8-9-2006

Artificial Reef Performance in Lake Pontchartrain, Louisiana

Kelly Whitmore
University of New Orleans

ARTIFICIAL REEF PERFORMANCE IN LAKE PONTCHARTRAIN, LOUISIANA

A Thesis

Submitted to the Graduate Faculty of the
University of New Orleans
in partial fulfillment of the
requirements for the degree of

Master of Science
in
Biology

by

Kelly Ann Whitmore

B.S. Union College, 2000

August 2006

ACKNOWLEDGMENTS

This work was supported by grants from the Lake Pontchartrain Basin Foundation and J. Bennett Johnston Science Foundation. I thank my major professor Dr. James Grady for his support, knowledgeable suggestions, attention to detail, and connecting me with this research project. I thank Dr. Michael Poirrier for his guidance, enthusiasm, and the opportunity to conduct this research. I also thank him for supplying use of research vessels, sampling equipment, laboratory space, and field assistants. I thank Dr. John Lopez for his cooperative field efforts and evaluation of this manuscript.

My appreciation is extended to members of the Estuarine Research Laboratory including Carol Franze, Beth Spalding, Chip Crews, Ashley Walker, Ryan Poirrier, and Zoe Rodriguez del Rey who provided excellent advice and assistance in the field and laboratory. I thank Kenny Blank for fish identification and sampling tips. I thank the faculty and staff of the University of New Orleans Department of Biological Sciences for providing me with valuable experience as a teaching assistant.

Thank you to my husband William Whitmore for his diving expertise, encouragement, and love. I thank my parents Carol and Michael Houle, for forever supporting my interests in biology and marine science.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Artificial reef development is a common fishery enhancement tool used in aquatic systems worldwide. In 2003 and 2004, a series of artificial reefs were constructed in a large oligohaline estuary, Lake Pontchartrain, Louisiana to improve recreational fisheries. The reefs are the first in Louisiana to be built of reef balls, concrete domes deployed primarily in marine environments. Although they attract fish and invertebrates in high salinities, reef balls have not been tested in low-salinity estuarine systems. The objective of this study was to determine contributions of artificial reefs to habitat quality in Lake Pontchartrain. Evaluations of invertebrate and fish assemblages, structural integrity, water quality, and recreational use of the reefs were conducted. Findings indicated that the reefs support estuarine fauna and have enhanced fishing and diving opportunities. In addition, a framework for reef monitoring was developed to guide future artificial reef projects in Lake Pontchartrain and other brackish water systems.

INTRODUCTION

Lake Pontchartrain Artificial Reefs

Artificial reef development is a common fishery and aquatic management practice that has been used in nearly all countries and U.S. states with coastal borders (Christian et al. 1998, Seaman and Jensen 2000) to enhance commercial and recreational fisheries or mitigate marine habitat losses (Bohnsack and Sutherland 1985, Pickering et al. 1998). Artificial reefs are defined as objects of natural or human origin deployed on the seafloor to influence aquatic species, usually for biological or socioeconomic gain (Seaman and Jensen 2000). Typical goals of artificial reef construction include increasing commercial and recreation fisheries, enhancing tourism (via snorkeling, diving, and charter-fishing opportunities), protecting benthic habitat, and stabilizing shorelines. Reefs increase species richness and abundance on a local scale by augmenting biotic and abiotic habitat complexity (Wilding and Sayer 2002). Although reefs attract and aggregate fishes, whether they contribute to new production of fish stocks is controversial (Bohnsack 1989, Bohnsack et al. 1997, Martin and Bortone 1997, Pickering and Whitmarsh 1997). If shelter or food is a limiting resource for fishes, primary production, benthic secondary production, and refuge habitat fostered by artificial reefs may increase survival and growth of new individuals (Miller and Falace 2000). In contrast, structure that provides neither food nor refuge also attracts fishes and the attraction may simply relocate and concentrate existing populations (Bohnsack 1989, Martin and Bortone 1997). This latter point is critical in assessing reef effects on fish stocks, because aggregation of otherwise scattered individuals inshore where reefs are typically deployed, increases their catchability and may lead to over-harvesting (see Cowan and Patterson 2005).

Project goals regularly incorporate human benefits such as improved fisheries, but documentation of whether theses human benefits are attained is rare (McGlennon and Branden 1994). For example, fish abundance and diversity on artificial versus natural reefs has been well studied (e.g. Bohnsack and Sutherland 1985, Matthews 1985, Ambrose and Swarbrick 1989), yet whether reefs ultimately enhance fishery stocks remains unanswered (McGlennon and Branden 1994, Christian et al. 1998, Seaman and Jensen 2000). Few studies have compared productivity of different artificial reef materials in acquiring faunal assemblages (Walker et al. 2002), although prudent material selection reduces development costs, enhances floral and faunal settlement, augments fisheries, and increases economic returns.

Monitoring of artificial reefs frequently warrants equal or greater effort than construction to determine whether project goals are being met, yet assessment is seldom funded (Christian et al. 1998). Reef managers know that artificial habitats attract fishes but other ecological effects are poorly understood (Bohnsack and Sutherland 1985). The scale of most research on artificial reefs is too small to detect changes in population size or composition, even at a local level (Seaman et al. 1991). From both a management and biological perspective, it is important to assess whether artificial habitats simply redistribute exploitable biomass, enhance biomass available to harvest, or contribute to new production. Evaluation is needed to identify limitations, benefits, and potential ecological impacts of artificial reef development, and to assess its efficacy as a fishery management tool.

As result of the lack of assessment, anecdotal reports that artificial reefs "work" led to extensive, unregulated artificial reef construction in the late 1970's and early 1980's which prompted concerns that reef development would become another form of ocean dumping (Christian et al. 1998). Congress addressed the issue in 1981 and 1983 and established the National Fishing Enhancement Act in 1984. The Act called for development of a National Artificial Reef Plan to promote and facilitate responsible and effective artificial reef use. Published in 1985, the Plan provides guidance on all phases of reef development and prompts states to develop their own artificial reef plans (Christian et al. 1998). In 1986, the Louisiana Fishing Enhancement Act led to the creation of the Louisiana Artificial Reef Program (Wilson et al. 1987, Louisiana Department of Wildlife and Fisheries 2005). Although the primary focus of the Louisiana program is offshore (Kasprzak 1998), the plan also addresses development of low-profile reefs in the coastal zone.

Cooperative efforts among environmental organizations, state and federal agencies, commercial and sport fishers, and local interest groups led to the organization of the Lake Pontchartrain Artificial Reef Working Group (LPARWG), co-chaired by the Lake Pontchartrain Basin Foundation. The LPARWG developed five artificial reefs in Lake Pontchartrain, a large low-salinity estuary in southeastern Louisiana. One reef was created in 2001, and four between August 2003 and January 2004 (Lopez 2004). The reefs complement the inshore component of the Louisiana Artificial Reef Program and are the first in the state to utilize Reef Balls, commercially fabricated concrete units. Other coastal reefs have been created in Louisiana using shell hash to restore oyster reefs elsewhere in the Pontchartrain Basin (Louisiana Department of Wildlife and Fisheries 2005).

Lake Pontchartrain (Figure 1) is an embayment in a large estuarine system with a surface area of 1,630 km^2, mean salinity of 4 ppt, and mean depth of 3.7 m (Swenson 1980, Sikora and Kjerfive 1985). Historically, Lake Pontchartrain fisheries have been of cultural and economic importance to Louisiana, where it is essential habitat for many of the state's coastal fisheries (Boesch et al. 1994, Penland et al. 2002). Commercially and recreationally important species include blue catfish *Ictalurus furcatus*, red drum *Sciaenops ocellatus*, spotted seatrout *Cynoscion nebulosus*, blue crab *Callinectes sapidus*, brown shrimp *Farfantepenaeus aztecus*, and white shrimp *Peneaus setiferus* (Chesney et al. 2000). Around 1.5 million Louisiana citizens live immediately around the lake and enjoy its recreational and economic benefits (Penland et al. 2002) but have also contributed to its decline. Anthropogenic disturbances such as sewage and urban runoff, industrial effluent, shell dredging, and saltwater intrusion degraded water quality, wetlands, commercial and recreational fisheries, and recreational opportunities in the lake (Stone 1980). Over the last decade, environmental quality in the lake has improved due to reduction of effluent, shell dredging, and other human-caused stressors (Stone 1980, Abadie and Poirrier 2001, Bourgeois-Calvin et al. 2004). Efforts to revitalize the lake have gained widespread support from area residents, including the Lake Pontchartrain artificial reef program, which has fostered awareness of improved lake conditions and resources.

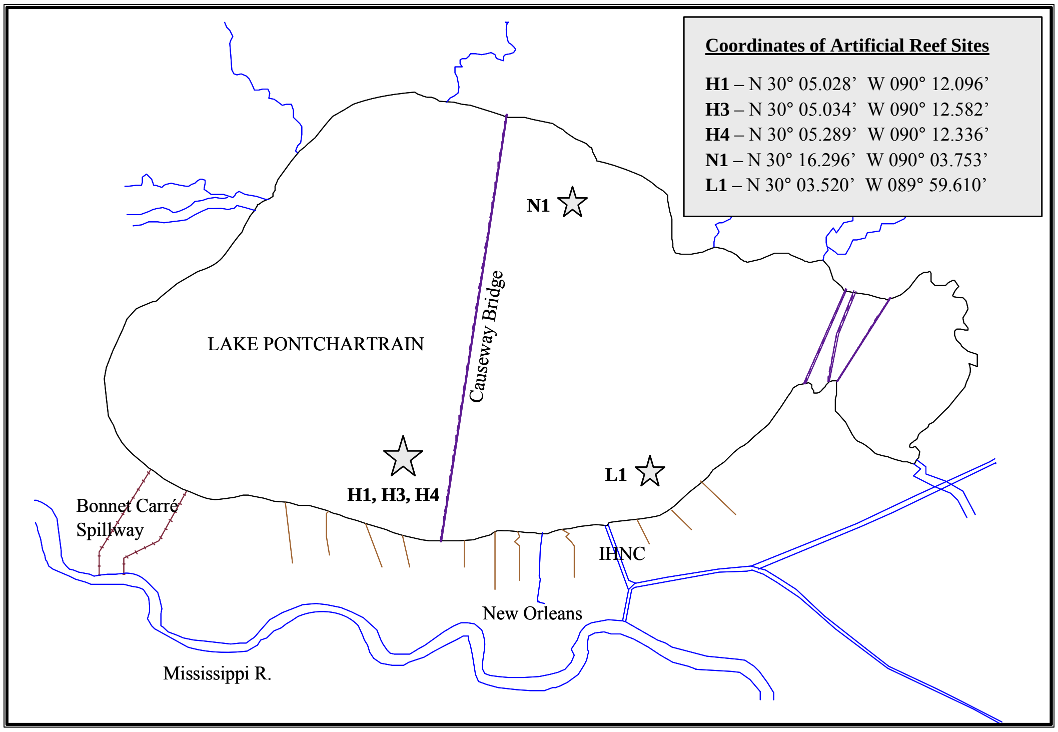

Figure 1. Location of artificial reef sites in Lake Pontchartrain, Louisiana. Stars indicate locations of reefs including reef ball reefs (H1, H3, H4, and N1) and the limestone reef (L1).

The Lake Pontchartrain artificial reefs were constructed to enhance biodiversity and environmental quality in the lake by supplementing hard substratum, a resource severely depleted by dredging for Rangia clam (*Rangia cuneata*) shells from 1933 to 1990 (Abadie and Poirrier 2001). The shells were mined from the lake bottom for use in road and levee construction. Dredging increased turbidity and reduced hard-bottom habitat in the lake (Bourgeois-Calvin et al. 2004, Penland et al. 2002). The projected benefits of artificial reefs in Lake Pontchartrain reflect their demonstrated contributions in marine habitats, including greater abundance and diversity of invertebrates and fishes and increased fishing and diving opportunities (e.g. Serviss and Sauers 2003, Kasprzak 1998, Zalmon et al. 2002, Stephens and Pondella 2002, Turpin and Bortone 2002). Additional advantages of reef construction in estuaries include proximity to boat launches and ease of access when weather conditions may be unsuitable for offshore recreation (Bortone et al. 1994). Artificial reefs have been used extensively in marine environments and occasionally in freshwater, but their performance in low-salinity estuaries has not been examined (Martin and Bortone 1997, Barber, pers. comm.).

The four reefs recently established in Lake Pontchartrain include three located near the south shore approximately 5.6 km (3.5 mi) offshore and 6.4 km (4.0 mi) west of the Causeway Bridge ("H1" at N 30º 05.028' W 090º 12.096'; "H3" at N 30º 05.034' W 090º 12.583'' and "H4" at N 30º 05.289' W 090º 12.336' (Lopez 2004). The fourth reef is located near the north shore, 8.9 km (5.5 mi) south of Mandeville ("N1" at Nº 30 16.296' W 090º 03.753') (Lopez 2004, LPARWG 2004) (Figure 1). Reefs are at a depth of about 4.6 m (15 ft) and positioned on the perimeter of shell pads originally created for oil and gas platform support in 1956 (H1), 1975 (H3), 1958 (H4), and 1977 (N1) (Lopez 2004) (Figure 2). The obsolete platforms were removed prior to reef development. Two hundred reef balls were deployed in a single layer on each of the three south shore sites and 80 on the north shore site. Most balls were positioned correctly with their flat base on the substrate, with exception of a few inverted, stacked, or tipped balls on each reef (Lopez 2004). Total area of each reef is between 0.4 to 0.8 ha^2 (Lopez 2004). One other artificial reef in the lake ("L1" at N 30º 03.520' W 090º 59.610') is north of the Lakefront Airport in New Orleans, LA. It was developed by the LPARWG in 2001 and composed of limestone rubble. The limestone was placed atop a Rangia shell reef that was created circa 1970 (Lopez 2004). This reef is structurally stable, has been colonized by fish and invertebrates, and is used recreationally (Poirrier and Sinclair 2002).

Reef balls were selected for the Lake Pontchartrain project because they are structurally stable, non-toxic, and typically colonized quickly by invertebrates (RBDG 2002). Concrete used to make reef balls contains microsilica, resulting in a pH similar to seawater (~8) (Suprenant 2001, Buckeridge 2002, RBDG 2002). Standard concrete mixtures, when placed in saltwater, leach calcium hydroxide and increase alkalinity of the surrounding seawater to around pH 12. This can affect settlement of some organisms (Anderson 1996, Walker et al. 2002). In marine environments and potentially Lake Pontchartrain, the microsilica additive will prevent such inhibition of invertebrate colonization (Bell et at. 1997). Reef balls provide refugia for juvenile and adult fishes and attachment sites for sessile invertebrates (RBDG 2002, Serviss and Sauers 2003, EPA 2005). On an otherwise barren muddy bottom, the reefs offer spatial and structural heterogeneity, which have been correlated with fish growth and abundance (Eklund 1997, Demers et al. 2000, Serviss and Sauers 2003).

In June 2004, a two-year evaluation was initiated to assess performance of the four artificial reefs in Lake Pontchartrain (Whitmore and Poirrier 2006). The main goals of the program were to develop techniques for using local volunteer divers and creel surveys to collect reef performance data, and to monitor: (1) structural integrity, in particular, any movement of reef balls; (2) water quality; (3) colonization of benthic macroinvertebrates; (4) fish assemblages; and (5) angler utilization of the reefs. This study investigates the biological contribution of artificial reefs in brackish systems, with the objective of evaluating the use of this fishery management strategy in estuaries.

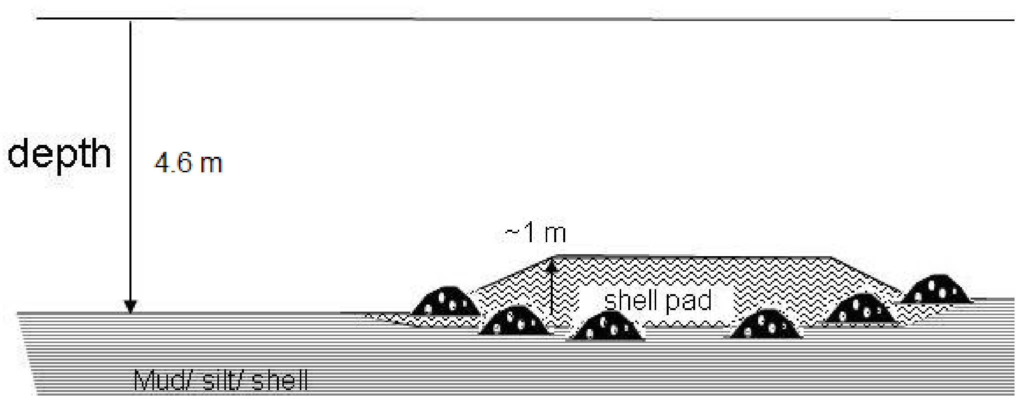

Figure 2. Generalized illustration of a Lake Pontchartrain artificial reef site.

Reef Structural Integrity

Reef movement is a primary concern to reef managers because it could compromise invertebrate colonization, reducing the reef's capacity to support permanent communities. Although movement is not anticipated due to the stable reef ball design, the reefs in Lake Pontchartrain were deployed on the shallowly sloping perimeter of shell pads, which is elevated relative to the sediment bottom (Figure 2). Sliding could potentially alter location and persistence of the reefs. Reports on reef ball stability were reviewed and an analysis of Lake Pontchartrain reef stability was conducted to address management concerns. For the structural analysis, individual reef balls were tracked prior to and following the 2004 hurricane season to determine whether the balls move horizontally or vertically (sink) as strong storms pass over southern Louisiana.

Two sizes of reef balls compose the Lake Pontchartrain artificial reefs: 0.6 m high x 0.9 m wide (2 ft x 3 ft) "bay balls," which weigh between 181.4 and 340.2 kg (400 and 750 lbs), and 0.9 high x 1.2 m wide (3 ft x 4 ft) "pallet balls", which weight between 680.4 and 997.9 kg (1500 and 2200 lbs) (Lopez 2004). Both types are designed so that over half of the weight is in their flat base. A large opening at the top of the unit reduces hydrofoil-lifting forces common to dome shapes (RBDG 2002). Side holes in the dome also help reduce horizontal movement due to water currents. As reported by the Reef Ball Development Group (2002), all sizes of reef balls have remained in position through tropical storms in as little as 6.1 m (20 ft) of water without having been anchored.

An environmental scientist for the Sarasota Bay National Estuary Program reported no reef balls were missing or out of position from Sarasota Bay artificial reefs after a series of storms over Florida in 2004, although the area experienced tropical storm-force winds, shoreline erosion, and strong wave action (Raulerson, pers. comm.). An interim report on a New Zealand artificial reef composed of reef balls also reported no appreciable scouring, settlement into the sediment, or movement of balls during storm periods (Buckeridge 2002). A formal study on reef ball stability conducted by the Florida Institute of Technology in Melbourne, Florida examined minimum weights necessary for stability under various environmental conditions (Roehl and Harris 1996). Wave tank and wind tunnel experiments were conducted using scale models of reef balls subjected to various wave heights, wave periods, depths, and substrate types. The only structural instability observed was sliding; no overtopping occurred (Roehl and Harris 1996). Although there were differences in sediment type, the study appears to indicate that minimum production weights of 181.4 kg (400 lbs) for bay balls and 680.4 kg (1500 lbs) for pallet balls used to construct Lake Pontchartrain reefs, will be sufficient for stability under moderate storm conditions. To assess stability of Lake Pontchartrain artificial reefs, locations of individual reef balls at a south shore reef were monitored before and after the 2004 hurricane season.

Water Quality

Abiotic conditions around artificial reefs such as dissolved oxygen, temperature, and salinity influence biotic assemblages (Bortone et al. 2000, Ninio et al. 2003). In Lake Pontchartrain, bottom hypoxia, or low dissolved oxygen, could disrupt or destroy established invertebrate communities on and around the reefs. Saltwater intrusion from the Inner Harbor Navigation Canal (IHNC) causes salinity stratification and hypoxic zones in the southeastern portion of the lake, which can adversely affect the benthic fauna (Poirrier 1978, Junot et al. 1983, Abadie and Poirrier 2001). If hypoxia occurs around the reefs, vertical relief provided may shelter benthic invertebrates and fishes during such adverse conditions (Bortone et al. 1994).

