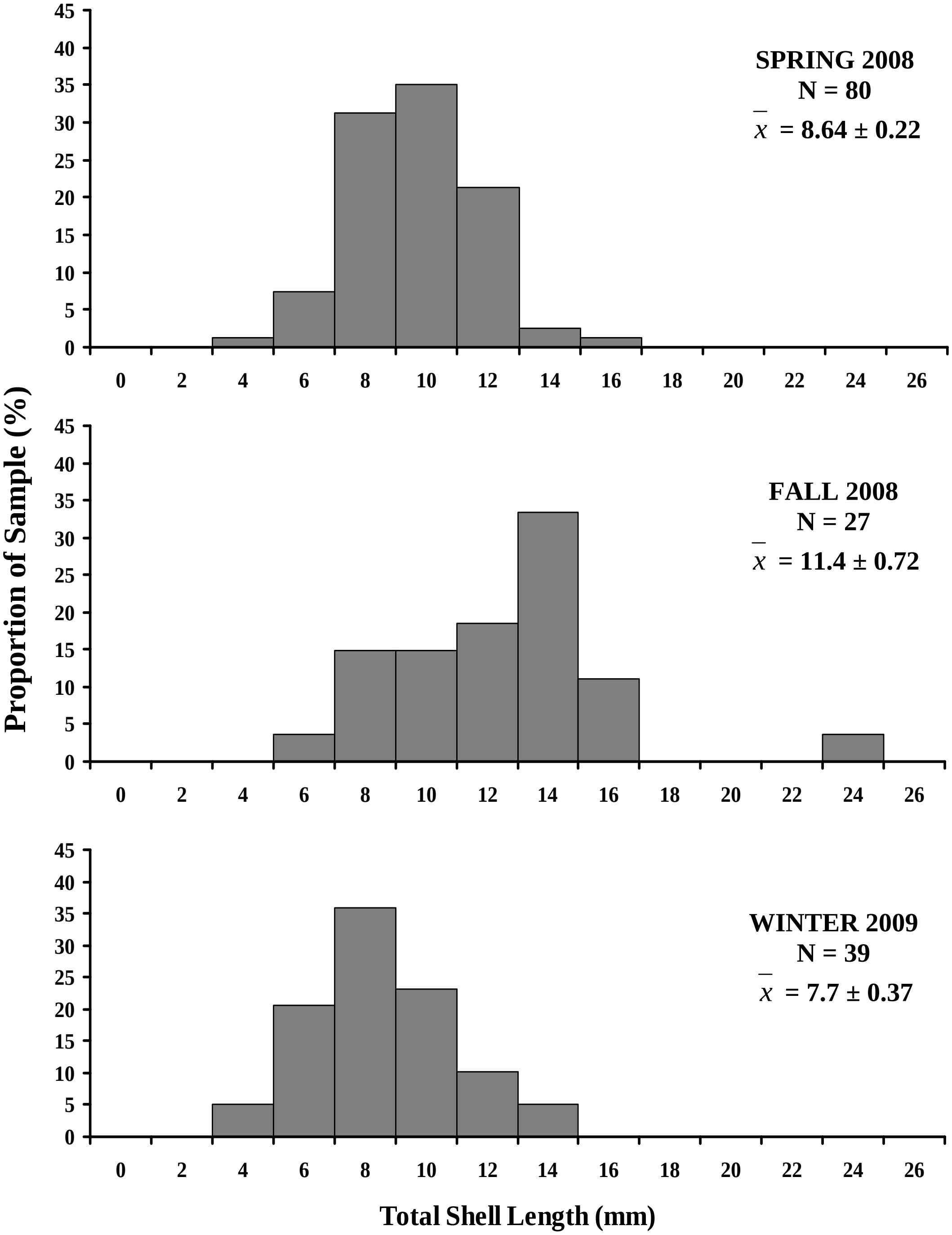

Figure 20. Selected length frequency distributions, sample size (N), and mean (± SE) of zebra mussels in Bayou Lafourche from spring 2008 through winter 2009. All samples were taken from benthic ponar grabs and from bridge scrapes in the upper part of the bayou (RKM < 40). Other seasons and years were not included due to low sample sizes (N<10).

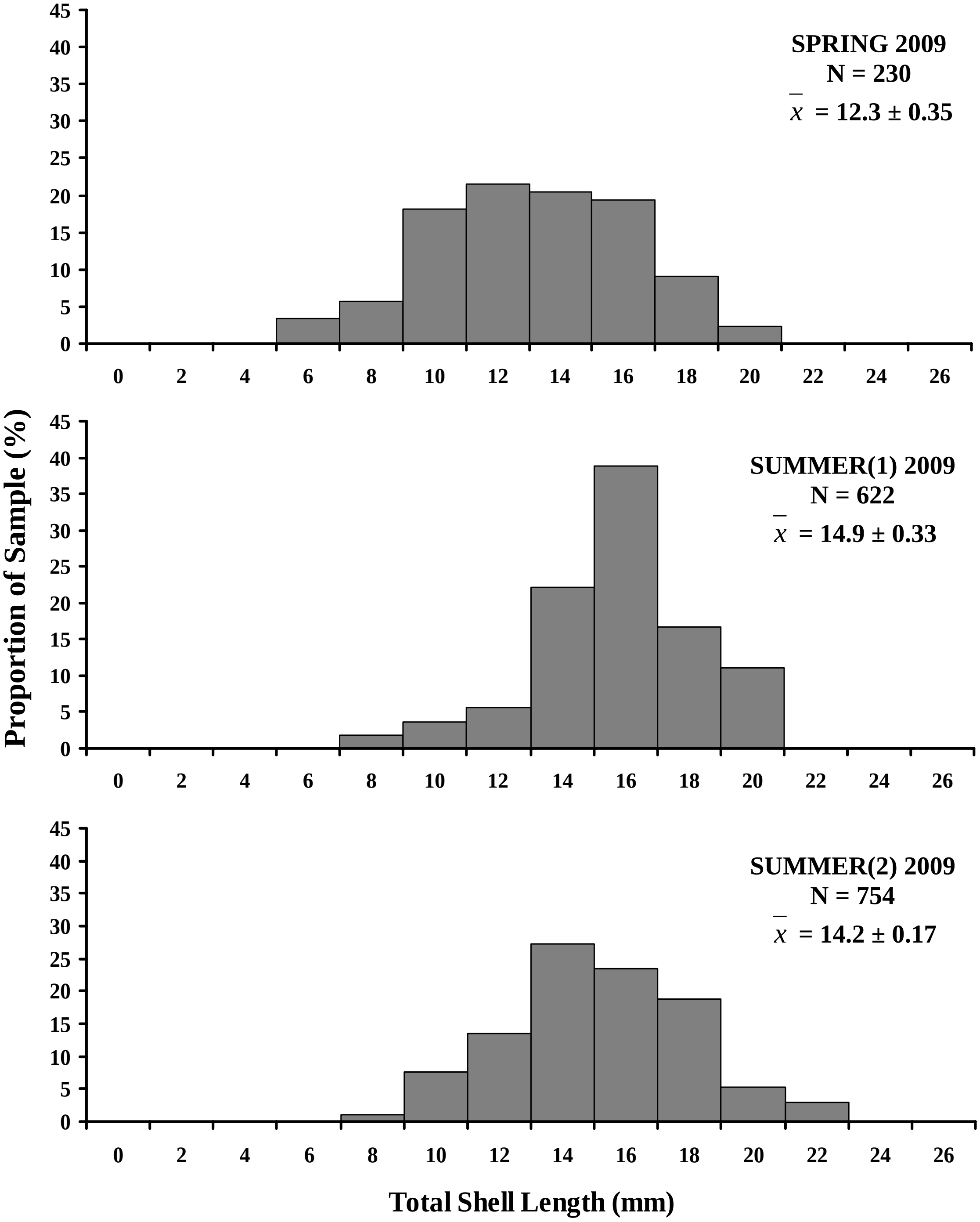

Figure 21. Selected length frequency distributions, sample size (N), and mean (± SE) of zebra mussels in Bayou Lafourche from spring 2009 through late summer 2009. All samples were taken from benthic ponar grabs and from bridge scrapes in the upper part of the bayou (RKM < 40). Other seasons and years were not included due to low sample sizes (N<10).

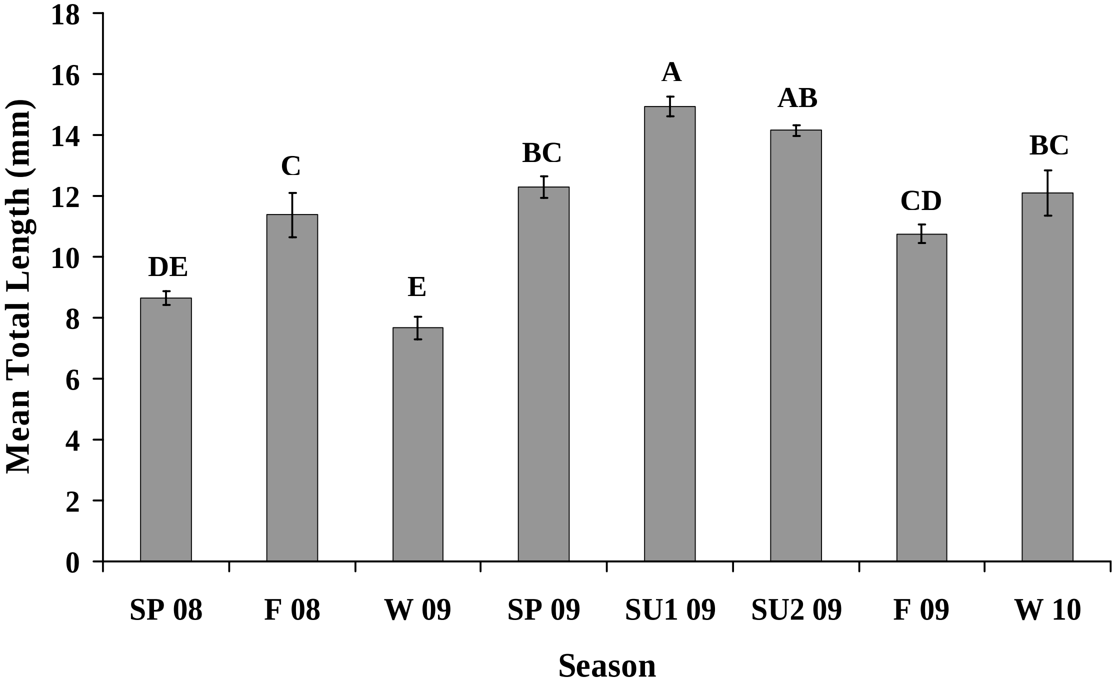

Figure 22. Mean (± SE) total length (mm) of zebra mussels collected with benthic sampling and bridge scrapings during the spring (March) and fall (October) of 2008, the winter (January), spring (April), early summer (June), late summer (August) and fall (October/November) of 2009, and the winter (January) of 2010. Letters above samples represent Tukey groupings based on ANOVA results and denote differences among sample seasons.

Asian Clam

Benthic Sampling

Benthic sampling for the Asian clam occurred with seasonal zebra mussel sampling, from January 2009 to January 2010 (Table 3) and consisted of 628 petit ponar samples and 182 post-hole digger samples. A total of 2,099 live Asian clams were collected from Bayou Lafourche, above the Thibodaux weir ($\leq$ RKM 54). Only one live clam was collected below the Thibodaux weir (RKM 54; Figure 23) and few (N=8) were collected with the post-hole digger, therefore post-hole digger samples were not included in analyses. Asian clams dominated the benthic bivalve fauna (76.2%), with 22.8% (N=143) of benthic ponar samples (N=628) containing Asian clams. Mean Asian clam densities ranged from 0 to 3,210 clams/m^2, and the range of densities was 0 to 6,070 clams/m^2. The highest Asian clam density (6,070 clams/m^2) was collected in the upper part of Bayou Lafourche (RKM 6) during fall 2009 (27 October 2009).

Principal Component Analysis

PCA produced two principal components that accounted for 73.9 % of the variation. PC1 accounted for 46.3% of the variation and PC2 accounted for 30.5% of the variation. Loadings (>0.4) were used to describe each physiochemical and abundance parameter. On PC1, temperature and specific conductance were positively loaded (Figure 24; Table 5). Asian clam abundance was positively loaded with DO negatively loaded on PC2.

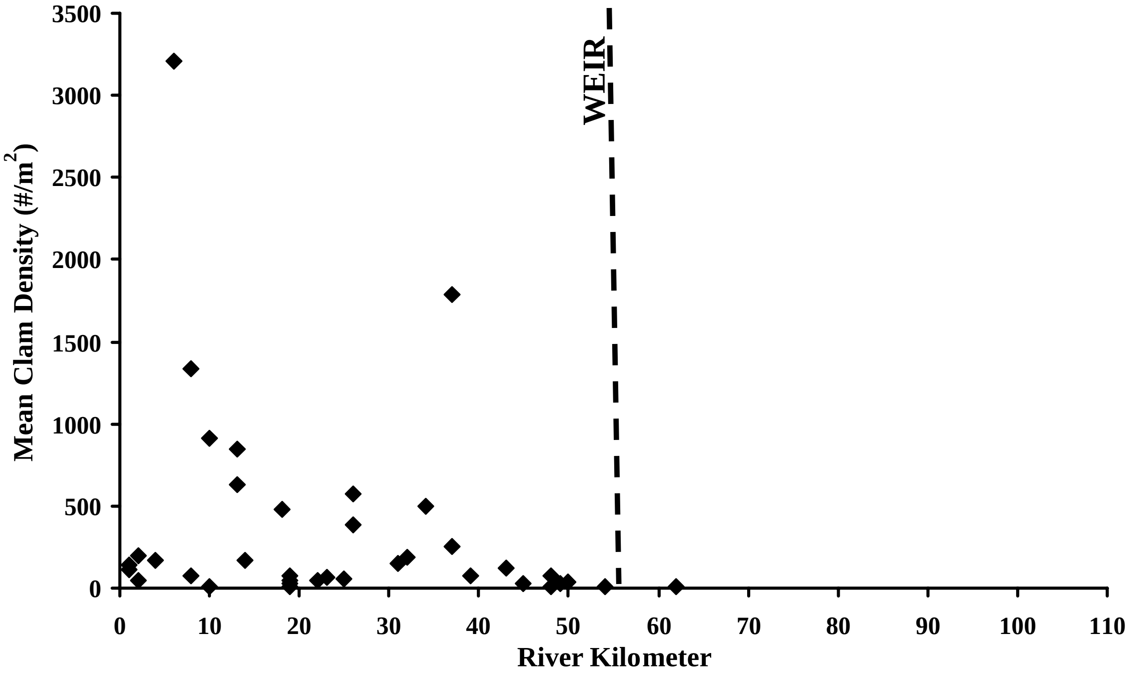

Figure 23. Mean live Asian clam density (#/ m^2) by river kilometer collected from January 2009 to January 2010 from Donaldsonville (RKM 1) to the GIWW (RKM 110).

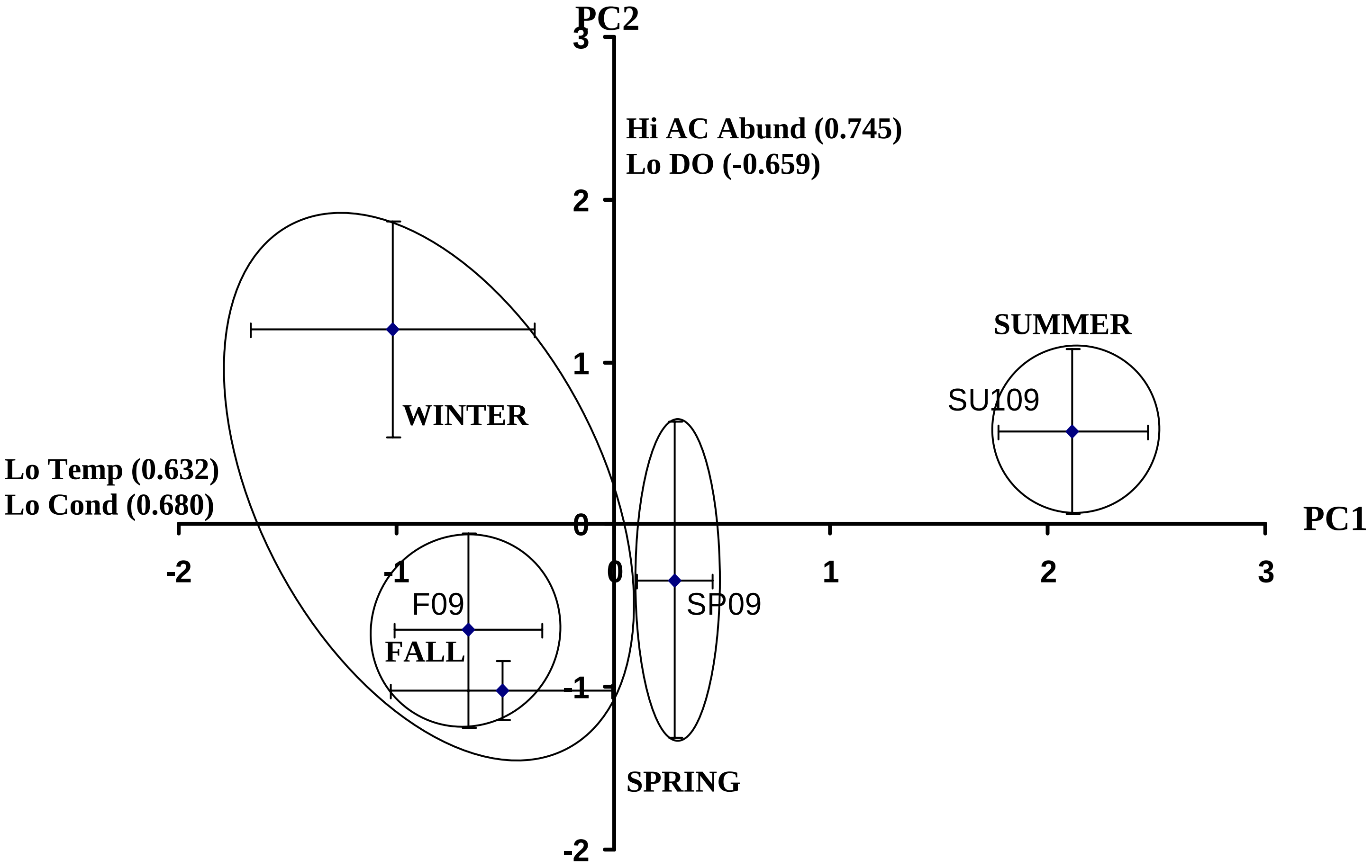

Figure 24. Seasonal associations between principal components 1 and 2 (PC1 and PC2). PC1 accounted for 46.3% of the variation and PC2 accounted for 30.5% of the variation among temperature (Temp), conductivity (Cond), dissolved oxygen (DO) and Asian clam abundance (AC Abund). Loadings (>0.4) are listed to describe each parameter.