Benthic Macroinvertebrates

Invertebrate communities provide a basis for the transfer of energy from the water column to reef-associated fish and macroinvertebrate predators (Bortone et al. 2000). They are vital for fish colonization and enhance fishery resources (Seaman and Jensen 2000, Perry et al. 2001, Relini et al. 2002, Steimle 2002). Invertebrate settlement rate, abundance, and species diversity are indicators of reef productivity (Bortone et al. 2000). The elevated, solid reef balls supplement hard substrate and should support a more diverse invertebrate community and productive fishery than the alternative soft substrates in Lake Pontchartrain. Estuarine species that are substrate-limited are likely to increase in abundance with the additional structure (Bortone et al. 1994). Although Lake Pontchartrain has no natural reefs, Rangia clam shells are a source of benthic hard substrate. In addition to the recently constructed reefs, other artificial hard substrates include a seawall along the south shore, shoreline rip-rap, a limestone reef, and pilings supporting the Causeway bridge and oil and gas production platforms. These structures support epifaunal invertebrates (Porrier and Rogers 1975, Poirrier and Sinclair 2002) that should enhance recruitment to the artificial reefs. Identification of food web interactions and effects of predation are also important for understanding colonization patterns, and determining trophic dynamics of reefs (Bohnsack and Sutherland 1985, Bohnsack et al. 1991). Comparisons among assemblages on various hard substrates will indicate reef performance and potential climax-community structure.

Fish Assemblages

Abundance, richness, and residency of fishes are indicators of reef performance (Bortone et al. 2000). Reefs supplement food resources through macroinvertebrate colonization and aggregate baitfishes such as *Anchoa mitchilli* (bay anchovy), *Menidia beryllina* (tidewater silverside), and *Brevoortia patronus* (Atlantic menhaden). These fishes conserve energy by gathering in lees where reefs have disrupted bottom currents (Baynes and Szmant 1989, Linquist and Pietrafesa 1989, Bohnsack et al. 1991, Sheng 2000). As potential prey accumulate around the reefs, larger predatory fishes such as *Cynoscion nebulosus* (spotted seatrout), *Sciaenops ocellatus* (red drum), and *Caranx hippos* (Crevalle jack) follow. In addition to food, the reefs provide a point of reference and refuge (Bohnsack et al. 1991, Eklund 1997, Walker et al. 2002). The fish assemblage at the Lake Pontchartrain artificial reefs was assessed in 2005. Fishes at a south shore reef were surveyed and compared to two reference sites, a shell pad (former oil/gas platform site) without reef balls and the sediment bottom. Additionally, feasibility of using local volunteer divers to monitor reef stability and fish assemblages over the long-term was assessed.

Fishing Activity

One objective in developing the Lake Pontchartrain Artificial Reef Program was to enhance recreational fishing opportunities in Lake Pontchartrain (LPARWG 2004). Also, public awareness of improved water quality generated through recreational use is important for current and future restoration and conservation efforts. Documenting recreational activity at the reefs provides information on the success of the reefs in attracting fishes and fishers. Landings data provide information on species at the reefs, including those not observed during underwater visual surveys. An early goal of the monitoring program was to identify effective methods for collecting information on recreational activity at the artificial reefs (Poirrier and Whitmore 2005). Vessel observations, personal interviews, and an internet-based creel survey were found to be effective and carried out in 2004 and 2005 (Whitmore and Poirrier 2006).

METHODS

Reef Structural Integrity

The H3 south shore artificial reef (N 30° 05.034’, W 090° 12.582’) was selected as the primary monitoring site for movement due to uniform deployment of reef balls around the perimeter of the shell pad. Other reef sites had sections of deep mud where reef balls were not deployed (Lopez 2004). On 1 July, 5 July, 10 July, 11 July, 22 July, and 28 July, divers surveyed the H3 site and designated two areas for monitoring reef stability. One was in the northern quadrant and the other in the southern quadrant of the reef. Each area contained 10 to 15 reef balls including both bay and pallet balls, and was approximately square with sides oriented east to west and north to south. The presence of pallet balls, the larger of the two sizes of reef balls, within each survey area confirmed that the outer perimeter of the reef had been included because pallet balls were only deployed on the outer limits of each reef (Lopez 2004). Divers marked the corners of each survey area by driving PVC poles into the substrate approximately 1 m. The area was then delimited with flagging tape and the identification numbers of all balls within the plot were recorded. Divers measured the distance from PVC markers to reef balls and between reef balls within the survey area until all balls were accounted for and each had multiple measurements to PVC markers and other reef balls. Measurements were taken to the nearest 0.17 m (0.5 ft), which was the error determined by collecting repeated measurements and attributable to sagging and elasticity of the vinyl measuring tape used underwater. The error was less than 3% of the average distance between balls and PVC markers.

A rough sketch of the plot and relative distances between balls and PVC poles was drawn (Figure 2) on an underwater slate.

Following the 2004 hurricane season and prior to storms affecting Lake Pontchartrain in 2005, SCUBA divers relocated the PVC makers and survey area at the H3 reef on 4 August, 27 August, and 28 October 2004. Measurements were again taken repeatedly to and from PVC makers and reef balls. Distances from July 2004 and August-October 2004 were numerically compared. Divers also assessed sinking and scouring around the balls by locating the bottom edge of the ball and measuring any recession into the sediment or shell and compared those values pre- and post-hurricane season.

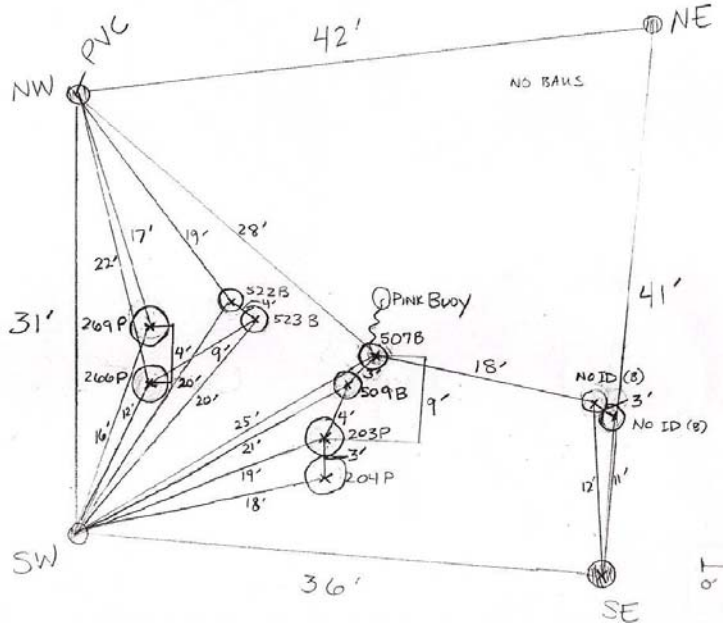

Figure 2. Diver sketch of the relative distances among reef balls on the H3 Lake Pontchartrain artificial reef-monitoring plot.

Water Quality

Physiochemical parameters, including temperature, dissolved oxygen, and salinity, were measured monthly at reefs. Surface and near-bottom measurements were taken using a handheld YSI model 85 SCT-DO meter and a YSI model 6600 multi-parameter sonde maintained and calibrated by the methods in the manufacturer's manual. Depth and Secchi disc transparency were measured using a standard 20 cm Secchi disc. All physiochemical parameters were assessed using the methods described in the Lake Pontchartrain Artificial Reef Evaluation Program Quality Assurance Project Plan (QAPP) (Poirrier 2001). Water samples were taken when algal blooms were observed at or near the reefs. Samples were kept on ice and later examined under a compound microscope to determine algal taxa contributing to the bloom.

Benthic Macroinvertebrates

Reef balls were inspected visually for macroinvertebrate epifauna on each dive to the H3 reefs from July - October 2004 and May - August 2005. Presence of encrusting and mobile macroinvertebrates was recorded. Epifaunal samples were obtained on 28 October 2004, 14 May 2005, and 5 August 2005 by scraping 10.2 x 10.2 cm (4 x 4 in) patches on the outer surface of three reef balls on the H3 site using a putty knife. To compare macroinvertebrate diversity of the reefs to other hard substrates in the lake, epifaunal samples were also taken from oil/gas production platform pilings located about 2.4 km east of the south shore reefs on 17 May 2005, and from Causeway Bridge pilings located about 5.6 km east of the reefs on 17 May 2005. Epifaunal samples were obtained from reef balls at the north shore reef N1 on 21 August 2005. Three replicate samples were taken at each site during each sampling event.

Epifauna were trapped in a plastic bag with habitat water and preserved in a 10% formalin solution. Organisms in the sample were rinsed through a 500 µm sieve, examined under a dissecting microscope, identified to the lowest practical taxon, and enumerated by experienced technicians using the Identification Guide to the Macroscopic Invertebrates of the Lake Pontchartrain Estuary, Louisiana (Poirrier 1984) and other regional keys. Benthic macroinvertebrate samples were handled according to QAPP methods (Poirrier 2001). Because many of the species collected were colonial, such as *Spongilla alba* (freshwater sponge) and *Garveia franciscana* (hydroid), presence and absence of macroinvertebrate taxa was compared among sites and over time. Specifically, similarity of assemblages at the north shore reef (N1) and south shore reef (H3), and south shore reef and hard-substrate reference sites were compared. Also, similarity of assemblages over a 10-month period (three sampling dates) was examined at the H3 reef.

Epifaunal macroinvertebrate assemblages were analyzed using multivariate methods in Plymouth Routines in Multivariate Ecology (PRIMER v. 5 2000). A Bray-Curtis similarity matrix was calculated on presence/absence of macroinvertebrate taxa (Clarke and Warwick 1994). The similarity matrix was used to construct a non-parametric multidimensional scaling (MDS) plot of spatial relationships among the samples. The similarity matrix and MDS plot were used in combination to check adequacy and mutual consistency of both data representations (Clarke and Warwick 1994).

Fish Assemblages

Visual survey of fishes is one of the few non-destructive methods for assessing reef fish communities (Brock 1982). This type of sampling also captures a greater proportion of the fish assemblage than does many physical collection methods such as gillnetting or trapping (Kimmel 1985). When determining whether to employ visual survey, the benefit of no mortality was weighed against problems encountered with this technique such as misidentification, group size estimation error, and bias towards diurnal species (Sale and Douglas 1981, Brock 1982). Underwater visual survey by divers was the primary method used to census fish at the Lake Pontchartrain artificial reefs. Various types of visual census have been described including transect, point-count, and species-time ranks (Kimmel 1985, Bortone et al. 1986, Schmitt and Sullivan 1996, Pattengil-Semmens and Semmens 1998, Bortone et al. 2000). The Roving-Diver Technique (RDT) was selected as the most appropriate survey method for Lake Pontchartrain based on project goals, time and resources available, and level of water clarity. This technique is a rapid and inexpensive method of assessing natural and artificial reef populations, and is used by fish survey groups worldwide (Schmitt and Sullivan 1996, Pattengill-Semens and Semmens 1998, REEF 2002). The RDT allows for comparison of species composition and relative abundance among sites but does not require laying of a line underwater, waiting for high-visibility conditions, or other time-consuming disadvantages as do the transect and point-count methods (Kimmel 1985).

Underwater fish surveys were conducted on 2 June, 3 June, 23 June, 24 June, 30 June, 4 August, 5 August, 16 August, 18 August, and 21 August 2005. Certified SCUBA divers surveyed the H3 south shore artificial reef, the H shell pad at N 30° 05.110’ W 090° 12.198’ (Lopez 2004), and a sediment bottom site at N 30° 04.864’ W 090° 11.953’. The reef, shell pad, and sediment bottom sites were roughly the same area, about 4047 m^2 (1 acre) (Lopez 2004, LPARWG 2004). All divers had training and experience identifying estuarine fishes and macroinvertebrates of the Gulf of Mexico region and were instructed on formal survey protocols.

Water quality and weather conditions were assessed before conducting fish surveys. Vertical and horizontal water clarity was measured using a Secchi disk. Visual surveys were only conducted when vertical transparency was 1.8 m (6 ft) or greater. Horizontal transparency provided a measure of diver visibility. A pair of divers obtained this measurement by holding the Secchi disk and chain horizontally while standing on the lake-bottom (Sheng 2000).

Using the RDT, paired divers censused fishes by swimming randomly throughout the reef, shell pad, or sediment bottom site. Divers recorded species and number of individuals per species sighted during two 10-minute intervals per site. Twenty minutes of survey time per site was selected because a standard 80-ft^3 airtank supplies the average diver for around 60 minutes with a safety reserve of 500 lbs of air, at 4 m depth. Area surveyed on each 10-minute interval was about 1000 m^2 (0.25 acre). Divers carried a compass to monitor heading and changed course by 90 degrees, either to the right or left, every 2 to 2.5 minutes, or when the edge of the reef or shell pad was encountered, to maximize area surveyed. Two diver teams surveyed each site, for a total of 40 minutes of survey time per site. The order that the reef, shell pad, and sediment bottom sites were surveyed was random, although occasionally influenced by angler presence. Fish surveys began as divers descended. Divers swam horizontally to the bottom and recorded all fish and mobile macroinvertebrates observed during census interval, including species, number, and estimated length of individuals. Each diver pair carried an underwater slate with waterproof paper and a ruler. One diver primarily observed while the other recorded and the pair communicated regularly to avoid duplicate records.

Abundances of fishes and mobile macroinvertebrates at the reef, shell, and sediment bottom sites were compared by one-way analysis of variance (ANOVA) performed using the

Compare Means procedure in SPSS (SPSS, Chicago, Illinois, USA). Bonferroni post-hoc tests were run to determine significance of the multiple comparisons.

Visual surveys were supplemented by gillnet sampling in the summer 2005. On 22 July and 18 August 2005, a 30 m gillnet with five panels of varying mesh sizes was deployed within 10 m of the H3 south shore reef. The net was not deployed directly over the reef due to avoid entangling the net in the reef balls. Two diel sets were made on 22 July, and three nocturnal sets on 18 August 2005. Ten minutes after net deployment the research vessel was driven around the net three times in gradually tightening circles, corresponding to the "Gillnet Strike Method" used by the Louisiana Department of Wildlife and Fisheries. Total set time was 20 minutes. The net was retrieved and all captured fishes were identified to species and measured from the most anterior point to the fork or median of the caudal fin. Stomach contents were examined in the field and recorded.

Fishing Activity

To assess fishing activity at the Lake Pontchartrain artificial reefs, 15 X 35 binoculars were used to detect vessels at the south shore artificial reefs from the Williams Boulevard boat launch and the Causeway Bridge in May 2004. Since the approach was ineffective due to distance of the reef sites from shore (Poirrier and Whitmore 2005), angler presence was documented when the reefs were visited to conduct other monitoring activities. The number of vessels at each reef, type of recreation being conducted (i.e. fishing or diving), number of people present, and observed catch were recorded. Additionally, interviews at fishing rodeos were conducted, and an internet-based creel survey was posted to document recreational activity and experiences at the reefs.

Anglers were interviewed at the Lake Pontchartrain Basin Foundation (LPBF) Fishing Rodeos on 29 and 30 May 2004 and 22 and 23 April 2005 at the Bonnabel Boat Launch in Metairie, Louisiana. Information was solicited from anglers accessing the Internet sites: "Louisiana Fishing and Hunting" (http://rodnreel.com), "Louisiana Sportsman Magazine" (http://www.louisianasportsman.com), and "Fishing Louisiana" (http://www.fishinglouisiana.com). Anglers were asked to report their fishing experiences at the Lake Pontchartrain artificial reefs, including catch, problems encountered, and opinion on whether or not the reefs contributed to fishing opportunities in Lake Pontchartrain. On 21 October 2004, a recreational fishing and diving survey (Appendix E) of the Lake Pontchartrain artificial reefs was posted on the LPBF website (http://saveourlake.org). The survey is currently maintained on this website. This survey was also posted on the Louisiana Fishing and Hunting website (http://rodnreel.com) from June 2005 through August 2005. Responses were compiled and summarized.

RESULTS

Reef Structural Integrity

Divers identified, measured, and monitored the locations of reef balls on a south shore reef on ten days from 2004 to 2005, totaling over 37 hours (Appendix A). Most surveys were conducted during the summer, when water clarity in the lake was highest.

2004 Pre-Storm Measurements

H3-South Plot - On 10 and 11 July 2004 divers recorded the locations of 10 reef balls (six bay balls and four pallet balls) within a plot in the southern section of the reef (Figure 2). The eastern boundary of the plot measured 9.4 m (31 ft), the northern 12.8 m (42 ft), the western 12.5 m (41 ft), and the southern 11.0 m (36 ft). All reef balls were upright and none exhibited sinking. Identification plates on two bay balls were missing.

H3-North Plot - On 4 and 27 August 2004 divers recorded the locations of 14 reef balls (seven ball balls and seven pallet balls) in a plot in the northern section of the reef. All boundaries measured 12.5 m (41 ft). One bay ball near the center of the plot was inverted, due to placement error during deployment that was not corrected.

2004 Storms

Two named storms affected Lake Pontchartrain during the 2004 hurricane season, Hurricane Ivan on 16 September 2004, and Tropical Storm Matthew on 10 October 2004 (Figure 3). Hurricane Ivan made landfall near Gulf Shores, Alabama as a category 3 storm on 16

September 2004. Lake Pontchartrain experienced steady northwest winds 14 to 19 m/s (31 to 43 mph) that pushed water towards the south shore of the lake (LUMCOM 2004, NOAA 2004). Gauge data for West End on the south shore of Lake Pontchartrain showed the water level was 1.3 m (4.4 ft) above average (USGS 2005). Tropical Storm Matthew crossed the south-central Louisiana coast near Cocodrie on 10 October 2004. Considerable inland flooding occurred across much of southeastern Louisiana due to heavy rainfall (>25 cm in some locations). Broad circulation of the storm and continuous east winds varying from 12 to 20 m/s (27 to 45 mph) pushed up to three feet of storm surge into portions of Lake Pontchartrain (LUMCON 2004, NOAA 2004).

2004 Post-Storm Measurements

Turbulent conditions in Lake Pontchartrain following Hurricane Ivan precluded reassessment of the study area until late October 2004. On 28 October 2004, divers surveyed reef balls in the H3 South plot. All four PVC markers were intact as were the 10 reef balls previously identified within the plot. All distances from reef balls to PVC markers and to other reef balls were within the allowable range of 0.17 m (0.5 ft) difference permitted for sagging of the measuring tape. No appreciable horizontal movement or vertical movement (sinking) was observed. Ball locations on the H3 North and H3 South plots were resurveyed on 9 June 2005. Many identification plates were missing from balls that were surveyed in 2004. The total number of balls within each survey area was the same, as well as relative positions of the balls comparing compass bearings and distances to the previous year's records. Divers swam the perimeter of the shell pad to check for displacement of reef balls. All balls appeared to be on the shell pad and no signs of sliding, rolling, sinking, or other movement was observed.

2005 Storms

Five major storms affected Lake Pontchartrain during the 2005 hurricane season: Tropical Storm Arlene on 11 June, Tropical Storm Cindy on 6 July, Hurricane Dennis on 10 July, Hurricane Katrina on 29 August, and Hurricane Rita on 23-24 September 2005 (Figure 3). Tropical Storm Arlene made landfall west of Pensacola (NOAA 2005). Winds across Lake Pontchartrain were 11 - 16 m/s (25-36 mph) (LUMCON 2005). Tropical Storm Cindy made landfall on Grand Isle, Louisiana, and moved over eastern Lake Pontchartrain with sustained winds of 22 - 31 m/s (50 - 70 mph) (LUMCON 2005). Hurricane Dennis, a category 4 storm, made landfall on the Florida/Alabama border producing sustained north winds of 8 - 11 m/s (17 - 25 mph) and gusts to 16 m/s (36 mph) in Lake Pontchartrain (NOAA 2005, LUMCON 2005). Hurricane Katrina made landfall on the Louisiana/Mississippi border on 29 August 2005 as a category 3 storm and produced sustained winds of 27 - 33 m/s (60 - 74 mph) and gusts to 49- 54 m/s (110 - 120 mph) across Lake Pontchartrain (LUMCON 2005, NOAA 2005, NOAA 2006) and a 10 - 11 ft storm surge (LSU 2006, NOAA 2006). Hurricane Rita made landfall in eastern Texas and generated 20 - 24 m/s (45 - 54 mph) winds across Lake Pontchartrain (NOAA 2005, LUMCON 2005).