Table 5. Asian clam abundance and water quality PCA loadings with PC1 explaining 46.3% of the variation and PC2 explaining 30.5% of the variation. Loadings > 0.4 were used in analyses (bold).

VARIABLE	PC1	PC2
Mean AC Abundance	-0.182	**0.745**
Temperature (ºC)	**0.632**	-0.103
Dissolved Oxygen (mg L^{-1})	-0.323	**-0.659**
Specific Conductance (μS)	**0.68**	-0.017

Seasonal Growth Patterns

Based on regression analysis, Asian clams were widely dispersed throughout the upper half of Bayou Lafourche (RKM < 54; Figures 23 and 25), and abundance above the weir did not vary with river kilometer. Asian clams collected from Bayou Lafourche with the petit ponar from January 2009 to January 2010 showed seasonal growth patterns (Figures 26 and 27). Mean (± SE) total shell length ranged from 8.4 ± 0.23 mm to 12.5 ± 0.09 mm. The largest Asian clam (12.5 ± 0.09mm) was collected in fall 2009 and the smallest Asian clam (8.5 ± 0.23mm) was collected in spring 2009 ($P < 0.05$; Figure 28).

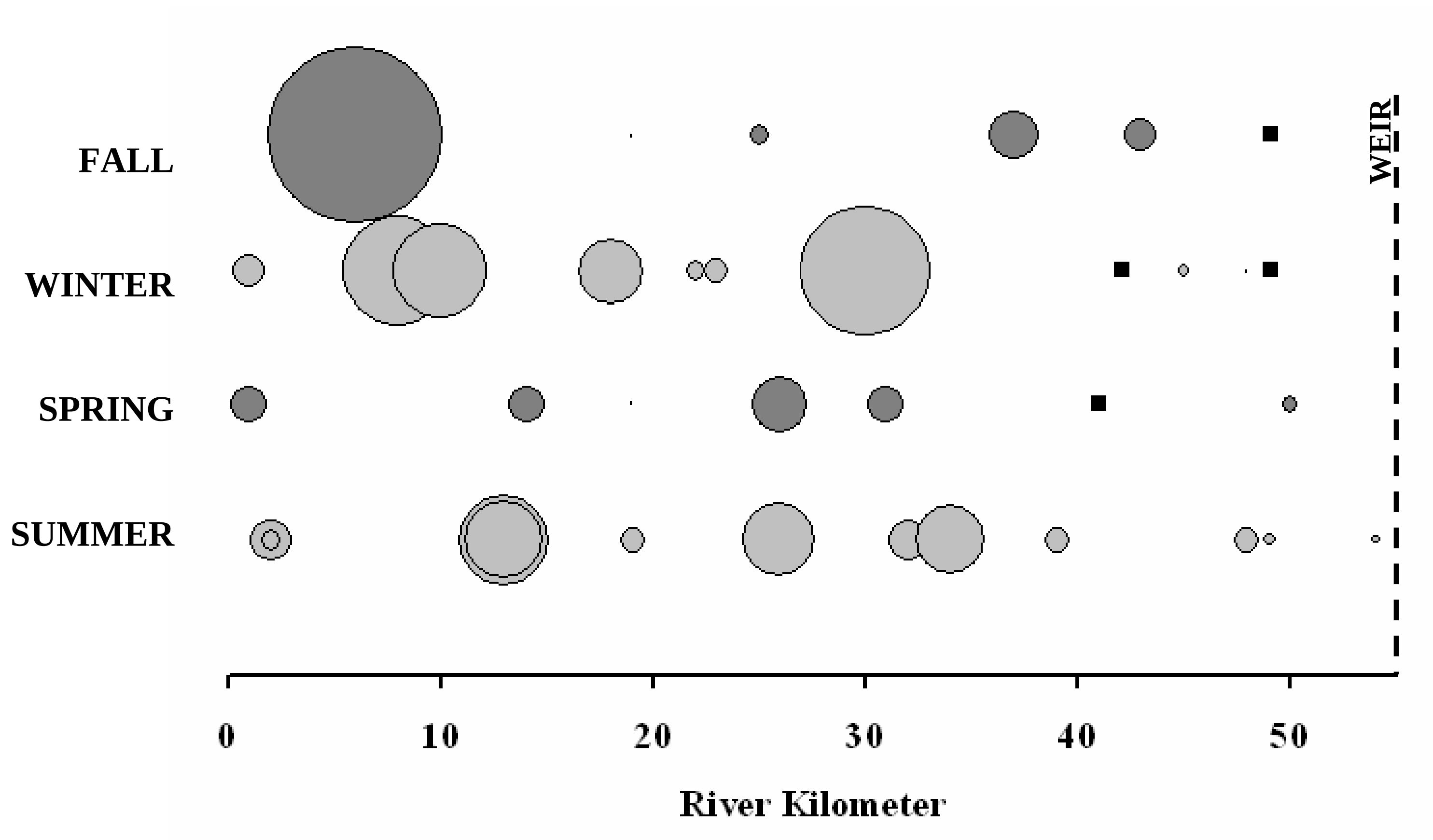

Figure 25. Seasonal trends in Asian clam abundance by river kilometer above the Thibodaux weir (RKM 54) from winter 2009 to January 2010. Circle diameter represents total live Asian clam abundance at each transect site, excluding the black squares, which represent transects sampled with no Asian clams present.