2005 Post-storm Measurements

Impacts from Hurricane Katrina have precluded reassessment of the artificial reefs post-2005 hurricane season. University resources including research vessels were damaged and researchers were dislocated. In addition, windy conditions in January 2006 caused low water clarity in the lake and prevented follow-up underwater survey. When feasible, effects of Hurricane Katrina on the Lake Pontchartrain artificial reefs will be assessed and reported.

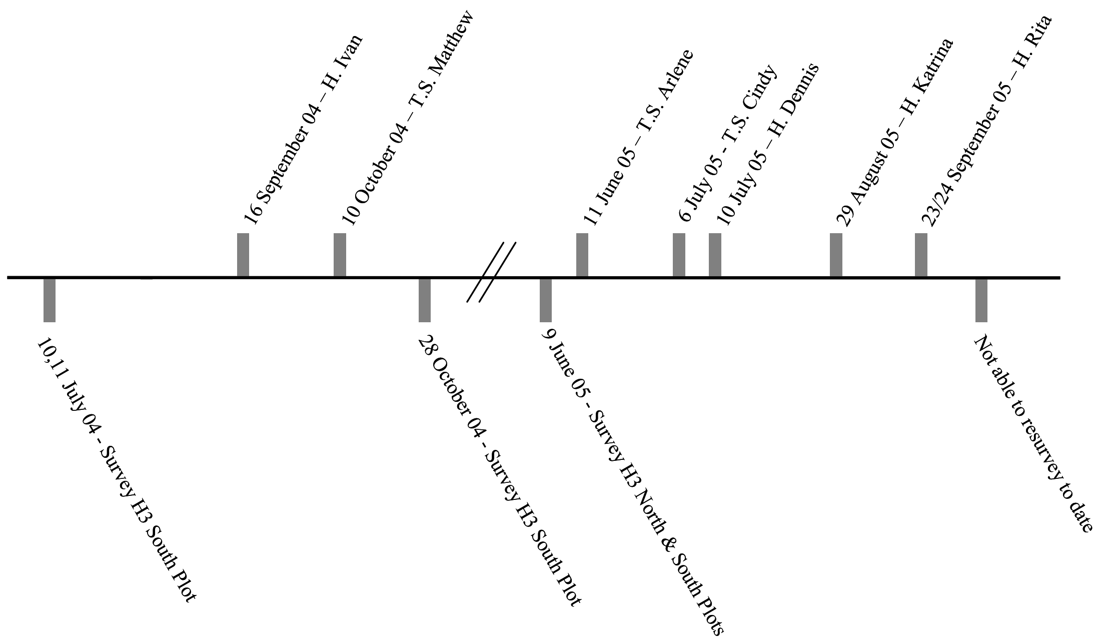

Figure 3. Timeline of reef ball stability surveys and storms affecting Lake Pontchartrain in 2004 and 2005. The H3 reefs was deployed in October 2003.

Water Quality

Water quality measurements were taken at least once a month from July - October 2004 and April - August 2005 and when reefs were accessed for stability or fish and macroinvertebrate surveys. Neither salinity stratification nor hypoxia was detected at any of the reef sites in 2004 or 2005 (Appendix B). In 2004, water clarity at the south shore reefs ranged from 1.5 - 2.1 m (5.0 – 7.0 ft), with an average clarity of 1.3 ± 0.7 m (4.3 ± 2.4 ft). On 1 July and 5 July 2004, a cyanobacterial bloom (*Anabaena* sp.) was observed at the H3 reef. The bloom extended vertically from the surface down to about 3 m (9.8 ft).

In 2005, water clarity was highest on average in June and August and lowest in May. Daily water clarity at the reefs ranged from 0.8 - 3.4 m (2.5 – 11.0 ft) with an average transparency of 1.9 ± 0.7 m (6.2 ± 2.3 ft). These values represent the average transparency for only days that the reefs were visited. No algal blooms were observed in 2005.

Benthic Macroinvertebrates

Visual observations from July until September 2004 revealed little or no macroinvertebrate epifauna on the reef balls. A thin layer, approximately 0.3 cm (0.1 in) thick, of sediment was present on the balls. In October 2004, visual surveys recorded about 10 percent coverage by macroinvertebrates. Most growth was on the lower half of the balls and composed primarily of *Spongilla alba* (freshwater sponge) and the sponge colony had gemmules (Brusca and Brusca 1990). *Congeria leucophaeta* (false mussel) was found in crevices or small depressions in the outer surface of reef balls. *Callinectes sapidus* (blue crab) was sighted at the base of the balls.

Ten species of macroinvertebrates from seven phyla were identified in the October 2004 scrape samples (Table 1). In addition to *S. alba* and *C. leucophaeta*, *Garveia franciscana* and *Cordylophora caspia* (hydroids), *Victorella pavida* and *Conopeum* sp. (byozoans), *Balanus subalbidus* (barnacle), *Polydora websteri* (polychaete), *Uromunna reynoldsi* (isopod), and nematodes worms occurred on reef balls. Fifteen species from seven phyla were found in the 2005 epifaunal samples taken at the south shore reef (H3). Additional species found in the 2005 south shore reef samples that were not found in the 2004 samples included *Neanthes succinea* (polychaete), oligochaetes, *Balanus improvisus* (barnacle), *Corophium lacustre* and *Melita* sp. (amphipods), and *Rhithropanopeus harrissi* (mud crab) (Table 1). *Cordylophora caspia* (hydroid) was found in 2004 but not 2005. The north shore reef (N1) sampled in August 2005, had a total of twelve species from seven phyla. One species of macroinvertebrate was found on the north shore reef that was not found on the south shore, *Ischadium recurvum* (hooked mussel) (Table 1). *Balanus subalbidus* and *B. improvisus*, *C. caspia*, and *Melita* sp. were not found in the north shore epifaunal samples in August 2005, but were also not found at the south shore in that month either (Table 1).

Estimated macroinvertebrate epifauna on the south shore reef (H3) increased from 10% in 2004 to 40 to 60 percent cover in 2005. Growth was primarily *G. franciscana* and *S. alba*. *Garveia franciscana* was observed from May to July 2005 and *S. alba* from June to August 2005. *Congeria leucophaeta* was observed only in crevices, consistent with observations from 2004. Small *B. subalbidus and B. improvisus* were around the crown of some reef balls in May 2005 (Table 1). Estimated epifaunal cover at the north shore reef (N1) was higher, around 80 percent, than at the south shore reef (H3) in August 2005. Predominant species were *G. franciscana* and *S. alba* analogous to the south shore reefs. Epifaunal growth was limited and had decreased from May to August 2005, on the south shore reef at the time of fall sampling. In August 2005 the balls appeared to be covered with decaying organic matter rather than live hydroids or sponge. Oil and gas platform pilings and Causeway bridge pilings just east of the south shore artificial reefs were surveyed on 17 May 2005. The pilings had epifaunal assemblages similar to the south shore reef sampled on 5 May 2005. In comparison, all species on the pilings were on the reef. Two additional species on the reef included *C. leucophaeta* and *U. reynoldsi* (Table 1).

Results of multivariate analyses using the Bray-Curtis similarity matrix and multidimensional scaling (MDS) plot of presence/absence of epifaunal macroinvertebrates showed 90 – 100% similarity of assemblages at the south shore reef (H3) and Causeway bridge and oil/gas platform piling samples taken in May 2005 (Figures 4 and 5). Epifaunal samples taken from the south shore reef (H3) in October 2004 and north shore reef in August 2005 also exhibited strong similarity, around 70%. The south shore had the greatest departure from the others sites sampled in August 2005, at slightly less than 50%. In August 2005, the reefs were visually devoid of most sponge and hydroid growth for unknown reasons, reflected in sample analysis (Table 1, Figures 4 and 5).

Phylum	**Species**	**Date** **Site**	10/28/04 H3 reef	5/04/05 H3 reef	8/05/05 H3 reef	5/17/05 Causeway	5/17/05 Oil Platform	8/21/05 N1 reef
Porifera	*Spongilla alba*		+	-	+	-	-	+
	S. alba gemmules		+	+	-	+	+	+
Cnidaria	*Garveia franciscana*		+	+	-	+	+	+
	Cordylophora caspia		+	-	-	-	-	-
Nematoda	nematodes		+	+	+	+	+	+
Bryozoa	*Victorella pavida*		+	-	+	+	+	+
	Conopeum sp.		+	+	-	+	+	+
Annelida	*Polydora websteri*		+	+	+	+	+	+
	Neanthes succinea		-	-	+	-	-	+
	Class Oligochaeta		-	-	+	-	-	+
Mollusca	*Congeria leucophaeta*		+	+	+	-	-	+
	Ischadium recurvum		-	-	-	-	-	+
Arthropoda	*Balanus improvisus*		-	+	-	+	+	-
	Balanus subalbidus		+	+	-	+	+	-
	Corophium lacustre		-	+	+	+	+	-
	Uromunna reynoldsi		+	+	-	-	-	+
	Melita sp.		-	+	-	+	+	-
	Rhithropanopeus harrissii		-	+	-	+	+	+

Table 1. Macroinvertebrates identified in epifaunal samples collected from the north (N1) and south (H3) shore artificial reef sites, a south shore Causeway piling, and an oil/gas platform piling. The symbol (+) indicates species was found, (-) indicates it was not found in the samples taken.

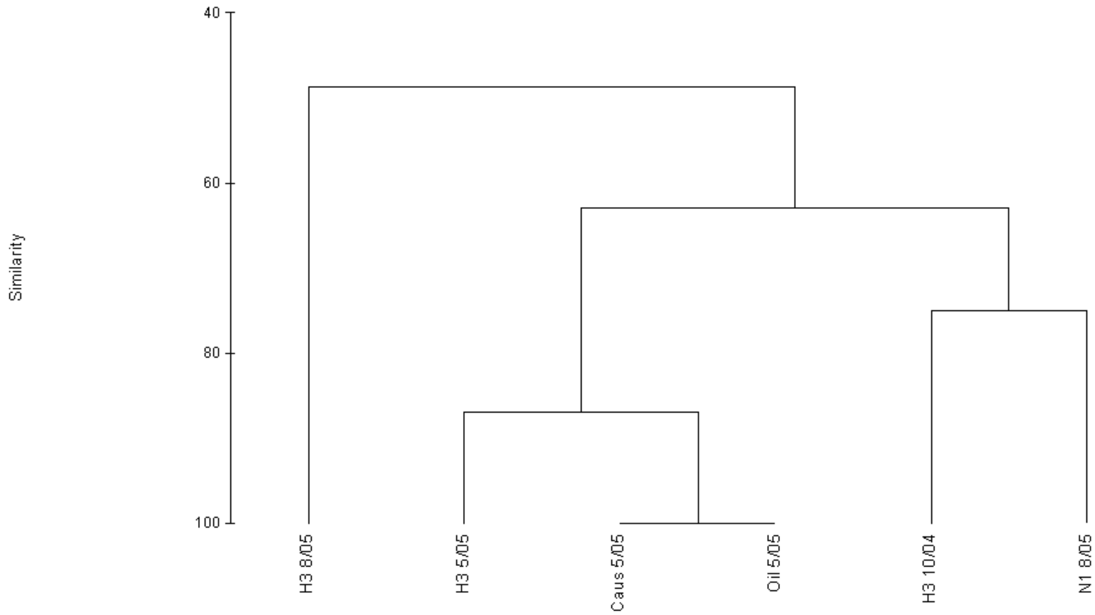

Figure 4. Bray-Curtis similarity matrix (cluster plot) of epifaunal macroinvertebrate samples taken at the south shore reef (H3), Causeway bridge piling (Caus), oil and gas platform piling (Oil), and north shore reef (N1).

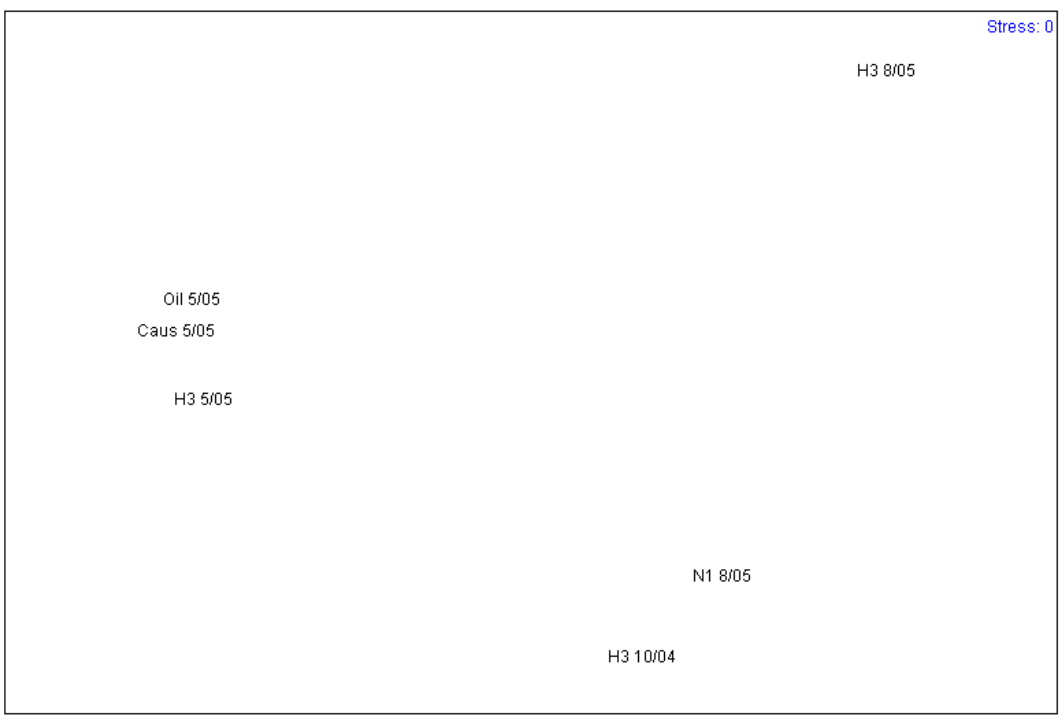

Figure 5. Multidimensional scaling (MDS) plot of spatial relationships between epifaunal macroinvertebrate samples taken at the south shore reef (H3), Causeway bridge piling (Caus**)**, oil and gas platform piling (Oil), and north shore reef (N1).

Fish Assemblages

Divers observed seven fish species at the H3 reef in 2004, including *Gobiosoma bosc* (naked goby), *Hypsoblennius iothonas* (freckled blenny), *Archosargus probatocephalus* (sheepshead), *Caranx hippos* (Crevalle jack), *Mugil cephalus* (striped mullet), *Ictalurus furcatus* (blue catfish), and *Anchoa mitchilli* (bay anchovy) (Table 2).

Table 2. Fishes sighted during monitoring efforts at the Lake Pontchartrain artificial reefs in 2004.

Date	Site	Species Sighted
07/01/04	H3	*Gobiosoma bosc* (naked goby), *Hypsoblennius iothonas* (freckled blenny), *Archosargus probatocephalus*(sheepshead), *Caranx hippos* (Crevalle jack), *Mugil cephalus* (striped mullet)
07/05/04	H3	*Ictalurus furcatus* (blue catfish), *G. bosc*, *H. iothonas*, *A. probatocephalus*, *M. cephalus*
07/10/04	H3	*A. probatocephalus*
07/11/04	H3	*A. probatocephalus*, *M. cephalus*
07/22/04	H4	*A. probatocephalus*, *G. bosc*, *M. cephalus*
07/28/04	H3	No fishes sighted
08/04/04	H3	*A. probatocephalus*, *G. bosc*, *H. iothonas*
08/27/04	H3	*A. probatocephalus*, *G. bosc*
10/28/04	H3	*Anchoa* mitchilli (bay anchovy), *H. iothonas*, *I. furcatus*, *M. cephalus*

Fish surveys were conducted on ten days in 2005, totaling 900 observation minutes (Appendix C). Observers recorded 17 fish species from 15 families and three species of mobile macroinvertebrates from three families at the reef, shell pad, and sediment bottom sites (Table 3). Thirteen of the 17 fish species occurred at the south shore artificial reef, including *A. probatocephalus*, *I. furcatus*, *C. hippos*, *M. cephalus*, *G. bosc*, *H. iothonas*, *Paralichthys lethostigma* (southern flounder), *Lagodon rhomboids* (pinfish), *Micropogon undulatus* (Atlantic croaker), *Opsanus beta* (Gulf toadfish), *Anguilla rostrata* (American eel), *Dasyatis sabina* (Atlantic stingray), and *Gobiesox strumosus* (skilletfish) (Appendix D). Macroinvertebrates on the reef included *Callinectes sapidus* and *Farfantepenaeus aztecus* (brown shrimp) (Table 3, Appendix D). A nocturnal survey was conducted at the south shore reef on 18 August 2005.

Two species of fish were sighted including *A. rostrata* and *G. strumosus* and one species of macroinvertebrate, *C. sapidus* (Table 3). The north shore reef (N1) was surveyed on 21 August 2005. Species sighted at the N1 reef included *Aplodinotus grunniens* (freshwater drum), *A. probatocephalus*, *G. bosc*, *H. iothonas*, and *A. rostrata* (Table 3).

Eight fish species were observed on the shell pad site (no reef balls) including *Myrophis punctatus* (speckled worm eel), *Menidia beryllina* (tidewater silverside), *Trinectes maculatus* (hogchoker), *A. probatocephalus*, *P. lethostigma, G. bosc*, *H. iothonas,* and *G. strumosus* (Table 3, Appendix D). Two species of mobile macroinvertebrates observed on the shell pad including *C. sapidus* and *R. harrisii* (Table 3). One species of fish and two species of mobile macroinvertebrates were sighted over the sediment bottom including *G. bosc*, *C. sapidus,* and *R. harrisii* (Table 3, Appendix D).

At the south shore reef, shell pad, and sediment bottom site, 549, 215, and 8 individual fishes were observed, respectively. Sightings per unit effort at the three survey sites were 1.9, 0.7, and 0.3 fish per minute per pair of divers, respectively. Abundance of fishes at the south shore reef was significantly higher than at the shell pad ($p = 0.016$, $df = 2$) and sediment bottom ($p < 0.001$, $df = 2$) (Figure 6). Fish abundance did not differ significantly between the shell and sediment bottom sites ($p = 0.185$, $df = 2$). The north shore reef (N1) survey and H3 nocturnal survey were not included in these comparisons because they were only surveyed once. Abundance of mobile macroinvertebrates did not differ significantly between the reef and the shell pad sites ($p = 0.435$, $df = 2$). However, mobile macroinvertebrates were more abundant at the reef and shell pad than at the sediment bottom site (reef $p < 0.001$; shell $p = 0.049$). Total number of mobile macroinvertebrates recorded at the reef, shell, and sediment bottom sites were

65, 41, and 3, respectively. Sightings per unit effort at the three survey sites were 0.2, 0.1, and 0.01 macroinvertebrate per minute per pair of divers, respectively.

Fishes recorded most frequently at the reef were *G. bosc*, *A. probatocephalus*, and *H. iothonas* (Figure 6, Appendix D). *Gobiosoma bosc* and *M. beryllina* were most common at the shell pad (Figure 6, Appendix D), however all *M. beryllina* individuals were in a single school. Nine fish species were observed only at artificial reefs including *C. hippos*, *M. cephalus*, *I. furcatus*, *M. undulatus*, *L. rhomboides*, *D. sabina*, *A. rostrata*, and *O. beta,* and *A. grunniens* (north shore only) (Table 3, Figure 6, Appendix D).