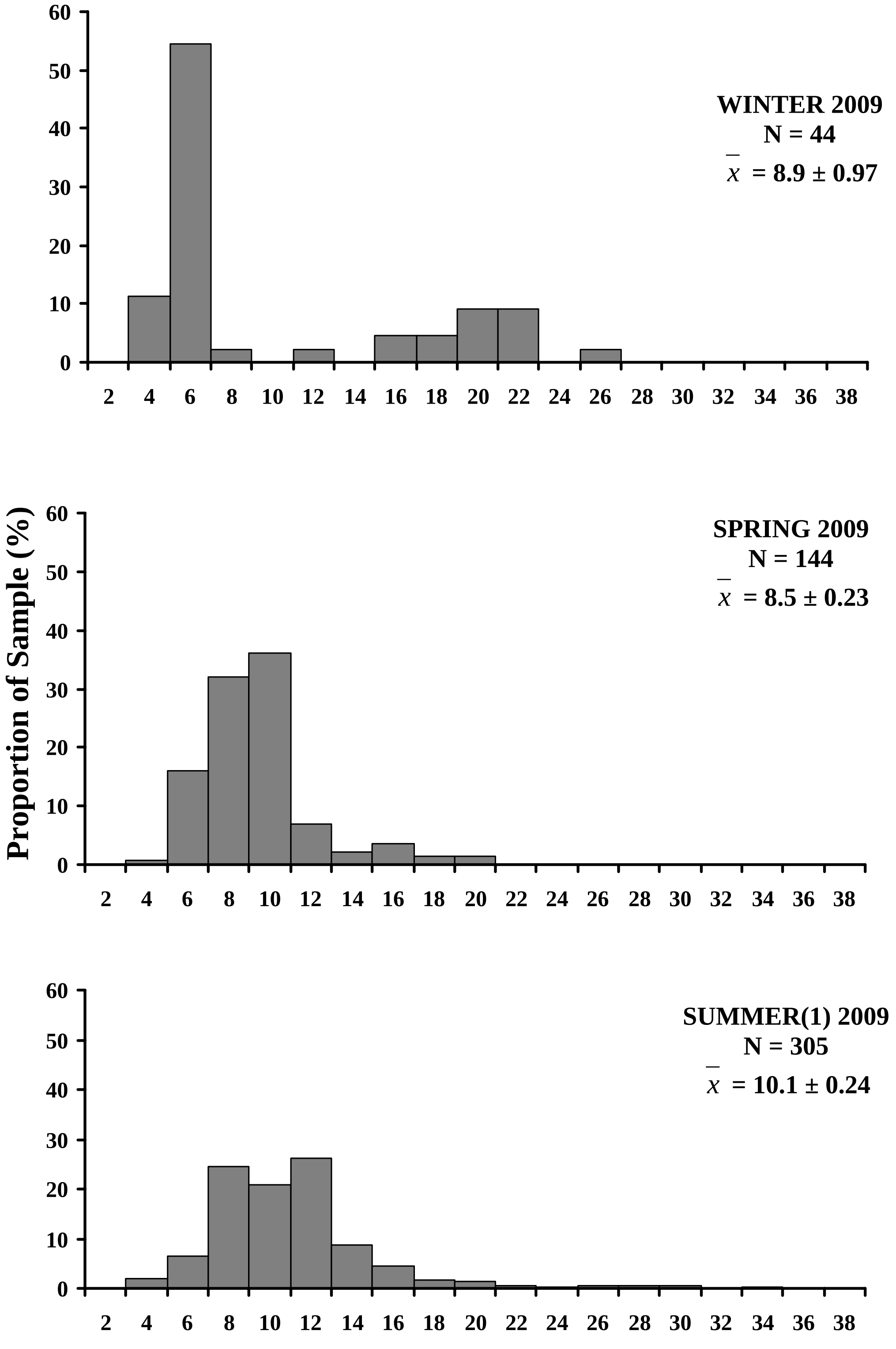

Figure 26. Length frequency distributions, sample size (N), and mean (± SE) of Asian clams in Bayou Lafourche from winter 2009 through summer 2009. All samples were taken with benthic ponar grabs in the upper half of Bayou Lafourche (RKM ≤ 54).

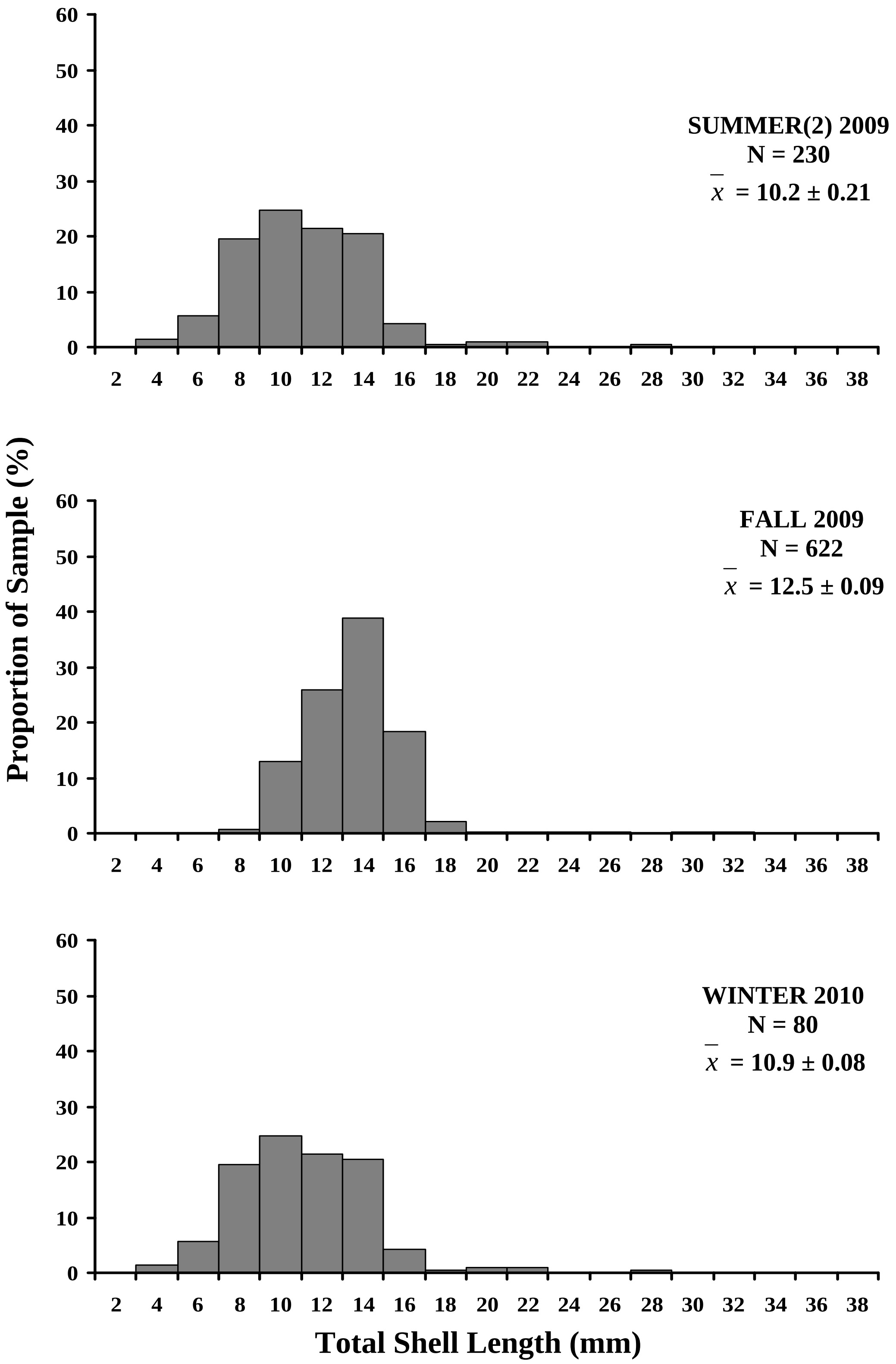

Figure 27. Length frequency distributions, sample size (N), and mean (± SE) of Asian clams in Bayou Lafourche from summer 2009 through winter 2010. All samples were taken with benthic ponar grabs in the upper half of Bayou Lafourche (RKM ≤ 54).

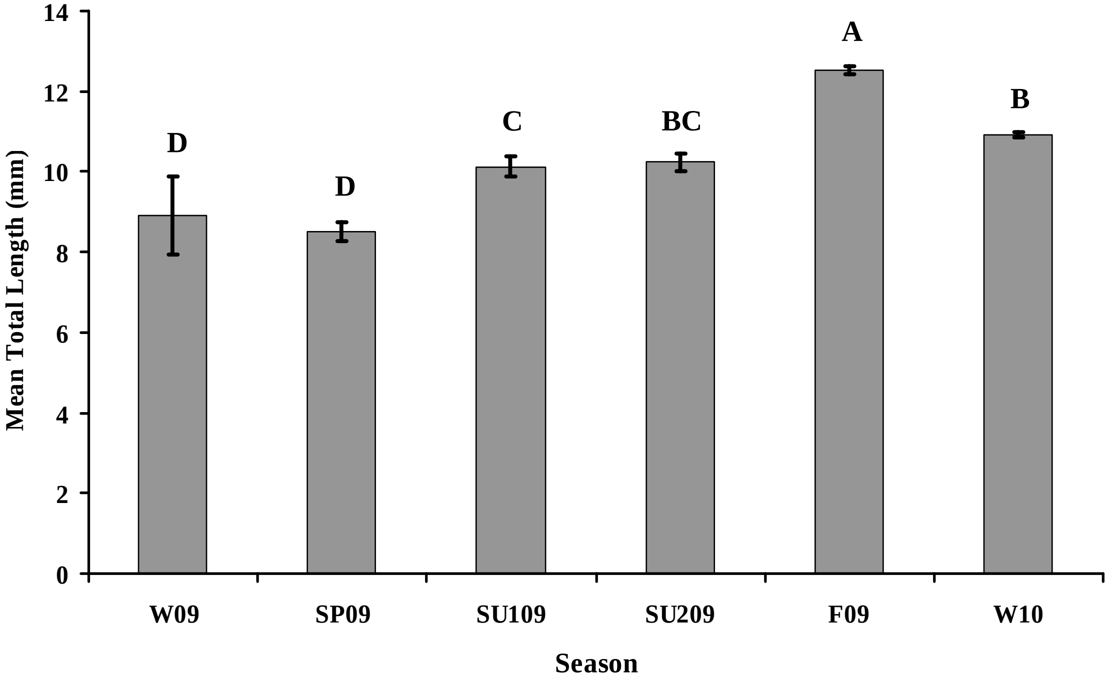

Figure 28. Mean (± SE) total length (mm) of Asian clams collected with a petit ponar during the winter (January), spring (April), early summer (June), late summer (August) and fall (October/November) of 2009, and the winter (January) of 2010. Letters above samples represent Tukey groupings based on ANOVA results and denote differences among sample seasons.

DISCUSSION

Freshwater bivalve distribution and abundance is influenced by the capacity to disperse, physical variables, and anthropogenic activities (McMahon and Bogan 2001). Differences among these factors allow some freshwater bivalve species to dominate mussel communities or to be more widespread than others. Non-native, invasive species, such as the zebra mussel and the Asian clam have relatively widespread distributions in North America. In contrast, many native freshwater mussel species have more restricted distributions (McMahon and Bogan 2001). In Bayou Lafourche, the range of zebra mussels, Asian clams and at least five species of unionids overlap. Unfortunately, not all interactions between native and invasive species are fully understood (Benson 1999).

Dispersal capacities vary among mussel species found in Bayou Lafourche. Zebra mussels produce a free-swimming veliger stage that can remain suspended in the water column for two to four weeks (Sprung 1993), depending on water temperature. The lower Mississippi River has an established zebra mussel population, providing a constant source of zebra mussel veligers for Bayou Lafourche via the Donaldsonville pumping station. As a result, the highest adult zebra mussel abundances in Bayou Lafourche occur closest to the pumping station (RKM < 40). Juvenile Asian clams can also be passively dispersed by water currents and can disperse via aquatic birds (McMahon 1999). Juvenile Asian clams produce byssal-like threads consisting of mucus; which become tangled in algae or the feet of wading birds (McMahon 1999). In Bayou Lafourche, Asian clams dominate the bivalve fauna and are widely dispersed above the Thibodaux weir. Asian clams occur in high densities above the weir (6,070 clams/m^2), but are virtually absent below the weir. In contrast to the invasive bivalves, native freshwater mussels require fish hosts for larval development and dispersal (Baur 1994). Baur (1994) determined that some freshwater mussel species (Margaritiferidae) are limited to specific habitats due to narrow host-fish ranges. Host-fish ranges are limited by geological and anthropogenic barriers that prevent fish migration. Watters (1996) described two unionid species, the fragile papershell *Leptodea fragilis* and pink heelsplitter *Potamilus alatus*, that had restricted distribution because a dam served as a barrier to fish passage. The Thibodaux weir prevents upstream fish passage except during high flows when the weir is overtopped (>15 cm precipitation/24 hours; Archie Chaisson, Bayou Lafourche Freshwater District, personal communication). Although, no live native freshwater mussels were collected below the weir, potential distribution is restricted to areas that are accessible to fish-hosts. Live *Toxilasma parvum* were collected above the Thibodaux weir, suggesting suitable habitat that is not accessible to fish-hosts and to native freshwater mussels located below the weir. Additionally, recently dead specimens of *Glebula rotundata*, *Pyganodon grandis* and *Quadrula apiculata* were collected in a drainage canal that connects with Bayou Lafourche (RKM 72), below the weir. Native mussel species are able to persist in Bayou Lafourche, although the potential range may be restricted to areas accessible to fish-hosts.

Bivalve distribution is also influenced by physical factors such as water quality and the availability of suitable substrate. Bayou Lafourche has seasonal fluctuations in temperature, DO and specific conductance. Additionally, the daily discharge of the Donaldsonville pumping station fluctuates (0 to 8.6 m^3/sec), which directly influences temperatures in the upper part of Bayou Lafourche, and suspended sediment levels.

Bivalves are ectothermic organisms, and temperature plays a key role in overall physiology (McMahon and Bogan 2001). Zebra mussels are more susceptible to temperature induced mortality from high summer water temperatures than are Asian clams, and unionids (Mathews and McMahon 1999). The Asian clam can tolerate temperatures up to 34ºC (Mattice and Dye 1976), and possibly as high as 37ºC (Morgan et al. 2003). In contrast, the zebra mussel lethal limit is lower (approximately 32ºC to 35ºC; Alexander and McMahon 2004), although Iwanyzki and McCauley (1993) suggested that zebra mussels cannot tolerate chronic prolonged temperatures above 30ºC. Reproduction occurs at cooler water temperatures (10ºC to 26ºC; Sprung 1987), and does not occur above 29ºC (Allen et al. 1999). Like many organisms, the juvenile zebra mussel is more sensitive to high water temperatures than the adult stage. Although veligers have been collected at temperatures up to 29ºC in Poland (Lewandowski and Ejsmont-Karabin 1983), Sprung (1987, 1992, 1993) suggested that larval development is not successful above 24ºC. Mihuc et al. (1999) determined that zebra mussel settlement in the Atchafalaya River can occur up to approximately 31ºC. In Bayou Lafourche, estimated water temperatures in Donaldsonville never exceeded 30ºC, but increased downstream (0.1ºC/ RKM), potentially influencing zebra mussel distribution (Figure 29). Based on previous studies, reproduction ceases at 29ºC (Allen et al. 1999) and is unlikely to occur below RKM 14 during the summer in Bayou Lafourche. Settlement ceases at approximately 31ºC (Mihuc et al. 1999) and is unlikely to occur below RKM 34 during the summer. Bayou Lafourche zebra mussels are unlikely to survive temperatures above 32ºC, and therefore may not occur below RKM 44 in Bayou Lafourche. Live zebra

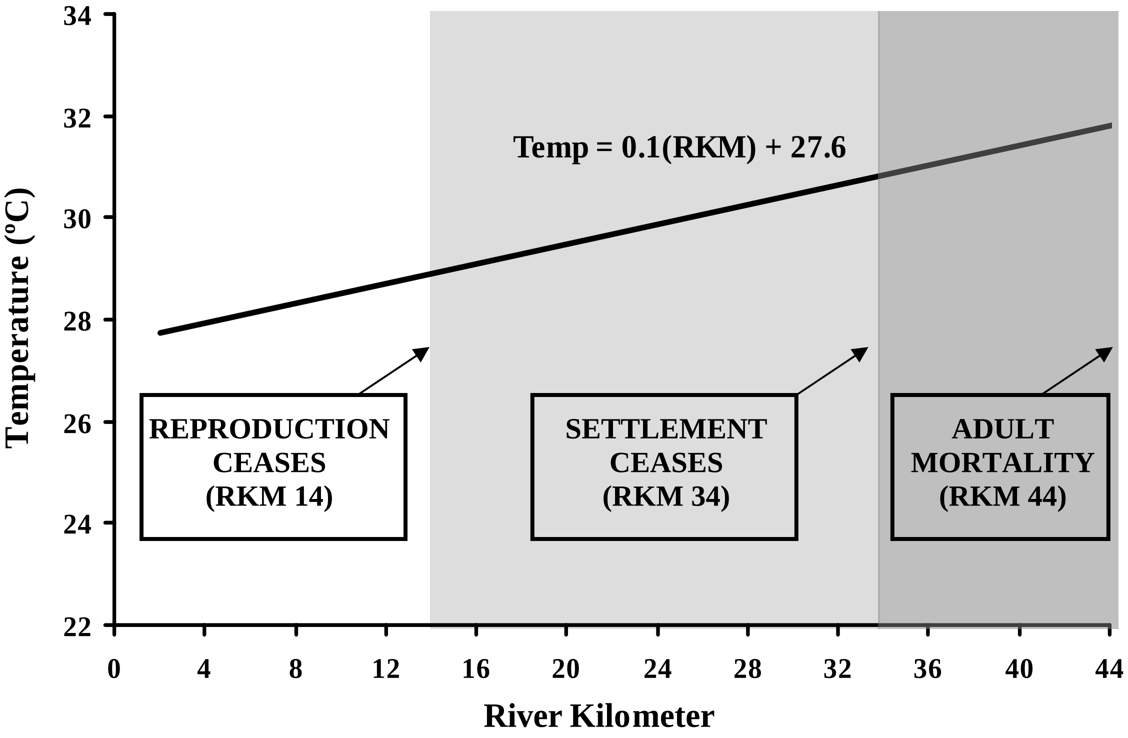

Figure 29. Predicted ranges by RKM for zebra mussel reproduction, settlement and adult mortality in Bayou Lafourche. Summer water temperatures in Bayou Lafourche may influence zebra mussel reproduction, settlement and mortality. Summer water temperatures in Donaldsonville never exceeded 30ºC, but did increase downstream (0.1ºC per RKM), thus influencing zebra mussel distribution. During the summer, reproduction ceases at approximately RKM 14, settlement ceases at approximately RKM 34 and adult mortality occurs at approximately RKM 44.

mussels were never collected below the bridge at RKM 39.4. Suitable substrate was limited and the next concrete bridge pilings were located at RKMs 50.5 and 51.5; where water temperatures may exceed the thermal lethal limit for zebra mussels. Allen et al. (1999) suggested that the level of adult summer mortality is related to acclimation and successful growth during the transitional temperatures in the spring and fall.

The rate of temperature acclimation influences zebra mussel lethal temperature limits. Laboratory and field studies have demonstrated that a longer acclimation period increased the upper thermal lethal limit of zebra mussels (McMahon 1996; Elderkin and Klerks 2005). Discharge can influence temperatures of a lotic water body, and ultimately influence the acclimation period for zebra mussels. In 1996, Allen et al. (1999) found that the Mississippi River took approximately one month to warm from 12 to 20ºC. In 1997, high discharge extended the warming period (12 to 20ºC) to 2.5 months (Allen et al. 1999). Bayou Lafourche is a much smaller system and the rate of seasonal temperature change is more rapid, producing a shorter spring acclimation period. Additionally, Bayou Lafourche is controlled by a pumping station, eliminating the natural flood pulse (Tye and Kosters 1986) that may have historically moderated temperature increases.