		Site	H3 Day	Shell Pad	Mud	N1 Reef	H3 Night
Fishes: Families	**Species**	**Common**					
Gobiidae	*Gobiosoma bosc*	naked goby	+	+	+	+	-
Sparidae	*Archosargus probatocephalus*	sheepshead	+	+	-	+	-
Blennidae	*Hypsoblennius iothonas*	freckled blenny	+	+	-	+	-
Bothidae	*Paralicthys lethostigma*	Southern flounder	+	+	-	-	-
Dasyatidae	*Dasyatis sabina*	Atlantic stingray	+	-	-	-	-
Carangidae	*Carnax hippos*	jack crevalle	+	-	-	-	-
Mugilidae	*Mugil cephalus*	striped mullet	+	-	-	-	-
Ictaluridae	*Ictalurus furcatus*	blue catfish	+	-	-	-	-
Anguillidae	*Anguilla rostrata*	american eel	+	-	-	+	+
Batrachoididae	*Opsanus beta*	oyster toad fish	+	-	-	-	-
Sparidae	*Lagodon rhomboides*	pinfish	+	-	-	-	-
Atherinidae	*Menidia beryllina*	tidewater silverside	-	+	-	-	-
Gobiesocidae	*Gobiesox strumosus*	skilletfish	+	+	-	-	+
Ophichthidae	*Myrophis punctatus*	speckled worm eel	-	+	-	-	-
Sciaenidae	*Micropogonias undulatus*	Atlantic croaker	+	-	-	-	-
Soleidae	*Trinectes maculatus*	hogchoker	-	+	-	-	-
Sciaenidae	*Aplodinotus grunniens*	freshwater drum	-	-	-	+	-
Invertebrates: Families	**Species**	**Common**					
Portunidae	*Callinectes sapidus*	blue crab	+	+	+	-	+
Penaeidae	*Farfantepenaeus aztecus*	brown shrimp	+	-	-	-	-
Xanthidae	*Rhithropanopeus harrisii*	mud crab	-	+	+	-	-

Table 3. Fish and mobile macroinvertebrate species observed during diurnal fish surveys at the south shore reef (H3), shell pad (H), sediment bottom site, north shore (N1) reef, and a nocturnal survey at the south shore reef (H3). The symbol (+) indicates species was observed, (-) indicates it was not observed during visual surveys.

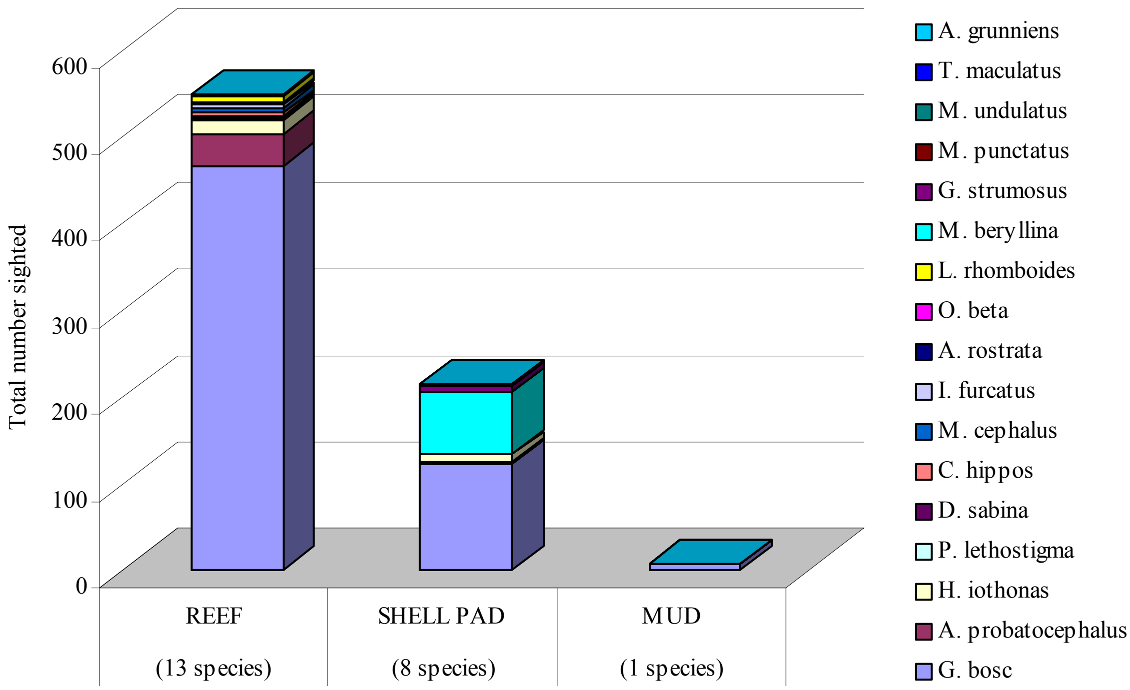

Figure 6. Comparison of species and abundances of fishes observed at the Lake Pontchartrain artificial reef, shell pad, and sediment bottom sites in 2005.

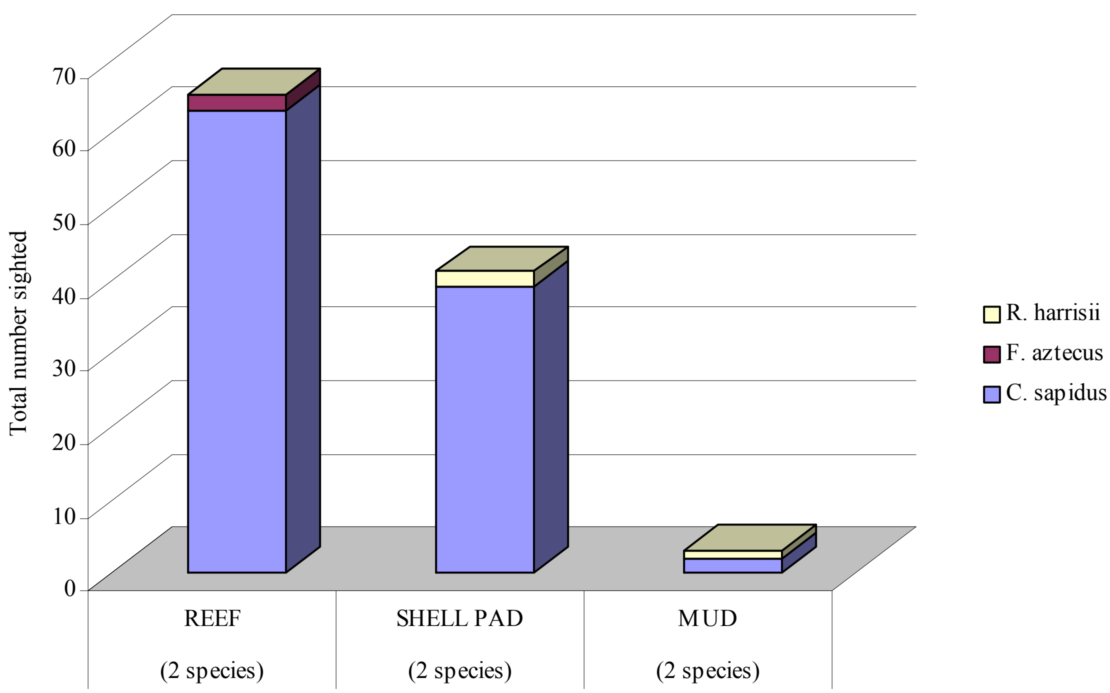

Figure 7. Comparison of species and abundances of mobile macroinvertebrates observed at the Lake Pontchartrain artificial reef, shell pad, and sediment bottom sites in 2005.

Callinectes sapidus was the most commonly observed macroinvertebrate at the artificial reef during visual surveys, totaling 86 out of 127 (68%) observations (Figure 7, Appendix D). Interestingly, 32 out of 39 *C. sapidus* on the shell pad were associated with additional artificial structures, including bricks, tires, pails, and other debris. On the reef site, cavities were observed in the shell around the base reef balls. These cavities were occupied and presumably dug by juvenile and adult *C. sapidus*. On 24 June 2005, four pairs of *C. sapidus* were observed in precopulatory or postcopulatory embraces, where a female was in an upright position cradled by a male (Bushmann 1991) inside hollows in the reef balls. In July, molted *C. sapidus* exoskeletons were present in and around reef balls on the south shore reefs.

Gillnet sampling on 22 July 2005 yielded two *Bagre marinus* (gafftopsail catfish). One *M. undulatus* was caught on 18 August 2005. Weather and time constraints due to Hurricane Katrina restricted further experimentation of gillnet sampling methods on the reefs, including deployment over the reefs with diver assistance.

Fishing Activity

Vessel Observations

Fifteen boats were observed at the Lake Pontchartrain artificial reefs during nine days in 2004 (Appendix F). Anglers occupied 14 of the 15 boats, and SCUBA divers visiting the south shore reefs occupied the one other. During 2005, 96 boats containing 70 or more anglers were recorded during 18 observation days (Appendix F). Anglers were observed catching fish on October 28 2004, 27 April 2005, and 14 May 2005 including *Cynoscion nebulosus* (spotted sea trout), *M. undulatus*, and *P. lethostigma* (Appendix F).

Boats were present at reefs on six of nine days (67%) in 2004, and on 15 of 18 (83%) days in 2005. At the south shore reefs, the number of boats per reef ranged from zero to five (mean of 0.6 ± 1.1) in 2004, and zero to eight (mean of 1.1 ± 1.3) in 2005. Commercial fishing for blue crabs was also noted at and around the south shore reefs on one day in 2004 and 14 days in 2005 (Appendix F).

Fishing Rodeo Surveys

Six fishing activity surveys were collected at the 2004 LPBF Fishing Rodeo. Poor weather conditions limited angler turnout at this event. Of the anglers interviewed, all were aware of the artificial reefs but none had fished them during the Rodeo. Reasons for this included rough conditions on the lake, having fished the reefs earlier that week/month with no success, and lack of transportation to the reefs. Three surveys were collected at the 2005 LPBF Fishing Rodeo. Windy conditions deterred anglers from fishing offshore at the reefs, but all fishermen were knowledgeable of the reefs and had fished them in the past.

Internet-based Creel Surveys

The Lake Pontchartrain Artificial Reef Recreational Fishing and Diving Survey (Appendix E) posted on the LPBF website in October 2004 generated two responses in 2004 (Appendix G). Visitors to the LPBF and Louisiana Fishing and Hunting websites submitted 19 surveys in 2005. Of the 21 respondents, 17 reported that the reefs have enhanced recreational fishing in Lake Pontchartrain and five said that the reefs have enhanced diving opportunities. Four of those five reported enhanced fishing and diving in the lake. Fourteen respondents fished more in the past year than the previous as result of reef presence, and four people had dived more

(Appendix G). Surveys indicated that sixteen respondents (76%) visited the south shore (Jefferson Parish) reefs, three visited the north shore (St. Tammany Parish) reef, and two visited the Orleans Parish artificial reef. Total time spent at each reef location was 43, 3.5, and 0.6 hours for the Jefferson (H1, H3, and H4), St. Tammany (N1), and Orleans reefs (L1), respectively. Seventeen of the respondents fished with hook and line, three spearfished, and the one diver did not fish. Individual respondents reported seeing between zero and 65 other anglers at the south shore reefs (mean of 17, 15 adults and two children) while fishing.

Most anglers' primary target species was speckled trout (17 of 21 respondents). Eight of those anglers caught speckled trout, landing 10 - 35 individuals (mean of 21 ± 9) per boat. All speckled trout were caught at the south shore reefs. Respondents caught other species at the south shore reefs including, flounder (three respondents), sheepshead (three respondents), white trout (one respondent), and catfish (one respondent) (Appendix G). One respondent fished the north shore reef and caught hardhead and gafftopsail catfishes at the north shore reef. The two respondents that fished the Orleans reef were not successful. Problems that anglers encountered at the reefs included fishing tackle losses (eight respondents), trouble locating reefs (five respondents), and crowded conditions (four respondents). Respondents comments included requests for a diagram depicting reef and buoy orientation, reports of missing buoys and vessel crowding, and concern for safety at the reef sites when divers are present (Appendix G).

DISCUSSION

Structural integrity analyses indicate that reef balls are a stable artificial reef material in Lake Pontchartrain when placed on shell pads. The reefs remained in their original deployment positions despite passage of strong storms over southeastern Louisiana and Lake Pontchartrain in 2004. One challenge for future evaluation of reef stability is that the fixative used to mount identification plates to the balls has deteriorated and many plates have fallen off. Application of a durable marine fixative is recommended for future reef construction.

The artificial reefs might act as vertical refuge for benthic invertebrates and fishes during episodes of low dissolved oxygen in bottom waters in Lake Pontchartrain, although hypoxia was not detected during this study. Impacts of hypoxia on fisheries in the Gulf of Mexico include fish avoidance or migration away from hypoxic areas for motile species, and stress or mortality for more sessile fishes and macroinvertebrates (Rabalais et al. 2001). Whether hypoxia caused by salinity stratification from the INHC persists as far west as the Jefferson Parish artificial reefs is not known but could be determined by further study of epifaunal macroinvertebrates on reefs and other hard substrates. Sessile invertebrates can be used as indicators of environmental stress through documentation of their survival, growth, and succession over time (Porrier and Rogers 1975). Salinity stratification was detected near the south shore reefs on 25 October 2004, during lake-wide benthos surveys conducted by UNO Estuarine Research Laboratory researchers. Surface and bottom dissolved oxygen levels differed by greater than 4 mg/L, and bottom dissolved oxygen was below 2 mg/L, suggesting a hypoxic event just west of the artificial reefs (unpublished data). Other evidence of hypoxia in the southwestern region of the lake came from a report by a commercial blue crab fisherman on 10 August 2005. The fisherman reported dead crabs in his traps from the Seabrook Bridge to the Bonnet Carre Spillway due to a "wedge of bad water." He also reported lower landings than average for that time of year (Ronnie, pers. comm.). Collection of water quality data throughout Lake Pontchartrain during the summer and fall would clarify whether the artificial reefs provide vertical relief from hypoxia, mitigating environmental stress and providing refuge for benthic invertebrates and fishes.

Initial macroinvertebrate colonization of the south shore artificial reefs was gradual. Percent cover of epifauna was negligible throughout 2004 but increased considerably in 2005. Interestingly, similarity of taxa on the south shore reefs and Causeway Bridge and oil/gas platform pilings was over 90% in May 2005 (Bray-Curtis similarity index, Clarke and Warwick 1994), although the ages of these structures vary from less than two years (reefs) to fifty years (Causeway Bridge pilings). Stress, a measure of adequacy of the Bray-Curtis similarity analysis, was less than 0.01, which indicated that the multidimensional scaling plot of similarity provided a strong representation of the relationships (Clarke and Warwick 1994). Epifaunal samples that exhibited the greatest similarity were those with spatial and temporal likeness, such as those taken in May 2005 from the south shore reef, Causeway pilings, and oil/gas platform pilings. Epifauna on the south shore reefs in August 2005 was most dissimilar (<50%) from epifauna found on south or north shore reefs or reference sites throughout the survey period. Visual observations of macroinvertebrates on the reefs indicated little to no live hydroid or sponge and epifaunal scrape samples primarily contained decaying organic matter. A plausible explanation for the lack of live sessile colonial macroinvertebrates in August 2005 is that an undetected hypoxic event affected the south shore reefs. Other reasons for the mortality could be abnormally high water temperatures or other adverse water quality parameter, none of which were detected in July or August 2005.

In visual comparisons, barnacles were found to be larger and more abundant on the Causeway and oil/gas platform pilings than on reef balls, which might be due to predation of the barnacles by fish and mobile macroinvertebrates. Barnacles and small clams, *Congeria leucophaeta,* were present only in crevices on irregular reef surfaces. The rugosity may have provided refuge from grazing pressure (Hixon and Brostoff 1985). Blue crabs *Callinectes sapidus* feed on a variety of crustaceans, molluscs, fish, and detritus and have been characterized as opportunistic benthic omnivores (Darnell 1959, Perry and McIlwain 1986). When available they will feed on barnacles (Ryer 1987). Certain fishes also regularly consume barnacles such as adult sheepshead *Archosargus* probatocephalus (Jennings 1985). This omnivorous fish is associated with structural habitat (Jennings 1985) and was regularly sighted at the reefs. Predation affects sessile assemblages on artificial reefs (Bohnsack et al. 1991), thus identification of food web interactions is important for understanding colonization patterns (Bohnsack and Sutherland 1985). One method for assessing predation would be to use predator exclusion devices such as mesh cages (Steele 1996, Connell 1997). Invertebrate assemblages on reef balls excluded from predators may have higher species diversity and surface coverage than assemblages on balls exposed to predators. Because water current modifications produced by the reef may also differentially affect epifaunal growth (Baynes and Szmant 1989, Lindquist and Pietrafesa 1989, Sheng 2000), treatments should be assigned to all orientations of surfaces of the reef. Fish stomach contents can also be analyzed to determine if prey items are associated with natural or artificial substrates. Additional research is necessary to test this hypothesis and determine if predation rates differ between reef and oil and gas platform or Causeway Bridge pilings. Changes in macroinvertebrate community composition are likely to occur as the reef matures. Information on factors affecting settlement of epifauna under estuarine conditions is valuable for future reef efforts in Lake Pontchartrain and in other low-salinity estuaries.

Visual surveys indicated that artificial reefs are productive fish and invertebrate habitats with higher diversity and abundance of fishes than the shell pad and natural sediment bottom sites. *Archosargus probatocephalus*, *Paralichthys lethostigma*, and *Ictalurus furcatus* are valued recreational species (O'Connell et al. 2005) and were recorded at the reef. The naked goby *Gobiosoma bosc* was highly abundant at the reefs. Although *G. bosc* is known to be one of the three most abundant species of fish along the Louisiana coast (Rakocinski et al. 1992, Baltz et al. 1993), its distribution is dependent on habitat attributes including reef structure (Weiderholm 1987). Gobies, including *G. bosc*, constitute a portion of the diet of several commercial and recreational fishes including *Cynoscion nebulosus*, *Micropogon undulatus*, *Pogonias cromis* (black drum), and *Sciaenops ocellatus* (red drum) (Darnell 1958, Dawson 1966, Carr and Adams 1973). When abundant, *G. bosc* larvae are an important food source for juvenile piscivorous fishes in estuarine environments (Peterson and Ross 1991, Hendon et al. 2000). *Gobiosoma bosc* presence indicates food availability at the reefs, which may enhance abundance of fishery species.

Blue crabs *Callinectes sapidus,* were commonly sighted in the reefs. Louisiana leads the US commercial landings (NMFS 2002) for this crustacean, of which a portion is harvested from Lake Pontchartrain (Guillory and Perret 1998). Blue crabs occupy estuaries during various phases as larvae, juveniles, and adults. As adults, males tend to stay within estuaries while females migrate there for mating and spawning (Perry and McIlwain 1986). It appears that the artificial reefs provide cover during certain vulnerable life stages. Juvenile *C. sapidus* were frequently observed occupying cavities at the base of reef balls and adults pairs were seen in mating (pre/postcopulatory) positions. Blue crab molts were also found inside cavities and around the bases of reef balls. Mating occurs in estuaries, while the female is in a soft-shell state (Guillory et al. 2001), and habitat structural complexity minimizes predation risk during this vulnerable period (Hovel and Lipcius 2001). Structurally complex habitat provided by the reefs likely enhances survival of *C. sapidus* in Lake Pontchartrain.

Some recreationally important species including *Cynoscion nebulosus*, *C. arenarius* (sand seatrout), and *Sciaenops ocellatus* (O'Connell et al. 2005), were not observed during surveys but were reported at the reefs by anglers (see following section on Fishing Activity). These cryptic species are less likely to avoid detection due to heightened sensitivity to noises produced by divers (i.e., bubbles exiting regulators) (Kimmel 1985). Although divers did not observe these species at the reef or reference sites, anglers caught them with rod and reel. To account for this discrepancy, visual surveys were supplemented by gillnet sampling at the reefs, but only *Bagre marinus* and *Micropogon undulatus* were collected. A major limitation of the gillnet method was that the net had to be placed adjacent to the reef rather than across it, in effect sampling a different environment and assemblage. Developing gillnet sampling techniques where the net is deployed directly over artificial reefs should improve efficacy of net use in structurally complex habitats. Displacement of personnel and damage to research equipment by Hurricane Katrina limited gillnet survey effort and precluded experimentation of over-reef net deployment techniques.