Periodic hypoxia (<2 mg/L) is common in floodplain regions of the Atchafalaya River Basin, particularly during summer months (Mihuc et al. 1999). Zebra mussels cannot tolerate prolonged periods of hypoxia (Matthews and McMahon 1999). Bayou Lafourche had hypoxic conditions immediately following Hurricane Gustav (landfall on 1 September 2008). The pumping station ceased operation for three days, eliminating flow and freshwater input. No flow, warm water temperatures and rotting debris caused water quality to deteriorate. Anoxic (<0.2 mg/L) conditions were recorded in upper Bayou Lafourche (RKM 25) on 7 September 2008 (26.7ºC) and on 10 September 2008 (28.4ºC; LADEQ 2008). On 4 October 2008, two live zebra mussels (11mm and 12mm TL) were collected from a bridge in the same region (RKM 18.4). Compared to other bivalves, zebra mussels and Asian clams are less tolerant of low dissolved oxygen conditions (Matthews and McMahon 1999). Matthews and McMahon (1999) determined that at 25ºC, Asian clams were unable to survive hypoxic conditions for more than 17 days, versus zebra mussels, which were unable to survive beyond 8 days under the same conditions. The Donaldsonville pumping station discharge was extremely low (≤ 3.5 m^3/sec) from 1 to 7 September 2008. The discharge returned to a normal (>4 m^3/sec) rate on 8 September 2008. Hypoxia was recorded for at least three days immediately following Hurricane Gustav, but the exact duration of the hypoxic event is unknown. The zebra mussels were most likely able to persist due to proximity to the pumping station.

Freshwater bivalve distribution is influenced by the availability of suitable substrate (McMahon and Bogan 2001). For benthic bivalves, sediment size influences distribution (Mellina and Rasmussen 1994) and Bayou Lafourche consists of silt, clay and sand (Tornqvist and Bridge 2002). Strayer and Ralley (1993) found virtually no unionids in areas with high amounts of silt and Strayer (1999) determined that few unionids were found in low flow environments. Although, *T. parvum, G. rotundata, Q. apiculata* and *P. grandis* may inhabit environments with little or no flow, containing sand or mud substrates (Williams et al. 2008). Asian clams settle in a variety of sediment types including, sand, silt, clay, mud, gravel, gravel and boulders (McMahon 1999).

Zebra mussels are epifaunal bivalves that attach to substrates via byssal threads. Although zebra mussels do attach to sand, mud and vegetation (Berkman et al. 1998), zebra mussels have a preference for hard substrates such as rock (dolomite/limestone) and steel (Ackerman et al. 1996). Due to the sediment composition of Bayou Lafourche, substrate may be a limiting factor for zebra mussels. Zebra mussels were found on concrete bridge pilings during summer months, but were rarely collected in benthic ponar samples. Kilgour and Mackie (1993) found that sheltered areas have higher zebra mussel abundances. The concrete bridges provide a preferred substrate for attachment and some degree of protection and shading, creating a microhabitat that is suitable for zebra mussel colonization and survival throughout the year.

Anthropogenic activities play a major role in shaping native and invasive bivalve communities. Modification of freshwater habitats can have a negative impact on native freshwater mussel abundances. Stream channelization, habitat fragmentation, poor land use practices (Straka and Downing 2000; Poole and Downing 2004) and dams (Watters 1996; Vaughn and Taylor 1999) directly impact freshwater environments. Freshwater mussel abundance and diversity is also shaped by chemical pollutants, such as toxicants, and “biological pollutants” (McMahon and Bogan 2001) such as non-native, invasive species. Numerous chemicals have been shown be toxic to juvenile mussels. Bringolf et al. (2007) found that juvenile *Lampsilis siliquoidea* were sensitive to MON 818 (an ingredient in Roundup©). Native freshwater mussel species diversity in Bayou Lafourche is low relative to surrounding regions. Vidrine (1993) reported 20 freshwater mussel species in the Atchafalaya River Basin and 32 species in Bayou Teche, Louisiana. Only five native freshwater mussel species were collected from Bayou Lafourche. Habitat modification, invasive species introductions and chemical pollution are possible reasons for low freshwater mussel diversity in Bayou Lafourche.

Impoundments alter the natural hydrology of freshwater systems (Watters 1999), changing sedimentation patterns, altering flows (Miller and Payne 1992), changing water depths and temperatures and preventing fish passage (Watters 1996). Increased sedimentation from poor agricultural practices can suffocate sedentary mussels that are not adapted to silty substrates (Bogan 1993). Bivalves are considered bioindicators of aquatic environmental health because they are sedentary and filter feed from the water column (Neves 1993). Bayou Lafourche is surrounded by agriculture (sugarcane) and residential development (CH2M HILL 2005). Additionally, a series of interconnecting drainage canals feed into Bayou Lafourche. The scope of this study did not address these particular anthropogenic effects on the mussel community, but they likely play a role in shaping the benthic biodiversity of Bayou Lafourche.

The ecological effects of invasive species introductions on native species are usually not fully understood (Strayer 2009). Zaiko et al. (2007) determined that habitats favored by native bivalve species are also favored by invasive bivalve species, with high invasive species diversity occurring in the habitats that contain high native species diversity. In Bayou Lafourche, the ranges of non-native, invasive bivalves overlap with native freshwater mussels where interspecific competition and direct physical interaction can shape the freshwater mussel community leading to low abundance of native bivalves and high abundance of invasive bivalves.

Filtration rates vary with bivalve species and densities. Asian clams have a higher filtration rate (0.3-10 m^3/m^2/day) than zebra mussels (0.1-5 m^3/m^2/day) and unionids

(0.1-0.3 m^3/m^2/day; Strayer 1999). Although zebra mussel densities are relatively low (< 60 mussel/m^2) in upper Bayou Lafourche, Asian clam densities can reach (6,070 clams/m^2). Highly abundant bivalves with high filtration rates may outcompete other benthic organisms. In Bayou Lafourche, no live unionids were collected in areas where Asian clams (> 1 clam/m^2) occurred.

Invasive bivalves can act as ecosystem engineers (Vanderploeg et al. 2002), providing habitat in a substrate limited environment and further facilitating the spread of other invasive species (Gutiérrez et al. 2003). Bivalve shells consist of calcium carbonate ($CaCO_3$) crystals suspended in a protein matrix (McMahon and Bogan 2001), and are often slow to decay (Strayer and Malcom 2007). In regions with soft sediments, live and dead bivalve shells provide substrate for zebra mussel attachment, allowing for further colonization in substrate limited environments (Hunter and Bailey 1992). In Bayou Lafourche, live zebra mussels (N=2) were found attached to live and dead Asian clam shells.

Bayou Lafourche is the southernmost extent of zebra mussel distribution in North America, surpassing initial predicted thermal and geographic ranges (Strayer 1991). In Bayou Lafourche, zebra mussels survive warm summer water temperatures (>30ºC), high sediment loads and periodic low dissolved oxygen levels (<2 mg/L). The Asian clam can tolerate higher summer water temperatures and is widespread throughout the U.S. (USGS 2010), including other southern states (McMahon 1982; Dundee and Dundee 1958). In contrast, the diversity of native freshwater mussels is declining (Williams et al. 1993; Neves et al. 1997; Williams et al. 2008). Only five species of native freshwater bivalves were collected from Bayou Lafourche and none of these species are currently of conservation concern (Williams et al. 2008).

Bayou Lafourche is a slow moving, riverine system that is an artificially controlled distributary of the Mississippi River. Zebra mussels in Bayou Lafourche occur at low densities (< 60 mussel/m^2) only in the upper part of Bayou Lafourche (RKM < 40) and are probably stressed during high summer water temperatures, high suspended sediment loads and periodic hypoxia. In southern Louisiana, higher zebra mussel densities occur in large river systems such as the Lower Mississippi River (400,000 mussels/ m^2; Kraft 1995) or the Atchafalaya River (1,200 mussels/m^2; Mihuc et al. 1999). In contrast, zebra mussel densities in the Great Lakes can reach 700,000-800,000 mussels/m^2 (Kovalak 1993). Zebra mussel densities in Bayou Lafourche are influenced by temperature, and ultimately flow regimes.

The Mississippi River Water Reintroduction into Bayou Lafourche is a project that aims to increase flows and improve water quality by allowing more Mississippi River water to flow into Bayou Lafourche. The goal of the project is to supply freshwater and sediment to nearly 500 km^2 of disappearing coastal Louisiana marshes, in addition to providing a reliable drinking water source to 300,000 area residents (CH2M HILL 2005). Additional aspects of the project include dredging the upper part of Bayou Lafourche, and the removal of the Thibodaux weir. The mean annual discharge of Bayou Lafourche is expected to increase from approximately 5 m^3/second to between 28 and 57 m^3/sec, depending on the project design (CH2M HILL 2005). In Donaldsonville, water temperatures in Bayou Lafourche are driven by Mississippi River temperatures and discharge at the Donaldsonville pumping station. Increased flows that will result from the reintroduction project may decrease temperatures further downstream and may increase zebra mussel veliger input in Bayou Lafourche, possibly allowing the zebra mussel range to expand. However, improved water quality conditions in Bayou Lafourche may provide long term benefits to native freshwater mussel populations. Although, consequences associated with dredging (Williams et al. 2008) may be detrimental to native freshwater bivalves throughout the system. Hydrologic changes can alter sedimentation patterns and cause further declines in native freshwater bivalve populations (Hartfield 1993; Neves 1993; Neves et al. 1997).

Freshwater bivalve distribution in Bayou Lafourche is influenced by dispersal capacities, environmental factors and anthropogenic activities. Non-native invasive bivalves dominated the bivalve community, with few native mussels collected during this study. Zebra mussel densities were low, and distribution was influenced by proximity to the pumping station. Additionally, Bayou Lafourche acts as a sink for Mississippi River zebra mussel veligers. Asian clam densities were high above the Thibodaux weir. The only live native freshwater mussel species collected was *T. parvum*, although shells of four other recently dead species were found in Bayou Lafourche and connected waterways. None of the freshwater mussels species collected in this study are currently listed as federal species of concern. However, the community composition of bivalves in Bayou Lafourche reflects a highly disturbed freshwater ecosystem.

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Appendix I. Zebra mussel collection date (year, month, day) from June 2007 to January 2010 in Bayou Lafourche, transect number, sample replicate (#), gear type (PD, PN), bayou side (HWY 1, HWY 308 or middle), river kilometer (RKM), above or below the Thibodaux weir (weir), sample season/year (season), total zebra mussel abundance from sample (Abund).

Date	Transect	#	Type	Side	Weir	SeasonYr	RKM	Abund
20080301	Upper2	4	PN	1	Above	Sp08	13	1
20080309	Upper1	5	PN	M	Above	Sp08	6	4
20080309	Upper2	5	PN	M	Above	Sp08	13	1
20081004	Upper1	4	PN	1	Above	F08	9	1
20081004	Upper1	5	PN	M	Above	F08	9	1
20081004	Upper1	6	PN	308	Above	F08	9	1
20081004	Upper2	4	PN	1	Above	F08	10	2
20090111	Upper1	6	PN	308	Above	W09	8	1
20090111	Upper2	6	PN	308	Above	W09	10	1
20090111	Upper3	6	PN	308	Above	W09	19	1
20090111	Upper5	5	PN	M	Above	W09	23	2
20090404	Upper2	4	PN	1	Above	S09	14	2
20090404	Upper5	4	PN	1	Above	S09	31	9
20090623	Upper1	7	PN	308	Above	Su109	2	1
20090623	Upper2	4	PN	1	Above	Su109	13	1
20090623	Upper5	5	PN	M	Above	Su109	34	1
20091027	Upper1	7	PN	308	Above	F09	4	7
20100125	Upper4	5	PN	M	Above	W10	18	1
20100125	Upper5	4	PN	1	Above	W10	30	1

Appendix II. Asian clam collection date (year, month, day) from January 2009 to January 2010 in Bayou Lafourche, transect number, sample replicate (#), gear type (PD, PN), bayou side (HWY 1, HWY 308 or middle), river kilometer (RKM), above or below the Thibodaux weir (weir), sample season/year (season), total Asian clam abundance from sample (Abund).

Date	Transect	#	Type	Side	Weir	SeasonYr	RKM	Abund
20090111	Upper1	5	PN	M	Above	W09	8	1
20090111	Upper1	6	PN	308	Above	W09	8	4
20090111	Upper1	3	PN	1	Above	W09	8	7
20090111	Upper2	5	PN	M	Above	W09	10	1
20090111	Upper3	4	PN	1	Above	W09	19	4
20090111	Upper4	6	PN	308	Above	W09	22	1
20090111	Upper4	7	PN	308	Above	W09	22	1
20090111	Upper4	5	PN	M	Above	W09	22	7
20090111	Upper5	2	PN	1	Above	W09	23	1
20090111	Upper5	5	PN	M	Above	W09	23	1
20090111	Upper5	6	PN	308	Above	W09	23	1
20090111	Upper5	3	PN	1	Above	W09	23	2
20090111	Upper5	4	PN	1	Above	W09	23	6
20090111	Middle1	5	PN	M	Above	W09	45	1
20090111	Middle1	9	PD	308	Above	W09	45	1
20090111	Middle1	8	PN	308	Above	W09	45	2
20090111	Middle2	4	PN	1	Above	W09	48	1
20090111	Middle3	3	PN	1	below	W09	62	2
20090404	Upper1	1	PD	1	Above	S09	1	1
20090404	Upper1	3	PN	1	Above	S09	1	1
20090404	Upper1	8	PN	308	Above	S09	1	1
20090404	Upper1	7	PN	308	Above	S09	1	2
20090404	Upper1	6	PN	308	Above	S09	1	3
20090404	Upper1	9	PD	1	Above	S09	1	3
20090404	Upper1	2	PN	1	Above	S09	1	4
20090404	Upper1	4	PN	1	Above	S09	1	4
20090404	Upper1	5	PN	M	Above	S09	1	4
20090404	Upper2	1	PD	1	Above	S09	14	1
20090404	Upper2	2	PN	1	Above	S09	14	1
20090404	Upper2	8	PN	308	Above	S09	14	1
20090404	Upper2	4	PN	1	Above	S09	14	4
20090404	Upper2	5	PN	M	Above	S09	14	6
20090404	Upper2	3	PN	1	Above	S09	14	7
20090404	Upper2	6	PN	308	Above	S09	14	7
20090404	Upper3	5	PN	M	Above	S09	19	1
20090404	Upper4	8	PN	308	Above	S09	26	3
20090404	Upper4	7	PN	308	Above	S09	26	4
20090404	Upper4	4	PN	1	Above	S09	26	11
20090404	Upper4	6	PN	308	Above	S09	26	16

Date	Transect	#	Type	Side	Weir	SeasonYr	RKM	Abund
20090404	Upper4	5	PN	M	Above	S09	26	28
20090404	Upper5	6	PN	308	Above	S09	31	2
20090404	Upper5	5	PN	M	Above	S09	31	7
20090404	Upper5	4	PN	1	Above	S09	31	16
20090404	Middle2	2	PN	1	Above	S09	50	6
20090623	Upper1	3	PN	1	Above	Su109	2	1
20090623	Upper1	5	PN	M	Above	Su109	2	1
20090623	Upper1	7	PN	308	Above	Su109	2	2
20090623	Upper1	8	PN	308	Above	Su109	2	3
20090623	Upper1	2	PN	1	Above	Su109	2	5
20090623	Upper1	4	PN	1	Above	Su109	2	20
20090623	Upper2	8	PN	308	Above	Su109	13	4
20090623	Upper2	7	PN	308	Above	Su109	13	10
20090623	Upper2	2	PN	1	Above	Su109	13	14
20090623	Upper2	3	PN	1	Above	Su109	13	15
20090623	Upper2	4	PN	1	Above	Su109	13	23
20090623	Upper2	5	PN	M	Above	Su109	13	31
20090623	Upper2	6	PN	308	Above	Su109	13	40
20090623	Upper3	2	PN	1	Above	Su109	19	1
20090623	Upper3	4	PN	1	Above	Su109	19	1
20090623	Upper3	8	PN	308	Above	Su109	19	1
20090623	Upper3	5	PN	M	Above	Su109	19	5
20090623	Upper4	3	PN	1	Above	Su109	32	1
20090623	Upper4	8	PN	308	Above	Su109	32	1
20090623	Upper4	5	PN	M	Above	Su109	32	3
20090623	Upper4	6	PN	308	Above	Su109	32	25
20090623	Upper5	2	PN	1	Above	Su109	34	3
20090623	Upper5	7	PN	308	Above	Su109	34	6
20090623	Upper5	3	PN	1	Above	Su109	34	11
20090623	Upper5	6	PN	308	Above	Su109	34	14
20090623	Upper5	5	PN	M	Above	Su109	34	47
20090623	Middle1	3	PN	1	Above	Su109	48	1
20090623	Middle1	7	PN	308	Above	Su109	48	1
20090623	Middle1	4	PN	1	Above	Su109	48	2
20090623	Middle1	5	PN	M	Above	Su109	48	9
20090627	Middle2	3	PN	1	Above	Su109	49	1
20090627	Middle2	5	PN	M	Above	Su109	49	3
20090814	Upper1	1	PD	1	Above	Su209	2	1
20090814	Upper1	2	PN	1	Above	Su209	2	1
20090814	Upper1	3	PN	1	Above	Su209	2	1
20090814	Upper1	4	PN	1	Above	Su209	2	1
20090814	Upper1	9	PD	308	Above	Su209	2	1
20090814	Upper1	5	PN	M	Above	Su209	2	3