An additional purpose of the visual surveys was to determine whether volunteers could be used to systematically monitor Lake Pontchartrain artificial reefs. Based on the success of the visual surveys, it is feasible to utilize volunteers to conduct RDT-style fish surveys and to monitor reef stability (Whitmore and Poirrier 2006). Water clarity is usually sufficient for reef surveys after three to five days of low wind conditions (less than 10 knots), especially in late summer. Implementing a regular dive schedule should help to coordinate volunteers, as it was difficult to assemble teams during brief windows of suitable visibility. In 2004, a list of about 50 divers interested in participating in Lake Pontchartrain artificial reef surveys was compiled. Many of these volunteers were active divers with the Aquarium of the Americas in New Orleans, LA and the Hammerhead Dive Club in Mandeville, LA. Several had assisted with deployment and early monitoring dives at the reef sites (Lopez 2004). A protocol for surveying the reefs using volunteers was developed based on methods used by the Reef Environmental Education Foundation (REEF). Pending authorization from REEF, Lake Pontchartrain will be added to REEF's list of Project Areas, which would allow current and future fish survey data to be submitted online and later accessed by the public. Public involvement in reef monitoring will encourage support and knowledge of the reefs, supplement key datasets on reef performance, and support a long-term monitoring program.

Observations of recreational activity indicated that fishing and diving have been taking place at the Lake Pontchartrain artificial reefs, and that recreational activity increased from 2004 to 2005. Data on fishes at the reefs gathered through the internet-based creel surveys supplemented visual surveys, and revealed angler experiences at the artificial reefs sites. Internet-based creel surveys can be used to inexpensively and consistently monitor reef performance, recreational user preferences, and experiences when on-site evaluation is not feasible. Creel surveys provided insight to problems that users experienced, such as confusion about reef size and orientation relative to the buoy, displaced buoys, and errors in and difficulty interpreting the format of published coordinates. We observed anglers mooring to reef buoys, which probably caused the buoys to be dragged off of the reef sites and later contributed to confusion about reef to buoy orientation. Signage at boat launches and greater public outreach of proper mooring techniques could address this problem. Overall, recreational users are satisfied with the reefs and feel that they have enhanced fishing and diving opportunities in Lake Pontchartrain. Many suggested that the program be expanded to accommodate growing interest and offer reef-fishing opportunities in other parts of the lake.

Data collected during this two-year evaluation of the Lake Pontchartrain artificial reefs demonstrate that the reefs have performed according to expectations. Macroinvertebrates have begun colonizing available hard substrate, recreationally important fish species have been observed by divers and caught by anglers, and commercially important blue crabs have also been recorded at the reefs. Reef development has also expanded recreational fishing and diving opportunities in the lake.

CONCLUSIONS

Lake Pontchartrain is the largest oligohaline estuary in the southeastern U.S. (Moore 1992) and essential habitat for many of Louisiana's coastal fisheries (Penland et al. 2002). Generally, coastal estuaries are the most productive and commercially important fisheries habitats worldwide (Boesch et al. 1994, Chesney et al. 2000, Demers et al. 2000). Despite their importance, estuaries are also among the most endangered and altered aquatic habitats. Lake Pontchartrain restoration and revitalization efforts have improved environmental quality in the lake over the last few decades (Abadie and Poirrier 2001, Bourgeois-Calvin et al. 2004, LPBF 2005). The Lake Pontchartrain Artificial Reef Program has fostered awareness of these improved conditions and lake resources. Study of the reefs has generated background on artificial reef performance in low-salinity estuaries and can be used to assess the efficacy of future estuarine artificial reef development. Although estuaries are not commonly selected for artificial reef development, they are likely to become a focus of such efforts. Reef development tends to be highest near urban centers (Booth and Cox 2003) in coastal areas, and sites that are within easy access of boat launches or ports and have reasonable water clarity for diving are most likely to be considered. As coastal populations grow, citizens push for expanded local recreational opportunities. Development around estuaries such as Lake Pontchartrain continues to intensify and thus estuarine artificial reef development is expected to rise as well. Additional work is necessary to compare and consolidate information on brackish water habitat enhancements and to determine strategies for designing reefs that maximize ecological, social, and economic benefits.

LITERATURE CITED

Abadie, W. and M. Poirrier. 2001. Increased density of large *Rania* clams in Lake Pontchartrain after the cessation of shell dredging. *Journal of Shellfish Researc*h 19:481-485.

Anderson, M.J. 1996. A chemical cue induces settlement of Sydney rock oysters, *Saccostrea commercialis*, in the laboratory and in the field. *Biological Bulletin of the Marine Laboratory, Woods Hole* 190:350-358.

Ambrose, R.F. and S.L. Swarbrick. 1989. Comparison of fish assemblages on artificial and natural reefs off the coast of southern California. *Bulletin of Marine Science* 44:718-733.

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

Baynes, T.W. and A.M. Szmant. 1989. Effect of current on the sessile benthic community structure of an artificial reef. *Bulletin of Marine Science* 44:545-566.

Bell, M., M. Buchanan, J. Culbertson, J. Dodrill, R. Kasprzak, R. Lukens, and W. Tatum. 1997. Guidelines for marine artificial reef materials. Gulf States Marine Fisheries Comm.123 p.

Boesch, D.F., M.N. Josselyn, A.J. Mehta, J.T. Morris, W.K. Nuttle, C.A. Simmestad, D.P. Swift. 1994. Scientific assessment of coastal wetland loss, restoration, and management in Louisiana. *Journal of Coastal Research* 20:1-103.

Bohnsack, J.A. 1989. Are high densities of fishes at artificial reefs the result of habitat limitation or behavioral preference? *Bulletin of Marine Science* 44:631-645.

Bohnsack, J.A., A.M. Ecklund, and A.M. Szmant. 1997. Artificial reef research: Is there more than the attraction-production issue? *Fisheries* 22:14-16.

Bohnsack, J.A. and D.L. Sutherland. 1985. Artificial reef research: a review with recommendations for future priorities. *Bulletin of Marine Science* 37:11-39.

Bohnsack, J.A., D.L. Johnson, and R.F. Ambrose. 1991. Ecology of artificial reef habitats and fishes. Pp 61-107. *In:* W. Seaman, Jr. and L.M. Sprague (eds.). *Artificial Habitats for Marine and Freshwater Fishes*. Academic Press, New York.

Booth, J.D. and O. Cox. 2003. Marine fisheries enhancement in New Zealand: our perspective. *New Zealand Journal of Marine and Freshwater Research* 37:673-690.

Bortone, S.A., R.W. Hastings, J.L. Oglesby. 1986. Quantification of reef fish assemblages: a comparison of several *in situ* methods. *Northeast Gulf Science* 8:1-22.

Bortone, S.A., T. Martin, and C.M. Brundrick. 1994. Factors affecting fish assemblage development on a modular artificial reef in a northern Gulf of Mexico Estuary. *Bulletin of Marine Science* 55:319-332.

Bortone, S.A., M.A. Samoilys, and P. Francour. 2000. Fish and macroinvertebrate evaluation methods. *In:* Seaman, W. (ed.) *Artificial Reef Evaluation with Application to Natural Marine Habitats*. CRC Press, Boca Raton, pp. 1-20.

Brock, R.E. 1982. A critique of the visual census method for assessing coral reef fish populations. *Bulletin of Marine Science* 32:269-276.

Bourgeois-Calvin, A., J. Mastrototaro, S.L. Briuglio. 2004. A non-profit approach to addressing the effects of urbanization in the Lake Pontchartrain Basin, Louisiana. *Urban Ecosystems* 7:157-167.

Brusca, R. and G. Brusca. 1990. *Invertebrates*. Sinauer Associates Inc., Sunderland, Massachusetts, pp. 198-200.

Buckeridge, J. Interim Report on the Artificial Reef. November 2002. Earth and Oceanic Science Research Centre, Auckland University of Technology. Accessed 13 January 2005 from http://www.artificialreefs.org/ScientificReports/NewZealand/htm

Bushmann, P.J. 1991. Concurrent signals and behavioral plasticity in blue crab (*Callinectes sapidus* Rathbun) courtship. *Biological Bulletin* 197:63-71.

Carr, W.S. and C.A. Adams. 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida. *Transactions of the American Fisheries Society* 102:511-540.

Chesney, E.J., D.M. Baltz, and R.G. Thomas. 2000. Louisiana estuarine and coastal fisheries and habitats: perspectives from a fish's eye view. *Ecological Applications* 10:350-366.

Christian, R. F. Steimle, and R. Stone. 1998. Evolution of marine artificial reef development – a philosophical review of management strategies. *Gulf of Mexico Science* 1:32-36.

Clarke, K.R. and R.M. Warwick. 1994. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth Marine Laboratories, Plymouth, 144 p.

Connell, S.D. 1997. Exclusion of predatory fish on a coral reef: the anticipation, pre-emption and evaluation of some caging artifacts. *Journal of Experimental Marine Biology and Ecology* 213:181-198.

Cowan, J.H. and W.F. Patterson. 2005. Attraction versus production of red snapper *Lutjanus campechanus* on Alabama artificial reefs: conceptual models and evidence. Proceedings of the 8th International Conference on Artificial Reefs and Artificial Habitats, Biloxi, MS, 10-14 April 2005 (in press).

Darnell, R.M. 1958. Food habits of fishes and invertebrates of Lake Pontchartrain. *Publication of the Institute of Marne Science, University of Texas* 5:353:416.

Dawson, C.E. 1966. Studies on the gobies (Pisces: Gobiidae) of Mississippi Sound and adjacent waters. I. *Gobiosoma*. *American Midland Naturalist* 76:79-409.

Demers, E., S.B. Brandt, K.L. Barry, and J.M. Jech. 2000. Spatially explicit models of growth rate potential: linking estuarine fish production to the biological and physical environment, pp. 405-425. *In:* J.E. Hobbie, (ed.). Estuarine Science: *A Synthetic Approach to Research and Practice*. Island Press.

Eklund, A.M. 1997. The importance of post-settlement predation and reef resources limitation on the structure of reef fish assemblages. *Proceedings of the 8th International Coral Reef Symposium* 2: 1130-1142.

EPA (Environmental Protection Agency). Reef Ball – Punta Gorda Waterfront Juvenile Fisheries Habitat Project. Accessed 13 January 2005 from http://www.artificialreefs.org/Articles/PuntaGorda.htm

Guillory, V., W.E. Perret. 1998. Management, history, status, and trends in the Louisiana blue crab fishery. *Journal of Shellfish Research* 17:413-424.

Guillory, V., H.M. Perry, and S.J. VanderKooy. 2001. The blue crab fishery of the Gulf of Mexico, United States: A regional management plan. Ocean Springs, Mississippi: Gulf States Marine Fisheries Commission.

Hendon, J.R., M.S. Peterson, and B.H. Comyns. 2000. Spatio-temporal distribution of larval *Gobiosoma bosc* in waters adjacent to natural and altered marsh-edge habitats of Mississippi coastal waters. *Bulletin of Marine Science* 66:143-156.

Hixon, M.A. and Brostoff. 1985. Substrate characteristics and Caribbean fish assemblages: experiments with artificial reefs. *Bulletin of Marine Science* 44:666-680.

Hovel, K.A. and R.N. Lipcius. 2001. Habitat fragmentation in a seagrass landscape: patch size and complexity control blue crab survival. *Ecology* 82:1814-1829.

Jennings, C.A. 1985. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico) – sheepshead. U.S. Fish and Wildlife Service Biological Report 82(11.29). U.S. Army Corps of Engineers, TR EL-82-4, 10 p.

Junot, J., M. Poirrier, and T. Soniat. 1983. Effects of saltwater intrusion from the Inner Harbor Navigation Canal on the benthos of Lake Pontchartrain, Louisiana. *Gulf Research Reports* 7:247-254.

Kasprzak, R.A. 1998. Use of oil and gas platforms as habitat in Louisiana's Artificial Reef Program. *Gulf of Mexico Science* 1:37-45.

Kimmel, JJ. 1985. A new species-time method for visual assessment of fishes and its comparison with established methods. *Environmental Biology of Fishes* 12:23-32.

Lindquist, D.G. and L.J. Pietrafesa. 1989. Current vortices and fish aggregations: The current field and associated fishes around a tugboat wreck in Onslow Bay, North Carolina. *Bulletin of Marine Science* 44:533-544.

Lopez, J. 2004. The Lake Pontchartrain Artificial Reef Program Deployment from 2000 to 2004. Final Report submitted to the Lake Pontchartrain Basin Foundation and Louisiana Department of Wildlife and Fisheries, 70 p.

Louisiana Department of Wildlife and Fisheries. Louisiana Artificial Reef Program. Accessed 20 February 2005 from http://www.wlf.state.la.us/apps/netgear/index.asp?cn=lawlf

LSU (Louisiana State University). Hurricane Katrina and Rita Clearinghouse Cooperative. Accessed 14 February 2006. http://katrina.lsu.edu.

LPBF (Lake Pontchartrain Basin Foundation). Accessed 15 November 2005 from http://saveourlake.org/index.htm

LPARWG (Lake Pontchartrain Artificial Reef Working Group). Lake Pontchartrain Artificial Reef Program brochure. February 2004. Lake Pontchartrain Basin Foundation and members of the Lake Pontchartrain Artificial Reef Working Group, 2 p.

LUMCON (Louisiana Universities Marine Consortium). LUMCON Weather Archive Data for Lake Pontchartrain. Accessed 24 January 2004 from http://weather.lumcon.edu/archivedata/select.asp.

LUMCON (Louisiana Universities Marine Consortium). LUMCON Weather Data Archive. Accessed 20 January 2005 from http://weather.lumcon.edu/archivedata/select.asp.

Martin, T.R. and S.A. Bortone. 1997. Development of an epifaunal assemblage on an estuarine artificial reef. *Gulf of Mexico Science* 2:55-70.

Matthews, K.R. 1985. Species similarity and movement of fishes on natural and artificial reefs in Monterey Bay, California. *Bulletin of Marine Science* 37:252-270.

McGlennon, D. and K.L. Branden. 1994. Comparison of catch and recreational anglers fishing on artificial reefs and natural seabed in Gulf St. Vincent, South Australia. *Bulletin of Marine Science* 55:510-523.

Miller, M.W. and A. Falace. 2000. Evaluation methods for trophic resource factors – nutrients, primary production, and associated assemblages. *In:* W. Seaman, Jr. (ed.). *Artificial Reef Evaluation with Application to Natural Marine Habitats*. CRC Press, Boca Raton.

Moore, R.H. 1992. Low-salinity backbays and lagoons. *In:* Hackney, C.T., S.M. Adams, and W.H. Martin (eds.). *Biodiversity of the Southeastern United States: Aquatic Communities*. New York: Wiley, pp. 541-614.

NMFS. 2002. Fisheries of the Unites States, 2001. US Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

NOAA (National Oceanic Atmospheric Administration), National Weather Service, National Hurricane Center. Tropical Weather Summary. Accessed 8 November 2004 from http://www.nhc.noaa.gov/archive/2004/tws/MIATWSAT_sep.shtml

NOAA (National Oceanic Atmospheric Administration), National Hurricane Center, Tropical Prediction Center. 2005 Atlantic Hurricane Season. Accessed 23 January 2005 from http://www.nhc.noaa.gov/2005atlan.shtml

NOAA (National Oceanic Atmospheric Administration). 2006. Post Storm Data Acquisition Aerial Wind Analysis and Damage Assessment, Hurricane Katrina. Technical Report, October 31, 2005. Accessed April 3, 2006 from http://www.nws.noaa.gov/os/data/pdfs/KatrinaPSDA.pdf, 11 p.

O'Connell, M.T., C.D. Franze, E.A. Spalding, and M.A. Poirrier. 2005. Biological resources of the Louisiana coast: Part 2, coastal animals and habitat associations. *Journal of Coastal Research* SI44:146-161.

Pattengill-Semens, C. and B. Semmens. 1998. An analysis of fish survey data generated by nonexpert volunteers in the Flower Garden Banks National Marine Sanctuary. *Gulf of Mexico Science* 2:196-207.

Penland, S., A. Beall, and D. Maygarden. 2002. Environmental status and trends of the Lake Pontchartrain Basin. *In*: S. Penland, A. Beall, and J. Kinder (eds.) *Environmental Atlas of Lake Pontchartrain*. USGS Open File Report 02-206.

Perry, H.M. and T.D. McIlwain. 1986. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico) blue crab. U.S. Fish and Wildlife Service Biological Report 82(11.55). U.S. Army Corps of Engineers, 21 p.

Perry, H. K. Larson, J. Warren, and C. Trigg. 2001. Seasonal colonization of low profile artificial reefs in Mississippi coastal waters: Invertebrates. *Proceedings of the 52nd Annual Gulf and Caribbean Fisheries Institute* 52:498-511.

Peterson, M.S. and S.T. Ross. 1991. Dynamics of littoral fishes and decapods along a coastal river-estuarine gradient. *Estuarine, Coastal, and Shelf Science* 33:467-483.

Pickering, H.D. and D. Whitmarsh. 1997. Artificial reefs and fisheries exploitation: a review of the 'attraction versus production' debate, the influence of design and its significance for policy. *Fisheries Research* 31:39-59.

Pickering, H., D. Whitmarsh, and A.C. Jensen. 1998. Artificial reefs as a tool to aid rehabilitation of coastal ecosystems: investigating the potential. *Marine Pollution Bulletin* 37:505-514.

Poirrier, M.A. 1978. Studies of salinity stratification in southern Lake Pontchartrain near the Inner Harbor Navigation Canal. *Proceedings of the Louisiana Academy of Sciences* 41:26-35.

Poirrier, M.A. 1984. An Identification Guide to the Macroscopic Invertebrates of the Lake Pontchartrain Estuary, Louisiana. Louisiana Department of Environmental Quality, Water Pollution Control Division, 47 p.

Poirrier, M.A. 2001. Lake Pontchartrain Artificial Reef Evaluation Program Quality Assurance Project Plan. Estuarine Research Laboratory, Department of Biological Sciences, University of New Orleans, Louisiana, 24 p.

Poirrier, M.A. and J.S. Rogers. 1975. Epifaunal invertebrates as indicators of water quality in southern Lake Pontchartrain. Louisiana Water Resources Research Institute, Technical Report No. 5. Louisiana State University, Baton Rouge. 43 p.

Poirrier, M.A. and J.E. Sinclair. 2002. Lake Pontchartrain Artificial Reef Evaluation Program. Final report to the Lake Pontchartrain Basin Foundation, 13p.

Poirrier, M.A. and K.A. Whitmore. 2005. Lake Pontchartrain Artificial Reef Evaluation Program: June through December 2004 results. Submitted to the Lake Pontchartrain Basin Foundation, 29 p.

Rabalais, N.N, D.E. Harper, Jr., and R.E. Turner. 2001. Responses of nekton and demersal and benthic fauna to decreasing oxygen concentrations. *In:* N.N. Rabalais and R.E. Turner (eds.). *Coastal Hypoxia: consequences for living resources and ecosystems. Coastal and Estuarine Studies 58.* American Geophysical Union, Washington, D.C., pp. 115-128.

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

RBDG (Reef Ball Development Group, Ltd). 2002. Internet Brochure. The Reef Ball Foundation Inc. Services Division. Accessed 10 January 2005 from http://www/reefball.com/reef/htm.

REEF (Reef Environmental Education Foundation). REEF's Fish Survey Project. 2002. Accessed 12 January 2005 from http://reef.org/data/surveyproject.thm.

Relini, G., M. Relini, G. Torchia, and G. de Angelis. 2002. Trophic relationships between fishes and an artificial reef. *ICES Journal of Marine Science* 59:S36-S42.

Roehl, E. and L. Harris. 1996. Stability analysis of Reef Ball artificial reef units. Florida Institute of Technology Wave Tank and Stability Analysis. Report prepared for Reef Ball Development Group Ltd. Accessed 16 December 2004 from http://www.reefball.org/stab.htm.

Ryer, C.H. 1987. Temporal patterns of feeding by blue crabs (*Callinectes sapidus*) in a tidal-marsh creek and adjacent seagrass meadow in the lower Chesapeake Bay. *Estuaries* 10:136-140.

Sale, P.F. and W.A. Douglas. 1981. Precision and accuracy of visual census technique for fish assemblages on coral patch reefs. *Environmental Biology of Fishes* 6:333-339.

Schmitt, E. and K. Sullivan. 1996. Analysis of a volunteer method for collecting fish presence and abundance data in the Florida Keys. *Bulletin of Marine Science* 59:404-416.

Seaman, W and A. Jensen. 2000. Purposes and practices of artificial reef evaluation. *In:* Seaman, W. (ed) *Artificial Reef Evaluation with Application to Marine Habitats*. CRC Press, Boca Raton, pp. 1-20.

Seaman, W., R.M. Buckley, and J.J. Polovina. 1989. Advances in knowledge and priorities for research, technology, and management related to artificial aquatic habitats. *Bulletin of Marine Science* 44:527-532.

Serviss, G. and S. Sauers. 2003. Sarasota Bay Juvenile Fisheries Habitat Assessment. Final Report to the Sarasota Bay National Estuary Program, 212 p.

Sheng, Y.P. 2000. Physical characteristics and engineering at reef sites. *In:* W. Seaman, Jr. (ed.). *Artificial Reef Evaluation with Application to Natural Marine Habitats*. CRC Press, Boca Raton.

Sikora, W.B. and B. Kjerfive. 1985. Factors influencing the salinity regime of Lake Pontchartrain, Louisiana, a shallow coastal lagoon: Analysis of a long-term data set. *Estuaries* 8: 170-180.

Steele, M.A. 1996. Effects of predators on reef fishes: separating cage artifacts from effects of predation. *Journal of Experimental Biology and Ecology* 198:249-267.

Steimle, F., K. Foster, R. Kropp, and B. Conlin. 2002. Benthic macrofauna productivity enhancement by an artificial reef in Delaware Bay, USA. *ICES Journal of Marine Science* 59:S100-S105.

Stephens, J. and D. Pondella. 2002. Larval productivity of a mature artificial reef: the ichthyoplankton of King Harbor, California, 1974 – 1997. *ICES Journal of Marine Science* 59:51-58.

Stone, J.H. (ed.) 1980. Environmental analysis of Lake Pontchartrain, Louisiana, its surrounding wetlands, and selected land uses, Vol. 1 & 2. Coastal Ecology Laboratory Center for Wetland Response. Publication #LSU6180-08, LSU, Baton Rouge.

Suprenant, B.A. 2001. Designing concrete for exposure to seawater. *Concrete Construction.*

Swenson, E.M. 1980. General hydrography of Lake Pontchartrain, Louisiana. *In:* J.H. Stone. (ed.) Environmental analysis of Lake Pontchartrain, Louisiana, its surrounding wetlands, and selected land uses, Vol. 1. Prepared for U.S. Army Engineer District, New Orleans, pp. 57-156.

Turpin, R.K. and S.A. Bortone. 2002. Pre- and post-hurricane assessment of artificial reefs: evidence for potential use as refugia in a fishery management strategy. *ICES Journal of Marine Science* 59:74-82.

USGS (United States Geological Survey). USGS Real-Time Water Data for station USGS 073802331 (COE) Lake Pontchartrain at West End, Louisiana. U.S. Army Corps of Engineers, New Orleans District. Accessed 10 January 2005 from http://nwis.waterdata.usgs.gov/la/nwis/dv?format=html&period=130&site_no=073802

Walker, B.K., B. Henderson, and R.E. Spieler. 2002. Fish assemblages associated with artificial reefs of concrete aggregates or stone quarry offshore Miami Beach, Florida, USA. *Aquatic Living Resources* 15:95-105.

Weiderholm, A.M. 1987. Habitat selection and interactions between three marine species (Gobiidae). *Oikos* 48:28-32.

Whitmore, K.A. and M.A. Poirrier. 2006. Lake Pontchartrain Artificial Reef Evaluation: 2004 & 2005 Results. Final report submitted to the Lake Pontchartrain Basin Foundation, 62 p.

Wilding, T.A. and M.D.J. Sayer. 2002. Evaluating artificial reef performance: approaches to pre- and post-deployment. *ICES Journal of Marine Science* 59:S222-S230.

Wilson, C.A., V.R. Van Sickle, D.L. Pope. 1987. Louisiana Artificial Reef Plan. Louisiana Sea Grant College Program, Louisiana State University, Baton Rouge, Louisiana. Louisiana Department of Wildlife and Fisheries Technical Bulletin No. 41, 143 p.

Zalmon, I.R., R. Novelli, M.P. Gomes, and V.V. Faria. 2002. Experimental results of an artificial reef programme on the Brazilian coast of north Rio de Janeiro. *ICES Journal of Marine Science* 59:83-87.

Personal Communications

Lane, M. Publisher, Louisiana Fishing and Hunting website (http://rodnreel.com). 16 Nov. 04.

Ronnie. Lake Pontchartrain commercial blue crab fisherman. 10 Aug. 2005.

Raulerson, G. Sr. Environmental Scientist, Sarasota Bay National Estuary Program. 12 Jan. 04.

Appendix A. Dive log of all trips made to the artificial reef and reference sites in 2004 & 2005.

Reference	**Reef Site Descriptions:**	**Locations:**	**Diver Affiliations:**
	H3 - Monitoring Site - South Shore	N 30° 05.034' W 090° 12.582'	**UNO** - University of New Orleans
	H1 - South Shore	N 30° 05.028' W 090° 12.096'	**NOAA** - National Oceanic Atmospheric Administration
	H4 - South Shore	N 30° 05.274' W 090° 12.336'	**AOA** - Aquarium of the Americas, New Orleans
	N1 - North Shore	N 30° 16.296' W 090° 03.753'	**LPBF** - Lake Pontchartrain Basin Foundation
			MMS - Minerals Management Service
2004			
Dive #1	**Date:** 7/1/04	**Algae:**	**Notes:**
	Site: H3	*Anabaena* sp. bloom from surface to 3 m	Very little invertebrate colonization on reef balls
	Vessel: C-Hawk (UNO)	Green algae on balls (1-2 cm long)	Sediment covering surface of balls 0.1 in thick.
	Visibility: ~8ft	**Invertebrates:**	Cleaned off plates of some balls to read.
	Purpose: Observation	*Balanus* sp. only in small crevices on balls	Measured strip width to be ~35 ft.
	Approx. Bottom Time: 80 min	*Congeria* clams only in small crevices on balls	Buoy w/in reefballs on southwestern flank.
	Divers:	Box oysters (dead) 7-12 cm	Balls in pairs, pallet on inside, bay on outside.
	Kelly Whitmore (UNO)	**Fishes:**	
	William Whitmore (NOAA)	*Gobiosoma bosci* ball surfaces	
	Michael Poirrier (UNO)	*Archosargus probatocephalus* around & inside balls	
	Chip Crews (UNO)	*Hypsoblennius* sp. on surface of balls	
		Caranx hippos (~0.8 m in length) around balls	
		Mugil cephalus on surface water above balls feeding	
Dive #2	**Date:** 7/5/04	**Algae:**	**Notes:**
	Site: H3	*Anabaena* sp. bloom from surface to 3 m	Moved buoy back toward center of shell pad.
	Vessel: Cape Horn (LPBF)	Green algae on balls (1-2 cm long)	Measured strip width to be 30-40 ft.
	Visibility: ~8ft	**Invertebrates:**	Distance between balls ranges 5-15 ft.
	Purpose: Observation, Site Scouting	River shrimp (*Macrobranchium ohion*) inside balls	Usually one row pallet, two rows of bay balls cross through strip.
	Approx. Bottom Time: 75 min	*Congeria* only in small crevices on balls	Leety & Dautrive circumnavigated entire reef -
	Divers: Kelly Whitmore (UNO)	*Ishadium* on shell pad 4-7 cm	documented 6 crooked balls (2 pallet, 4 bay)
	William Whitmore (NOAA)	**Fishes:**	Surface temperature 86°F, bottom temperature 82°F
	Kenny Ripberger (AOA)	*Ictalurus furcatus* inside ball	Overturned or crooked balls: 211P (w), 230 (nw), 538 (n), 540 (n),
	Les Dauterive (AOA)	*A. probatocephalus* around and inside balls	580 (ne), 557 (nw)
	John Lopez (LPBF)	*G. bosci* on ball surface	
	Herb Leety (Hammerheads & MMS)	*Hypsoblennius* sp. on ball surface	
		M. cephalus on surface water above balls feeding	
Dive #3	**Date:** 7/10/04	**Algae:**	**Notes:**
	Site: H3	Surface algal bloom gone	Marked south quadrant using rebar. Hammered in 5 ft PVC
	Vessel: C-Hawk (UNO)	**Invertebrates:**	~2.5 ft through shell to mark corners. Marked south and west
	Visibility: 7ft (Secchi)	*Callinectes sapidus* underneath balls	sides of quadrant with flagging tape. Caught by storm, could not
	Purpose: Quadrant Set-up	**Fishes:**	finish distance measurements between poles and balls in quadrant.
	Approx. Bottom Time: 79 min	*A. probatocephalus* (~0.1-0.2 m in length)	Received updated deployment report from J. Lopez.
	Divers: Kelly Whitmore (UNO)		
	William Whitmore (NOAA)		
	Michael Poirrier (UNO)		
	Ryan Poirrier (UNO)		
Dive #4	**Date:** 7/11/04	**Algae:**	**Notes:**
	Site: H3	**Invertebrates:**	Finished south quadrant setup. Marked sides with flagging tape.
	Vessel: Cape Horn (LPBF)	*Callinectes sapidus* underneath balls	Measured distances of reef balls to corner poles
	Visibility: ~7ft	**Fishes:**	and to each other underwater w/ 50 m Kenson vinal tape.
	Purpose: Quadrant Set-up	*A. probatocephalus* (~0.1-0.2 m in length)	10 balls total, 4 pallet balls and 6 bay balls.
	Approx. Bottom Time: 103 min	*M. cephalus* on surface water above balls feeding	Received side scan sonar map and images on cd from J. Lopez.
	Divers: Kelly Whitmore (UNO)		
	William Whitmore (NOAA)		
	Les Dautrive (AOA)		
	John Lopez (LPBF)		
Dive #5	**Date:** 7/22/04	**Algae:**	**Notes:**
	Site: H4	Duckweed on surface (*Lemna*)	First look at site. No balls found on eastern side of the reef.
	Vessel: Aquarium of Americas boat	**Invertebrates:**	Balls on west packed tightly together, few overturned/crooked.
	Visibility: ~5ft	*Callinectes sapidus* underneath balls	3-4 anchors caught in the balls. Visibility low, but workable.
	Purpose: Site scouting, observation	**Fishes:**	6-8 balls no longer had ID plates .
	Approx. Bottom Time: 50 min	*A. probatocephalus* (~0.2-0.4 m in length)	
	Divers: Kelly Whitmore (UNO)	*G. bosci* on ball surface	
	Giulia Hammans (AOA)	*M. cephalus* on surface water above balls feeding	
	Brian (AOA)		
	Rich Toth (AOA) Boat Driver		
Dive #6	**Date:** 7/28/04	**Algae:**	**Notes:**
	Site: H3	Duckweed on surface (*Lemna*)	Poor visibility (~1ft). Could not set up northern quadrant.
	Vessel: C-Hawk (UNO)	**Invertebrates:**	Took water quality on shell pad and in reefball area.
	Visibility: ~1ft	**Fishes:**	Cleaned sediment off two balls; 507 & 509.
	Purpose: Set up quadrant		No sightings due to poor visibility.
	Approx. Bottom Time: 12 min		
	Divers: Kelly Whitmore (UNO)		
	Beth Spalding (UNO)		
	William Whitmore (NOAA)		
	Chip Crews (UNO) Boat Driver		

	Chip Crews (UNO) Boat Driver		
Dive #7	**Date:** 8/4/04	**Algae:**	**Notes:**
	Site: H3	**Invertebrates:**	Placed 4 PVC pipes in shell/mud to mark movement-monitoring
	Vessel: C-Hawk (UNO)	Remnants of barnacles on balls	area in the northern section of the H3 reef site.
	Visibility: 6 ft (Secchi)	*Congeria* only in small crevices on balls	Area is approximately 40x40 ft enclosing 15 reefballs.
	Purpose: Set up northern quadrant	*Callinectes sapidus* underneath balls	Visibility was good. Sunny, calm conditions.
	Approx. Bottom Time: 150 min	**Fishes:**	
	Divers:	*A. probatocephalus* around and inside balls	
	Kelly Whitmore (UNO)	*G. bosci* on ball surface	
	Ashley Walker (UNO)	*Hypsoblennius* sp. on and under balls	
	Chip Crews (UNO)		
Dive #8	**Date:** 8/27/04	**Algae:**	**Notes:**
	Site: H3	**Invertebrates:**	Took measurements on upside-down ball and surrounding balls
	Vessel: C-Hawk (UNO)	**Fishes:**	in the center of north quadrant plot.
	Visibility: 6 ft (Secchi)	*A. probatocephalus* around and inside balls	Visibilty wasn't good enough for new photos.
	Purpose: Finish measurements	*G. bosci* on ball surface - fewer than earlier dives	Short dive due to class.
	Approx. Bottom Time: 55 min		Small buoy marking plot was gone.
	Divers:		
	Kelly Whitmore (UNO)		
	Chip Crews (UNO)		
Dive #9	**Date:** 10/28/2004	**Algae:**	**Notes:**
	Site: H3	**Invertebrates:**	Repeated all ball measurements for southern quadrant on H3 site.
	Vessel: C-Hawk (UNO)	Hydroids up to 7 cm long	Balls were present within .15m of the original measurements.
	Visibility: 4.5 ft (Secchi)	Freshwater sponge growth w/in 0.3 m of bottom	5 boats of fishers fishing, one catching many speckled trout
	Purpose: Repeat measurements	Bryozoans underneath sponge layer	Did not have time to check northern quadrant plot.
	Approx. Bottom Time: 150 min	Sponges had gemmules	Took scrape samples of invertebrates.
	Divers:	**Fishes:**	More growth on balls than ever seen before, but still minimal.
	Kelly Whitmore (UNO)	*Anchoa* sp. schooling at surface and around balls	
	William Whitmore (NOAA)	*Hypsoblennius* sp. under balls in holes	
	Michael Poirrier (UNO)	*I. punctatus* (~0.5 m) inside ball	
		M. cephalus on surface water and around balls	
2005			
Dive #1	**Date:** 14 May 2005	**Algae:**	**Notes:**
	Site: H3	*None observed in water column or on reef balls*	First dive of the season
	Vessel: C-Hawk (UNO)		Greater epifaunal growth than previous summer and fall.
	Visibility: 5 ft (Secchi)	**Invertebrates:**	Sediment layer on balls where hydroids were not present. In some
	Purpose: Inspect invert growth	*Hydroids on balls - some long up to ~6 in upper part*	locations small barnacles present around top hole of reef balls
	Approx. Bottom Time: 35 min (70 total)	of balls	
	Divers: Kelly Whitmore (UNO)	*Small barnacles in some areas - not abundant*	Took scrape samples
	William Whitmore (NOAA)	**Fishes:**	
	Boat Driver: Michael Poirrier (UNO)	*Gobiosoma bosci*	
		Hypsoblennius iothonas	
Dive #2	**Date:** 17 May 2005	**Algae:**	**Notes:**
	Site: Oil/Gas Rid ~2 mi E of S reefs	*None observed on pilings*	Inspected wood pilings
	Vessel: Proline (UNO)		Other than barnacles and hydroids, no other sessile inverts present
	Visibility: 2.5 ft (Secchi)	**Invertebrates:**	Growth not very different from that seen on reef balls in previous dive
	Purpose: Inspect invert growth	*Hydroids ~2-3 in long in patches most dense @ 5ft*	
	Approx. Bottom Time: 15 min (45 total)	*Barnacles*	Took scrape samples
	Divers: Kelly Whitmore (UNO)		
	Ashely Walker (UNO)	**Fishes:**	
	Chip Crews (UNO)	*None observed*	
Dive #3	**Date:** 17 May 2005	**Algae:**	**Notes:**
	Site: Causeway pilings E/SE of S reefs	*None observed on pilings*	Less hydroid growth than on reef balls and wood pilings
	Vessel: Proline		
	Visibility: 2.5 ft	**Invertebrates:**	Took scrape samples
	Purpose: Inspect invert growth	*Large barnacles covering pilings except bottom*	
	Approx. Bottom Time: 12 min (36 total)	*Hydroids almost non-existent, small patches 2x3 in*	
	Divers: Kelly Whitmore (UNO)	around 5-8 ft	
	Ashely Walker (UNO)	**Fishes:**	
	Chip Crews (UNO)	*None observed on pilings*	
Dive #4	**Date:** 2 June 2005	**Algae:**	**Notes:**
	Site: H3 & mud		15 min fish surveys Chip & Kelly at H3 reef and mud
	Vessel: C- Hawk		GPS not working - couldn't survey shell pad
	Visibility: 6 ft	**Invertebrates:**	
	Purpose: Fish Survey	*Callinectes sapidus*	Weather: very calm ~1 knot wind
	Approx. Bottom Time: 40 min (80 total)		
	Divers: Kelly Whitmore (UNO)		
	Chip Crews (UNO)	**Fishes:**	
	Boat Driver: William Whitmore (NOAA)	*Gobiosoma bosci*	
		Archosargus probatocephalus	
Dive #5	**Date:** 3 June 2005	**Algae:**	**Notes:**
	Site: H1 & shell pad & mud		For detailed fish survey information see fish survey list
	Vessel: C-Hawk		Conducted two 10 min surveys per diver team per area: mud, shell
	Visibility: 6 ft	**Invertebrates:**	pad, and reef (H1)
	Purpose: Fish survey	*Callinectes sapidus*	Underwater visibility - horizontal secchi 4.5 ft
	Approx. Bottom Time: 70 min (280 total)		
	Divers: Kelly Whitmore (UNO)		
	Chip Crews (UNO)	**Fishes:**	
	William Whitmore (UNO)	*Archosargus probatocephalus*	
	Chad Ellinwood (UNO)	*Gobiosoma bosci*	
		Paralichthys lethostigma	
Dive #6	**Date:** 9 June 2005	**Algae:**	**Notes:**
	Site: H3		Took measurements on northern movement monitoring plot of H3
	Vessel: C-Hawk		Not as much hydroid growth as seen at the southern plot
	Visibility: 4 ft	**Invertebrates:**	Some algal growth on balls
	Purpose: Take measurements of balls		Many missing ID tags - 3 that had had them last year were gone
	Approx. Bottom Time: 140 min (420 total)		Large mullet around reef balls ~12-14 in
	Divers: Kelly Whitmore (UNO)		
	Chip Crews (UNO)	**Fishes:**	
	Ashley Walker (UNO)	*Archosargus probatocephalus*	
		Mugil cephalus	