Date	Transect	#	Type	Side	Weir	SeasonYr	RKM	Abund
20090814	Upper2	8	PN	308	Above	Su209	13	4
20090814	Upper2	2	PN	1	Above	Su209	13	5
20090814	Upper2	7	PN	308	Above	Su209	13	6
20090814	Upper2	5	PN	M	Above	Su209	13	16
20090814	Upper2	4	PN	1	Above	Su209	13	20
20090814	Upper2	3	PN	1	Above	Su209	13	51
20090814	Upper3	5	PN	M	Above	Su209	19	1
20090814	Upper3	7	PN	308	Above	Su209	19	1
20090814	Upper3	6	PN	308	Above	Su209	19	11
20090814	Upper4	2	PN	1	Above	Su209	26	3
20090814	Upper4	8	PN	308	Above	Su209	26	3
20090814	Upper4	3	PN	1	Above	Su209	26	9
20090814	Upper4	4	PN	1	Above	Su209	26	10
20090814	Upper4	7	PN	308	Above	Su209	26	12
20090814	Upper4	5	PN	M	Above	Su209	26	27
20090814	Upper4	6	PN	308	Above	Su209	26	29
20090814	Upper5	8	PN	308	Above	Su209	39	1
20090814	Upper5	7	PN	308	Above	Su209	39	5
20090814	Upper5	6	PN	308	Above	Su209	39	6
20090814	Middle1	3	PN	1	Above	Su209	54	2
20091027	Upper1	2	PN	1	Above	F09	4	2
20091027	Upper1	5	PN	M	Above	F09	4	2
20091027	Upper1	3	PN	1	Above	F09	4	5
20091027	Upper1	8	PN	308	Above	F09	4	7
20091027	Upper1	4	PN	1	Above	F09	4	12
20091027	Upper2	8	PN	308	Above	F09	6	12
20091027	Upper2	7	PN	308	Above	F09	6	31
20091027	Upper2	3	PN	1	Above	F09	6	44
20091027	Upper2	2	PN	1	Above	F09	6	64
20091027	Upper2	4	PN	1	Above	F09	6	107
20091027	Upper2	6	PN	308	Above	F09	6	123
20091027	Upper2	5	PN	M	Above	F09	6	141
20091027	Upper3	5	PN	M	Above	F09	19	1
20091027	Upper4	8	PN	308	Above	F09	25	1
20091027	Upper4	4	PN	1	Above	F09	25	2
20091027	Upper4	6	PN	308	Above	F09	25	2
20091027	Upper4	5	PN	M	Above	F09	25	4
20091027	Upper5	6	PN	308	Above	F09	37	2
20091027	Upper5	4	PN	1	Above	F09	37	5
20091027	Upper5	5	PN	M	Above	F09	37	35
20091027	Middle1	3	PN	1	Above	F09	43	2
20091027	Middle1	4	PN	1	Above	F09	43	2
20091027	Middle1	5	PN	M	Above	F09	43	16

Date	Transect	#	Type	Side	Weir	SeasonYr	RKM	Abund
20100125	Upper1	6	PN	308	Above	W10	1	2
20100125	Upper1	7	PN	308	Above	W10	1	3
20100125	Upper1	3	PN	1	Above	W10	1	14
20100125	Upper2	4	PN	1	Above	W10	8	4
20100125	Upper2	2	PN	1	Above	W10	8	5
20100125	Upper2	8	PN	308	Above	W10	8	6
20100125	Upper2	5	PN	M	Above	W10	8	13
20100125	Upper2	6	PN	308	Above	W10	8	14
20100125	Upper2	7	PN	308	Above	W10	8	70
20100125	Upper2	3	PN	1	Above	W10	8	105
20100125	Upper3	5	PN	M	Above	W10	10	1
20100125	Upper3	8	PN	308	Above	W10	10	2
20100125	Upper3	3	PN	1	Above	W10	10	10
20100125	Upper3	4	PN	1	Above	W10	10	11
20100125	Upper3	7	PN	308	Above	W10	10	19
20100125	Upper3	6	PN	308	Above	W10	10	24
20100125	Upper3	2	PN	1	Above	W10	10	82
20100125	Upper4	5	PN	M	Above	W10	18	78
20100125	Upper5	2	PN	1	Above	W10	30	2
20100125	Upper5	3	PN	1	Above	W10	30	16
20100125	Upper5	7	PN	308	Above	W10	30	48
20100125	Upper5	6	PN	308	Above	W10	30	65
20100125	Upper5	5	PN	M	Above	W10	30	68
20100125	Upper5	4	PN	1	Above	W10	30	92

BIOGRAPHICAL SKETCH

Kelsey Lynn Adkisson was born on 1 September 1982 in Seattle, Washington. She graduated from La Plata High School in La Plata, Maryland in 2001. Kelsey attended Western Washington University in Bellingham, Washington and received a Bachelor of Science degree in Environmental Science in June 2006. She worked for Oregon Department of Fish and Wildlife for two years and enrolled in graduate school at Nicholls State University in the August 2008. Kelsey is pursuing a Master of Science degree in Marine and Environmental Biology. After graduation she plans to pursue a career as a malocologist.

Kelsey L. Adkisson

1240 Plateau Drive ▪ Richland, Washington 99352 ▪ (503) 333-1424 ▪ Kelsey.Adkisson@gmail.com

EDUCATION

M.S. Candidate, Marine and Environmental Biology. May 2010. Nicholls State University, Thibodaux, LA, 70301. Thesis title: *Temporal and spatial distribution of native and invasive freshwater bivalves in Bayou Lafourche, Louisiana.*

B.S., Environmental Science. Spring 2006. Western Washington University, Bellingham, WA, 98225

TEACHING EXPERIENCE

Teaching Assistant, General Biology, Fall 2008 to Spring 2010
Teaching Assistant, Honors Biology, Costa Rica, 2009
Instructor, L'Ecole Cabanocey Private School, 2009

RESEARCH EXPERIENCE

1. Determined seasonal and spatial distribution of adult native and invasive mussels and clams in a southeastern Louisiana bayou

2. Conducted a study on temperature tolerance of zebra mussels, *Dreissena polymorpha*

3. Researched unionid reproduction in a southeastern Louisiana bayou

SCIENTIFIC PRESENTATIONS

Adkisson, K.L, Q.C. Fontenot and A.M. Ferrara. February 2010. Temporal and spatial distribution of native and invasive bivalves in Bayou Lafourche, Louisiana. 2010 Spring Meeting of the Southern Division of the American Fisheries Society, Ashville, North Carolina.

Adkisson, K.L., Q.C. Fontenot and A.M. Ferrara. January 2010. Temporal and spatial distribution of native and invasive bivalves in Bayou Lafourche, Louisiana. Annual Meeting of the Louisiana Chapter of the American Fisheries Society, Baton Rouge, Louisiana.

Adkisson, K.L., Q.C. Fontenot and A.M. Ferrara. January 2010. Temporal and spatial distribution of native and invasive bivalves in Bayou Lafourche, Louisiana. 2010 Nicholls State University Research Week, Thibodaux, Louisiana. (poster presentation, **2nd Place Graduate Student Competition**)

SCIENTIFIC PRESENTATIONS (continued)

Adkisson, K.L., Q.C. Fontenot and A.M. Ferrara. November 2009. Invasive bivalves in Bayou Lafourche, Louisiana. Louisiana Invasive Species Task Force Meeting, Baton Rouge, Louisiana.

Adkisson, K.L., Q.C. Fontenot and A.M. Ferrara. February 2009. Invasive bivalves in Bayou Lafourche, Louisiana. Louisiana Academy of Sciences, Hammond, Louisiana.

Adkisson, K.L., Q.C. Fontenot and A.M. Ferrara. February 2009. The effects of Hurricanes Gustav and Ike on zebra mussels in Bayou Lafourche, Louisiana. 2009 Nicholls State University Research Week, Thibodaux, Louisiana. (poster presentation, **1st Place Graduate Student Competition**)

Adkisson, K.L., Q.C. Fontenot, S. Burke, O. Smith and A.M Ferrara. January 2009. The effects of Hurricanes Gustav and Ike on zebra mussels in Bayou Lafourche, Louisiana. 2009 Spring Meeting of the Southern Division of the American Fisheries Society, New Orleans, Louisiana.

Adkisson, K.L., Q.C. Fontenot and A.M. Ferrara. November 2008. The effects of Hurricanes Gustav and Ike on zebra mussels in Bayou Lafourche, Louisiana. Louisiana Invasive Species Task Force Meeting, Baton Rouge, Louisiana.

RELATED WORK EXPERIENCE

Oregon Department of Fish and Wildlife, Portland, OR (April-July 2007and 2008) *Northern Pikeminnow Management Program, Columbia River White Sturgeon Program—Columbia River*

Oregon Department of Fish and Wildlife, Nehalem, OR (August 2007-December 2007) *Coho Salmon Life Cycle Monitoring Project*

Oregon Department of Fish and Wildlife, Corvallis, OR (August 2006-January 2007)*Coastal Chinook Research and Monitoring Project—Siletz River*

Western Washington University and Washington Department of Fish and Wildlife, Bellingham, WA (Summer 2005) *North Cascades Mountain Goat Research Project*

U.S. Forest Service, Okanogan-Wenatchee National Forest (Summer 2004) *Wildland Firefighter*