Dive #7	**Date:** 18 June 2005	**Algae:**	**Notes:**
	Site: H3	*Some short green algae on some balls*	Visibility was not good enough for fish surveys, conducted
	Vessel: C-Hawk		blue crab burrow survey instead - around base of reef balls
	Visibility: 5 ft	**Invertebrates:**	
	Purpose: Blue crab survey	*2 Callinectes sapidus*	
	Approx. Bottom Time: 65 min (130 total)	*Hydroids*	
	Divers: Kelly Whitmore (UNO)	*Balanus*	
	Ashley Walker (UNO)	**Fishes:**	
		Myrophis punctatus speckled worm eel 7"	
		Archosargus probatocephalus	
		Carnax hippos	
Dive #8	**Date:** 23 June 2005	**Algae:**	**Notes:**
	Site: H3, H, mud		Two 10 min surveys by each pair at each site. Great visibility
	Vessel: C-Hawk		
	Visibility:	**Invertebrates:**	
	Purpose: Fish survey	*Callinectes sapidus*	
	Approx. Bottom Time: 80 min (320 total)		
	Divers: Kelly Whitmore (UNO)		
	William Whitmore (UNO)	**Fishes:**	
	Chip Crews (UNO)	*Archosargus probatocephalus*	
	Ashley Walker (UNO)		
Dive #9	**Date:** 24 June 2005	**Algae:**	**Notes:**
	Site: H3, H, mud		Two 10 min surveys by each pair at each site. Great visibility
	Vessel: C-Hawk		
	Visibility: 9 ft (Secchi)	**Invertebrates:**	Crabs observed mating - 4 pairs of male and female inside balls
	Purpose: Fish survey	*Callinectes sapidus*	Many molts of juvenile crabs found around base of balls
	Approx. Bottom Time: 75 min (300 total)	*Hydroids*	
	Divers: Kelly Whitmore (UNO)	*Rhithropanopeus harrisii*	
	Mark Schexnayder (LSU Ag Center)	**Fishes:** *Ictalurus furcatus*	
	Ryan Poirrier (UNO)	*Archosargus probatocephalus*	
	Ashley Walker (UNO)	*Lagodon rhomboides*	
		Anguilla rostrata	
		Gobiosoma bosci	
		Hypsoblennius iothonas	
Dive #10	**Date:** 30 June 2005	**Algae:**	**Notes:**
	Site: H3, H, mud		Two 10 min surveys by each pair at each site. Visibility back to
	Vessel: C-Hawk		"normal"
	Visibility: 6 ft (Secchi)	**Invertebrates:**	
	Purpose: Fish survey	*Callinectes sapidus*	
	Approx. Bottom Time: 70 min (280 total)	*Spongilla alba*	
	Divers: Kelly Whitmore (UNO)		
	Chip Crews (UNO)	**Fishes:**	
	Ashley Walker (UNO)	*Gobiosoma bosci*	
	Beth Spalding (UNO)		
Dive #11	**Date:** 4 August 2005	**Algae:**	**Notes:**
	Site: H3, H, mud		Two 10 min surveys by each pair at each site.
	Vessel: C-Hawk		
	Visibility: 7.5 ft (Secchi)	**Invertebrates:**	Balls covered in soft, velvety organic matter. Took sample for
	Purpose: Fish survey	*Callinectes sapidus*	analysis.
	Approx. Bottom Time: 70 min (280 total)	*Spongilla alba*	Live sponge on some balls.
	Divers: Kelly Whitmore (UNO)		Fewer crabs sighted than in late June but still many holes under
	Chip Crews (UNO)	**Fishes:**	reef balls
	Ashley Walker (UNO)	*Carnax hippos*	
	Ryan Poirrier (UNO)	*Myrophis puncatus*	
		Lagodon rhomboides	
		Gobiosoma bosci & Hypsoblennius iothonas	
		Archosargus probatocephalus	
Dive #12	**Date:** 5 August 2005	**Algae:**	**Notes:**
	Site: H, H3, mud		Two 10 min surveys by each pair at each site.
	Vessel: C-Hawk		Excellent visibility but few fishes sighted
	Visibility: 11 ft	**Invertebrates:**	
	Purpose: Fish survey	*Callinectes sapidus*	No juvenile flounder sighted unlike earlier in the season
	Approx. Bottom Time: 70 min (280 total)		
	Divers: Kelly Whitmore (UNO)		
	Chip Crews (UNO)	**Fishes:**	
	Ashley Walker (UNO)	*Lagodon rhomboides*	
	William Whitmore (NOAA)		
Dive #13	**Date:** 16 August 2005	**Algae:**	**Notes:**
	Site: H, H3, mud		Good visibility over shell and reef but not over mud
	Vessel: C-Hawk		Few fishes sighted
	Visibility: 10.5	**Invertebrates:**	Small barnacles starting to colonize on upper portion of some balls
	Purpose: Fish survey	*Balanus*	
	Approx. Bottom Time: 90 min (320 total)	*Callinectes sapidus*	Deployed barnacle substratum from Bayou St. John - took pics
	Divers: Kelly Whitmore (UNO)		of coverage
	Ashely Walker (UNO)	**Fishes:**	
	Chip Crews (UNO)	*Gobisox strumosus*	No surface algal blooms
	Ryan Poirrier (UNO)	*Hypsoblennius iothonas*	Dead pogies in 17th st canal and at west end boat launch
		Lagodon rhomboides	
		Gobiosoma bosci	
Dive #14	**Date:** 18 August 2005	**Algae:**	**Notes:**
	Site: H1		Night gillnet sampling - no recovered catch (1-1" croaker in mud,
	Vessel: C-Hawk		1-13" unidentified fish fell out over shell, catfish slime over reef)
	Visibility: night - est. 8-10 ft	**Invertebrates:**	Night dive
	Purpose: Fish survey		American eels coming out from under balls, along with many
	Approx. Bottom Time: 25 min (50 total)	*Callinectes sapidus*	large (5-7 in) blue crabs - saw 23, one 1" blue crab
	Divers: Kelly Whitmore (UNO)		all coming out from holes dug under reef balls
	Chip Crews (UNO)	**Fishes:**	large skilletfish on balls w/ naked gobies
		Gobisox strumosus 2 - 3"	no large fish sighted
		Gobiosoma bosci	
		American eel - 3 - 15"	
Dive #15	**Date:** 21 August 2005	**Algae:**	**Notes:**
	Site: N1		North Shore dive
	Vessel: Glacier Bay (Mike's boat)		Took invertebrate scrape samples - ~80% cover of hydroids and
	Visibility: 6 ft	**Invertebrates:**	sponge, no barnacles or other bivalves
	Purpose: Invert samples	*hydroids*	Fish survey - 10 minutes
	Approx. Bottom Time: 50 min (120 total)	*Spongilla alba*	
	Divers: Kelly Whitmore (UNO)		6 - 5 x 5 cm scrapes from random areas of balls
	Willie Whitmore (UNO)	**Fishes:**	1 overall sample
	Ryan Poirrier (UNO)	*Gaspergou*	
		Gobiosoma bosci	Gemules in sponge samples
		Hypsoblennius iothonas	
		Archosargus probatocephalus	

Appendix B. Water quality measurements taken at the Lake Pontchartrain artificial reefs and reference sites in 2004 and 2005.

Date Time	Site	Location	Depth	DO % Saturation	DO (mg/L)	Salinity (ppt)	Temp. (deg C)	Secchi Depth (ft)	Notes	Equipment
2004										
7/28/2004	H3	Reef	Surface	114.0	8.60	2.3	30.2	1		YSI-85
		Reef	Near-bottom (11ft)	98.5	7.20	2.3	29.7			
7/28/2004	H3	Shell pad	Surface	112.5	8.60	2.3	30.2	1		YSI-85
		Shell pad	Near-bottom (11ft)	97.0	7.33	2.3	29.7			
8/27/2004	H3	Reef	Surface	101.1	7.32	2.9	31.9	6		YSI-85
		Reef	Near-bottom (11ft)	80.9	5.47	2.8	32.5			
8/27/2004	H3	Shell pad	Surface	101.5	7.16	2.9	32.8	6		YSI-85
		Shell pad	Near-bottom (11ft)	90.8	6.91	2.9	32.5			
9/27/2004	H3	Reef	No samples available due to poor weather conditions.							YSI-85
		Reef								
10/28/2004	H3	Reef	Surface	99.1		4.7	31.6	4.5		YSI-85
		Reef	Near-bottom (11ft)	93.1		5.0	30.4			
10/28/2004	H3	Shell pad	Surface	95.9		4.5	30.8	4.5		YSI-85
		Shell pad	Near-bottom (11ft)	88.1		5.0	29.4			
2005										
4/27/2005	N1	Reef	Surface	101.9	8.33	3.4	24.5	4		YSI-85
13:16		Reef	Near-bottom (15.2 ft)	90.1	7.82	3.5	23.0			
4/27/2005	H1	Reef	Surface	102.2	8.13	3.3	25.9	4		YSI-85
14:07		Reef	Near-bottom (14.1 ft)	92.6	7.79	3.5	23.3			
4/27/2005	H3	Reef	Surface	101.3	8.46	3.8	23.8	4		YSI-85
14:00		Reef	Near-bottom (10.5 ft)	91.7	7.83	3.7	22.3			
4/27/2005	H4	Reef	Surface	102.5	8.34	3.9	24.6	3.5		YSI-85
13:53		Reef	Near-bottom (14.7 ft)	83.0	7.28	3.8	22.3			
5/14/2005	center of 3	Mud	Surface	91.8	6.86	3.4	27.7	5	Rep #1	YSI-85
10:00	S shore reefs	Mud	Near-bottom (15 ft)	87.7	6.74	3.2	27.6			
5/14/2005	center of 3	Mud	Surface	91.4	7.17	3.8	26.8	4.5	Rep #2	YSI-85
10:15	S shore reefs	Mud	Near-bottom (15 ft)	82.8	6.73	3.8	26.4			
5/17/2005	H3	Reef	Surface	85.7	6.67	3.8	25.8	2.5	Rep #1	YSI-85
7:10		Reef	Near-bottom (10.5 ft)	83.5	6.57	3.7	26.0			
5/17/2005	H3	Reef	Surface	84.7	6.70	3.6	26.3	2.5	Rep #2	YSI-85
7:50		Reef	Near-bottom (10.5 ft)	83.7	6.60	3.6	26.2			
6/2/2005	center of 3	Mud	Surface	99.6	7.44	2.7	30.6	5		YSI-85
9:20	S shore reefs	Mud	Near-bottom (15 ft)	92.7	6.96	2.7	30.0			
6/2/2005	H3	Reef	Surface	92.7	6.70	2.4	31.2	6		YSI-85
9:40		Reef	Near-bottom (15 ft)	91.9	6.73	2.4	31.0			
6/3/2005	H3	Reef	Surface				32.0	6	YSI error	YSI-85
9:05		Reef	Near-bottom (15 ft)				31.8			
6/9/2005	H	Shell pad	Surface	109.0	7.84	3.9	28.8	4		YSI-85
9:05		Shell pad	Near-bottom (13 ft)	103.0	7.87	3.9	28.6			
6/18/2005	center of 3	Mud	Surface	99.5	9.94	4.5	31.0	4.5		YSI-85
	S shore reefs	Mud	Near-bottom (15ft)	94.9	7.23	4.6	29.7			
6/18/2005	H3	Reef	Surface	102.8	7.60	4.4	31.3	5		YSI-85
		Reef	Near-bottom (10 ft)	91.5	7.05	4.5	29.7			
6/23/2005	center of 3	Mud	Surface	97.7	7.12	4.9	29.9	8.5		YSI-85
	S shore reefs	Mud	Near-bottom (14.5 ft)	97.2	7.13	5.0	29.9			
6/23/2005	H3	Reef	Surface	90.6	6.74	4.9	30.2	9		YSI-85
		Reef	Near-bottom (14 ft)	94.3	6.99	4.9	30.0			
6/24/2005	H	Shell pad	Surface	93.0	6.59	4.9	30.2	10		YSI-85
		Shell pad	Near-bottom (14 ft)	95.5	6.63	5.1	29.0			
6/24/2005	center of 3	Mud	Surface	90.5	6.40	4.9	30.5	8		YSI-85
	S shore reefs	Mud	Near-bottom (14 ft)	90.2	6.35	4.9	30.3			
6/24/2005	H3	Reef	Surface	95.8	7.15	4.7	30.6	9		YSI-85
		Reef	Near-bottom (13 ft)	95.2	6.98	4.7	30.3			

6/30/2005	H	Shell pad	Surface	97.6	7.05	4.0	31.4	7.5		YSI-85
		Shell pad	Near-bottom (13.5 ft)	94.2	6.96	4.0	30.8			
6/30/2005	center of 3	Mud	Surface	95.2	6.55	4.0	32.8	7		YSI-85
	S shore reefs	Mud	Near-bottom (14 ft)	95.1	6.91	4.2	31.0			
7/22/2005	H3	Shell pad	Surface	95.4	6.90	5.2	30.5	4		YSI-85
8:40		Shell pad	Near-bottom (15 ft)	94.6	6.97	5.2	30.5			
7/22/2005	center of 3	Mud	Surface	93.5	7.00	5.2	30.5	4.5	Bottom sampler	YSI-85
9:00	S shore reefs	Mud	Near-bottom (10 out of	91.3	6.70	5.2	30.5		not available	
7/26/2005	H3	Shell pad	Surface	91.4	6.47	5.1	31.7	5		YSI-85
8:09		Shell pad	Near-bottom (13 ft)	91.4	6.60	5.1	31.8			
8/3/2005	H3	Shell pad	Surface	94.2	6.84	4.3	31.0	6		YSI-85
11:59		Shell pad	Near-bottom (14.5 ft)	92.0	6.71	4.3	30.8			
8/3/2005	center of 3	Mud	Surface	98.9	7.11	4.3	31.4	6		YSI-85
13:30	S shore reefs	Mud	Near-bottom (15 ft)	96.0	7.01	4.3	30.9			
8/4/2005	center of 3	Mud	Surface	95.9	7.07	4.2	30.6	7.5	Bottom sampler	YSI-85
9:09	S shore reefs	Mud	Near-bottom (10 out of	94.8	6.76	4.2	30.6		not available	
8/4/2005	H3	Shell pad	Surface	94.7	7.03	4.1	30.8	7		YSI-85
10:32		Shell pad	Near-bottom (13 ft)	94.5	6.87	4.1	30.8			
8/5/2005	H3	Shell pad	Surface	94.3	7.04	3.9	30.1	11		YSI-85
9:15		Shell pad	Near-bottom (13 ft)	91.5	6.74	3.8	30.1			
8/5/2005	H	Shell pad	Surface	97.9	7.15	4.0	30.0	11		YSI-85
9:50		Shell pad	Near-bottom (13 ft)	95.3	7.04	4.0	30.1			
8/5/2005	center of 3	Mud	Surface	99.3	7.29	4.1	30.2	6.5	Bottom sampler	YSI-85
10:45	S shore reefs	Mud	Near-bottom (10 out of	96.6	7.08	4.1	30.2		not available	
8/16/2005	H3	Shell pad	Surface	92.6	6.75	3.7	31.1	10.5	Used bottom	YSI-85
8:50		Shell pad	Near-bottom (12.5 ft)	91.6	6.71	3.7	31.2		sampler	
8/16/2005	H	Shell pad	Surface	92.4	6.77	3.6	31.3	10		YSI-85
10:09		Shell pad	Near-bottom (10.5 ft)	91.7	6.35	3.6	31.1			
8/16/2005	S/E of H1	Mud	Surface	99.5	7.23	3.6	31.5	5		YSI-85
11:05		Mud	Near-bottom (14 ft)	87.4	6.23	3.5	31.2			
8/18/2005	center of 3	Mud	Surface			3.9	31.4	N/A	pH 5.83 bottom	YSI-6600
19:10	S shore reefs	Mud	Near-bottom (14 ft)			4.0	31.4		possible DO error	
8/21/2005	N1	Mud	Surface	96.7	6.97	4.5	31.3	6	pH 7.16 surface	YSI-6600
10:15		Mud	Near-bottom (13 ft)	93.9	6.70	4.5	31.3		pH 7.11 bottom	

Appendix C. Divers, weather conditions, survey locations, and durations of 2005 visual surveys at the Lake Pontchartrain artificial reefs.

Date	Survey Team(s)	Weather Conditions	Regular Secchi (ft)	Diver Secchi (ft)	Survey Locations	Survey Duration	Total Survey Time (min)	Survey Times		
								Mud	Shell Pad	Reef
6/2/2005	A - Kelly Whitmore & Chip Crews	Calm	Mud: 5	Mud: 4.5	Mud: ~250 m NW of H3 reef	15 min ea.	30	A: 8:10 - 8:25	N/A	A: 9:40 - 9:55
		(~2 knots)	Shell:	Shell:	Shell: N/A	x 2 sites				
			Reef: 6	Reef: 4.5	Reef: H3	x 1 team				
6/3/2005	A - Kelly Whitmore & Chip Crews	Calm	Mud: 6	Mud: 4.5	Mud: 30 04.864 N 090 11.953 W	10 min ea. x 2	120	A: 11:40 - 11:50	A: 9:20 - 9:30	A: 10:35 - 10:45
	B - Willie Whitmore & Chad Ellinwood	(<1 knot)	Shell: 6	Shell: 5	Shell: H	x 3 sites		B: 11:51 - 12:01	B: 9:11 - 9:21	B: 10:40 - 10:50
			Reef: 6	Reef: 4.5	Reef: H1	x 2 teams		A: 12:00 - 12:10	A: 10:02 - 10:12	A: 11:05 - 11:15
								B: 12:12 - 12:22	B: 9:49 - 9:59	B: 11:11 - 11:21
6/23/2005	A - Kelly Whitmore & Chip Crews	Calm	Mud: 8.5	Mud: 7.5	Mud: 30 04.864 N 090 11.953 W	10 min ea. x 2	120	A: 12:28 - 12:38	A: 10:06 - 10:16	A: 11:16 - 11:26
	B - Willie Whitmore & Ashely Walker		Shell: 9	Shell: 8	Shell: H	x 3 sites		B: 12:24 - 12:34	B: 10:11 - 10:21	B: 11:13 - 11:23
			Reef: 9	Reef: 8.5	Reef: H3	x 2 teams		A: 12:39 - 12:49	A: 10:23 - 10:33	A: 11:29 - 11:39
								B: 12:40 - 12:50	B: 10:28 - 10:38	B: 11:27 - 11:37
6/24/2005	A - Kelly Whitmore & Mark Schexnayd	Calm	Mud: 8.5	Mud: 8	Mud: 30 04.864 N 090 11.953 W	10 min ea. x 2	120	A: 11:03 - 11:13	A: 10:10 - 10:20	A: 12:15 - 12:25
	B - Ashley Walker & Ryan Poirrier		Shell: 10	Shell: 9	Shell: H	x 3 sites		B: 10:52 - 11:02	B: 10:00 - 10:10	B: 12:02 - 12:12
			Reef: 9.5	Reef: 9	Reef: H3	x 2 teams		A: 11:14 - 11:24	A: 10:25 - 10:35	A: 12:40 - 12:50
								B: 11:06 - 11:16	B: 10:12 - 10:22	B: 12:16 - 12:26
6/30/2005	A - Kelly Whitmore & Beth Spalding	Calm	Mud: 7	Mud: 5.5	Mud: 30 04.864 N 090 11.953 W	10 min ea. x 2	120	A: 13:45 - 13:55	A: 11:55 - 12:05	A: 12:55 - 13:05
	B - Ashely Walker & Chip Crews		Shell: 7.5	Shell: 6	Shell: H	x 3 sites		B: 13:42 - 13:52	B: 11:49 - 11:59	B: 12:50 - 13:00
			Reef: 7.5	Reef: 5.5	Reef: H3	x 2 teams		A: 14:02 - 14:12	A: 12:12 - 12:22	A: 13:25 - 13:35
								B: 13:59 - 14:09	B: 12:06 - 12:16	B: 13:07 - 13:17
8/4/2005	A - Kelly Whitmore & Ashley Walker	Light chop	Mud: 7.5	Mud: 6.5	Mud: 30 04.864 N 090 11.953 W	10 min ea. x 2	120	A: 9:56 - 10:06	A: 10:30 - 10:40	A: 11:28 - 11:38
	B - Chip Crews & Ryan Poirrer	(~7 knots)	Shell: 7	Shell: 6.5	Shell: H	x 3 sites		B: 9:38 - 9:48	B: 10:25 - 10:35	B: 11:23 - 11:33
		Mostly sunny	Reef: 7	Reef: 6.5	Reef: H3	x 2 teams		A: 10:08 - 10:18	A: 10:46 - 10:56	A: 11:41 - 11:51
								B: 9:51 - 10:01	B: 10:40 - 10:50	B: 11:37 - 11:47
8/5/2005	A - Kelly Whitmore & Willie Whitmore	Light chop	Mud: 6.5	Mud: 5.5	Mud: 30 04.864 N 090 11.953 W	10 min ea. x 2	120	A: 9:15 - 9:25	A: 10:09 - 10:19	A: 10:37 - 10:47
	B - Ashley Walker & Chip Crews	(~9 knots)	Shell: 11	Shell: 10.5	Shell: H	x 3 sites		B: 9:04 - 9:13	B: 10:00 - 10:10	B: 10:41 - 10:51
		Mostly sunny	Reef: 11	Reef: 8.5	Reef: H3	x 2 teams		A: 9:30 - 9:40	A: 10:22 - 10:31	A: 10:51 - 11:01
								B: 9:15 - 9:25	B: 10:12 - 10:22	B: 10:55 - 11:05
8/16/2005	A - Kelly Whitmore & Ryan Poirrier	Sunny, clam	Mud: 5	Mud: 5	Mud: 30 04.864 N 090 11.953 W	10 min ea.	120	A: 9:10 - 9:20	A: 10:25 - 10:35	A: 11:15 - 11:25
	B - Ashely Walker & Chip Crews	(~3-5 knots)	Shell: 10	Shell: 11	Shell: H	x 3 sites		B: 9:15 - 9:25	B: 10:35 - 10:45	B: 11:13 - 11:23
			Reef: 10.5	Reef: 11.5	Reef: H3	x 2 teams		A: 9:23 - 9:33	A: 10:41 - 10:51	A: 11:29 - 11:39
								B: 9:26 - 9:36	B: 10:48 - 10:58	B: 11:27 - 11:37
8/18/2005	A - Kelly Whitmore & Chip Crews	Flat calm	N/A	N/A	Reef: H3	20 min	20	N/A	N/A	A: 22:30 - 22:50
		(0 knots)				x 1 site				
		Night				x 1 team				
8/21/2005	A - Kelly Whitmore & Willie Whitmore	Choppy	Reef: 6	Reef: 6	Reef: N1	10 min	10	N/A	N/A	A: 10:43 - 10:53
		(7-15 knots)				x 1 site				
						x 1 team				
						Total =	900 min.			

Appendix D. Fishes and mobile macroinvertebrates sighted during visual surveys at the Lake Pontchartrain artificial reef and reference sites in 2005.

		Date	6/2/05	6/3/05				6/23/05				6/24/05			
		Rep	1	1	1	2	2	1	1	2	2	1	1	2	2
		Team	A	A	B	A	B	A	B	A	B	A	B	A	B
		Site	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF
		Visibility (ft) vertical	6	6	6	6	6	9	9	9	9	9.5	9.5	9.5	9.5
		Visibility (ft) horizontal	5	4.5	4.5	4.5	4.5	8.5	8.5	8.5	8.5	9	9	9	9
		Duration of survey (min)	15	10	10	10	10	10	10	10	10	10	10	10	10
Fishes: Families	**Species**	**Common**													
Gobiidae	*Gobiosoma bosc*	naked goby	20	15		29	17	31	6	21	5	51	37	50	19
Sparidae	*Archosargus probatocephalus*	sheepshead	3	1		5		3		13		2		7	
Blenniidae	*Hypsoblennius iothonas*	freckled blenny		1				1				1	3		
Bothidae	*Paralicthys lethostigma*	Southern flounder							1	1		2			
Dasyatidae	*Dasyatis sabina*	Atlantic stingray	1												
Carangidae	*Carnax hippos*	jack crevalle													
Mugilidae	*Mugil cephalus*	striped mullet													
Ictaluridae	*Ictalurus furcatus*	blue catfish								1					1
Anguillidae	*Anguilla rostrata*	american eel													1
Batrachoididae	*Opsanus beta*	oyster toad fish								1					
Sparidae	*Lagodon rhomboides*	pinfish										1		2	
Atherinidae	*Menidia beryllina*	tidewater silverside													
Echeneidae	*Gobiesox strumosus*	skilletfish													
Ophichthidae	*Myrophis punctatus*	speckled worm eel													
Sciaenidae	*Micropogonias undulatus*	Atlantic croaker													
Soleidae	*Trinectes maculatus*	hogchoker													
Sciaenidae	*Aplodinotus grunniens*	freshwater drum													
Invertebrates: Families	**Species**	**Common**													
Portunidae	*Calinectes sapidus*	blue crab	1	1			1	2	5			6	6	10	8
Penaeidae	*Farfantepenaeus aztecus*	brown shrimp										2			
Xanthidae	*Rhithropanopeus harrisii*	mud crab													

		Date	6/2/05	6/3/05				6/23/05				6/24/05			
		Rep		1	1	2	2	1	1	2	2	1	1	2	2
		Team		A	B	A	B	A	B	A	B	A	B	A	B
		Site		SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL
		Visibility (ft) vertical		6	6	6	6	9	9	9	9	10	10	10	10
		Visibility (ft) horizontal		5	5	5	5	8	8	8	8	9	9	9	9
		Duration of survey (min)		10	10	10	10	10	10	10	10	10	10	10	10
Fishes: Families	**Species**	**Common**													
Gobiidae	*Gobiosoma bosc*	naked goby				11		3		13	6	11	7	11	14
Sparidae	*Archosargus probatocephalus*	sheepshead		1											
Blenniidae	*Hypsoblennius iothonas*	freckled blenny											3		2
Bothidae	*Paralicthys lethostigma*	Southern flounder				1									
Dasyatidae	*Dasyatis sabina*	Atlantic stingray													
Carangidae	*Carnax hippos*	jack crevalle													
Mugilidae	*Mugil cephalus*	striped mullet													
Ictaluridae	*Ictalurus furcatus*	blue catfish													
Anguillidae	*Anguilla rostrata*	american eel													
Batrachoididae	*Opsanus beta*	oyster toad fish													
Sparidae	*Lagodon rhomboides*	pinfish													
Atherinidae	*Menidia beryllina*	tidewater silverside													
Echeneidae	*Gobiesox strumosus*	skilletfish													
Ophichthidae	*Myrophis punctatus*	speckled worm eel													
Sciaenidae	*Micropogonias undulatus*	Atlantic croaker													
Soleidae	*Trinectes maculatus*	hogchoker													
Sciaenidae	*Aplodinotus grunniens*	freshwater drum													
Invertebrates: Families	**Species**	**Common**													
Portunidae	*Calinectes sapidus*	blue crab				1		1		1	1	3	3	1	2
Penaeidae	*Farfantepenaeus aztecus*	brown shrimp													
Xanthidae	*Rhithropanopeus harrisii*	mud crab											1		

		Date	6/2/05	6/3/05				6/23/05				6/24/05			
		Rep	1	1	1	2	2	1	1	2	2	1	1	2	2
		Team	A	A	B	A	B	A	B	A	B	A	B	A	B
		Site	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD
		Visibility (ft) vertical	4.5	6	6	6	6	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
		Visibility (ft) horizontal	4.5	4.5	4.5	4.5	4.5	7.5	7.5	7.5	7.5	8	8	8	8
		Duration of survey (min)	15	10	10	10	10	10	10	10	10	10	10	10	10
Fishes: Families	**Species**	**Common**													
Gobiidae	*Gobiosoma bosc*	naked goby										1	1	2	4
Sparidae	*Archosargus probatocephalus*	sheepshead													
Blenniidae	*Hypsoblennius iothonas*	freckled blenny													
Bothidae	*Paralicthys lethostigma*	Southern flounder													
Dasyatidae	*Dasyatis sabina*	Atlantic stingray													
Carangidae	*Carnax hippos*	jack crevalle													
Mugilidae	*Mugil cephalus*	striped mullet													
Ictaluridae	*Ictalurus furcatus*	blue catfish													
Anguillidae	*Anguilla rostrata*	american eel													
Batrachoididae	*Opsanus beta*	oyster toad fish													
Sparidae	*Lagodon rhomboides*	pinfish													
Atherinidae	*Menidia beryllina*	tidewater silverside													
Echeneidae	*Gobiesox strumosus*	skilletfish													
Ophichthidae	*Myrophis punctatus*	speckled worm eel													
Sciaenidae	*Micropogonias undulatus*	Atlantic croaker													
Soleidae	*Trinectes maculatus*	hogchoker													
Sciaenidae	*Aplodinotus grunniens*	freshwater drum													
Mobile Invertebrates:	**Species**	**Common**													
Portunidae	*Calinectes sapidus*	blue crab											2		
Penaeidae	*Farfantepenaeus aztecus*	brown shrimp													
Xanthidae	*Rhithropanopeus harrisii*	mud crab												1	

6/30/05				8/4/05				8/5/05				8/16/05					
1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2		
A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF	REEF		
7.5	7.5	7.5	7.5	7	7	7	7	11	11	11	11	10.5	10.5	10.5	10.5		
5.5	5.5	5.5	5.5	6.5	6.5	6.5	6.5	8.5	8.5	8.5	8.5	11.5	11.5	11.5	11.5		
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	295	min
																TOTAL	
7	1	18		13	4	29	4	18	6	26	9	21	4	5		466	*G. bosc*
				3												37	*A. probatocephalus*
	1	1		2			1			1		2			1	15	*H. iothonas*
																4	*P. lethostigma*
																1	*D. sabina*
				1				3								4	*C. hippos*
												6				6	*M. cephalus*
							1									3	*I. furcatus*
													1			2	*A. rostrata*
																1	*O. beta*
					1			2					1			7	*L. rhomboides*
																0	*M. beryllina*
				1		1										2	*G. strumosus*
																0	*M. punctatus*
										1						1	*M. undulatus*
																0	*T. maculatus*
																0	*A. grunniens*
																TOTAL	
1	1	1		3		3			3	2	1	1	1	3	3	63	*C. sapidus*
																2	*F. aztecus*
																0	*R. harrisii*
6/30/05				8/4/05				8/5/05				8/16/05					
1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2		
A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL	SHELL		
7.5	7.5	7.5	7.5	7	7	7	7	11	11	11	11	10	10	10	10		
6	6	6	6	6.5	6.5	6.5	6.5	10.5	10.5	10.5	10.5	11	11	11	11		
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	280	min
																TOTAL	
1	3		3	5	2	6		6	4	6	2	4	3		1	122	*G. bosc*
												1				2	*A. probatocephalus*
									2					2		9	*H. iothonas*
															1	2	*P. lethostigma*
																0	*D. sabina*
																0	*C. hippos*
																0	*M. cephalus*
																0	*I. furcatus*
																0	*A. rostrata*
																0	*O. beta*
																0	*L. rhomboides*
				70												70	*M. beryllina*
				1		1			1				1	1	3	8	*G. strumosus*
						1										1	*M. punctatus*
																0	*M. undulatus*
															1	1	*T. maculatus*
																0	*A. grunniens*
																TOTAL	
	3	1	3			2		2	1	1	3	3		2	5	39	*C. sapidus*
																0	*F. aztecus*
															1	2	*R. harrisii*
6/30/05				8/4/05				8/5/05				8/16/05					
1	1	2	2	1	1	2	2	1	1	2	2	1	1	2	2		
A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B		
MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD	MUD		
7	7	7	7	7	7	7	7	6.5	6.5	6.5	6.5	5	5	5	5		
5.5	5.5	5.5	5.5	6.5	6.5	6.5	6.5	5.5	5.5	5.5	5.5	5	5	5	5		
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	295	min
																TOTAL	
																8	*G. bosc*
																0	*A. probatocephalus*
																0	*H. iothonas*
																0	*P. lethostigma*
																0	*D. sabina*
																0	*C. hippos*
																0	*M. cephalus*
																0	*I. furcatus*
																0	*A. rostrata*
																0	*O. beta*
																0	*L. rhomboides*
																0	*M. beryllina*
																0	*G. strumosus*
																0	*M. punctatus*
																0	*M. undulatus*
																0	*T. maculatus*
																0	*A. grunniens*
																TOTAL	
																2	*C. sapidus*
																0	*F. aztecus*
																1	*R. harrisii*

Appendix E. Lake Pontchartrain Artificial Reef Recreational Fishing and Diving Survey.

Lake Pontchartrain Artificial Reef Recreation Survey

This survey is designed to collect information on the success of the artificial reefs in Lake Pontchartrain. Information on fisher and diver utilization of the reefs will be used to monitor the progress of the reefs and to develop recommendations for future reef efforts. Respondent contact information will remain confidential and responses will be pooled with those of others.

If you have recently fished or dived at any of the reef sites, please complete the form below and submit it via **email to: khoule@uno.edu** or print and mail the form to:

Lake Pontchartrain Artificial Reef Program, Estuarine Research Laboratory, Department of Biological Sciences, University of New Orleans, New Orleans, LA 70148.

Please complete and submit the form after each visit to the artificial reefs!

1. What was the date of your most recent trip to a Lake Pontchartrain artificial reef?
   MM/DD/YY ____ /____ /____

2. Which reef site(s) did you visit that day? (check all that apply)
   South shore - Jefferson Parish sites (H1, H3, H4), west of the Causeway Bridge: ☐
   North shore - St. Tammany Parish site (N1), south of Mandeville: ☐
   South shore - Orleans Parish site (L1) northeast of the Seabrook Bridge launch: ☐

3. What activities did you conduct there?
   ☐ Hook and line fishing
   ☐ Spear fishing
   ☐ Charter fishing
   ☐ Diving
   ☐ Other _______________

4. How many hours did you spend fishing or diving at the reef sites that day? Specifically, how many hours did you actually spent with your gear in the water?
   Total hours: ☐☐

5. How many other people were fishing or diving from <u>your</u> boat at the reef sites that day?
   Number of Adults (18+ yrs): ☐ Number of Children: ☐

6. How many people did you see fishing or diving from <u>other</u> boats at the reef sites that day?
   Number of Adults (18+ yrs): ☐ Number of Children: ☐

7. If you were fishing, what types of gear did you use to fish at the reef site(s) that day?
   ☐ Hook and line
   ☐ Dip net, A-frame
   ☐ Cast net
   ☐ Trawl
   ☐ Trap
   ☐ Spear
   ☐ Hand
   ☐ Other _________
   ☐ Unknown
   ☐ None, did not fish

8. If you were fishing, what type of fish were you fishing for at the artificial reef(s) that day?

   1st target species ________________________

   2nd target species ________________________
   ☐ No particular target species

9. Where else in the lake did you fish or dive from a boat that day?
   ☐ Standing oil & gas structure
   ☐ Causeway pilings
   ☐ Other structure (specify) __________________________________

☐ None/ No other areas

10. What fish did you catch, or if diving, what fish did you see at the reef sites that day?

Species	Number	Range of Length/Weight	Gear	Bait	Taken/Released

11. Since **January 2004**, how many days have you fished or dived at the artificial reefs in Lake Pontchartrain?
    Total days: ☐☐☐

    Of those days, how many were spent at each of the following artificial reef locations?
    Days at Jefferson Reefs: ☐☐☐
    Days at St. Tammany Reef: ☐☐☐
    Days at Orleans Reef: ☐☐☐

12. Within the past **2 months**, how many days have you fished or dived at the artificial reefs in Lake Pontchartrain?
    Total days: ☐☐☐

    Of those days, how many were spent at each of the following artificial reef locations?
    Days at Jefferson Reefs: ☐☐☐
    Days at St. Tammany Reef: ☐☐☐
    Days at Orleans Reef: ☐☐☐

13. Within the past **2 months**, how many days have you fished or dived <u>anywhere</u> in Lake Pontchartrain proper (including reef visits)?
    Total days: ☐☐☐

14. Do you feel that the artificial reefs have enhanced recreational fishing and/or diving opportunities in Lake Pontchartrain?
    ☐ Yes – enhanced fishing
    ☐ Yes – enhanced diving
    ☐ No
    ☐ Other ___________________

15. Have you fished or dived more often this year than last year as result of the presence of the Lake Pontchartrain artificial reefs?
    ☐ Yes – fished more
    ☐ Yes – dived more
    ☐ No
    ☐ Other ______________________

16. Did you experience any problems at the artificial reefs that day? What were they?
    ☐ Trouble anchoring
    ☐ Lost anchor
    ☐ Lost fishing tackle
    ☐ Difficulty finding reef site due to format of listed coordinates
    ☐ No buoy at the reef site
    ☐ Other ______________________________

17. What is your state and county of residence?

    State: _____________________ County: ________________________

18. If you are a frequent user of the artificial reefs and would like to participate in a more regular, formal survey and have logged your reef use, or would like to start, please check this box, and provide your contact information below: ☐

19. OPTIONAL:

    Please provide your name, address, phone number, and email address if you would like to receive more information about the Lake Pontchartrain Artificial Reef Project:

    ____

    ____

    ____

20. Any comments you have about the Lake Pontchartrain Artificial Reef Program:

If you have any questions about this survey or about the Lake Pontchartrain Artificial Reef Program, please email the Lake Pontchartrain Basin Foundation at info@saveourlake.org, or contact the Estuarine Research Laboratory at the University of New Orleans, LA, 504-284-3490, khoule@uno.edu. Thank you for your participation!

Appendix F. Observations of recreational fishing and diving activity at the Lake Pontchartrain artificial reefs in 2004 and 2005.

06/02/05	Th	9:20 - 9:30	H3	2	4	Fishing	Rods w/ line in water	Unknown		
06/02/05	Th	9:20 - 9:30	H4	1	3	Fishing	Rods w/ line in water	Unknown		
06/02/05	Th	9:20 - 9:30	H1	1	2	Fishing	Rods w/ line in water	Unknown		
06/02/05	Th	9:20 - 9:30	near H3	1	1	Checking traps	Crab pots	Unknown	Blue crabs	Crab pots set near H3 site
06/02/05	Th	9:40 - 9:50	H3	1	Unknown	Fishing	Rods w/ line in water	Unknown		
06/02/05	Th	9:40 - 9:50	H4	1	Unknown	Fishing	Rods w/ line in water	Unknown		
06/02/05	Th	9:40 - 9:50	H1	2	Unknown	Fishing	Rods w/ line in water	Unknown		
06/03/05	Fr	9:15 - 9:25	H3	3	Unknown	Fishing	Rods w/ line in water	Unknown		
06/03/05	Fr	9:15 - 9:25	H1	2	Unknown	Fishing	Rods w/ line in water	Unknown		
06/03/05	Fr	9:15 - 9:25	H4	3	Unknown	Fishing	Rods w/ line in water	Unknown		
06/03/05	Fr	10:10 - 10:15	H3	2	Unknown	Fishing	Rods w/ line in water	Unknown		Crab pots set near H3 & H4
06/03/05	Fr	10:10 - 10:15	H4	4	Unknown	Fishing	Rods w/ line in water	Unknown		
06/03/05	Fr	10:10 - 10:15	H1	2	Unknown	Fishing	Rods w/ line in water	Unknown		
06/03/05	Fr	12:20 - 12:25	H3	2	Unknown	Fishing	Rods w/ line in water	Unknown		
06/03/05	Fr	12:20 - 12:25	H1	0						
06/03/05	Fr	12:20 - 12:25	H4	3	Unknown	Fishing	Rods w/ line in water	Unknown		
06/09/05	Th	9:10 - 9:15	H3	3	4	Fishing	Rods w/ line in water	No		Caught 50 trout 6/8 at H4, 12 on 6/6
06/09/05	Th	9:10 - 9:15	H1	1	2	Fishing	Rods w/ line in water	Unknown		
06/09/05	Th	9:10 - 9:15	H4	1	1	Fishing	Rods w/ line in water	Unknown		
06/09/05	Th	12:12 -12:17	H3	0	0					
06/09/05	Th	12:12 -12:17	H4	2	3	Fishing	Rods w/ line in water	Unknown		
06/09/05	Th	12:12 -12:17	H1	0	0					
06/18/05	Sa	14:32 - 14:45	H3	2	7	Fishing	Rods w/ line in water	Unknown		Crab pots set around H3 & H4
06/18/05	Sa	14:32 - 14:45	H1	2	2	Fishing	Rods w/ line in water	Unknown		
06/18/05	Sa	14:32 - 14:45	H4	2	4	Fishing	Rods w/ line in water	Unknown		
06/23/05	Th	09:28 - 09:35	H3	2	3	Fishing	Rods w/ line in water	Unknown		Crab pots set around H3
06/23/05	Th	09:28 - 09:35	H1	1	2	Fishing	Rods w/ line in water	Unknown		
06/23/05	Th	09:28 - 09:35	H4	2	3	Fishing	Rods w/ line in water	Unknown		
06/23/05	Th	11:00 - 11:05	H3	2	3	Fishing	Rods w/ line in water	Unknown		
06/23/05	Th	11:00 - 11:05	H4	1	2	Fishing	Rods w/ line in water	Unknown		
06/23/05	Th	11:00 - 11:05	H1	0	0					
06/24/05	Fr	09:45 - 09:54	H3	3	5	Fishing	Rods w/ line in water	Unknown		Crab pots set b/w H1, H3, & H4
06/24/05	Fr	09:45 - 09:54	H1	0	0					
06/24/05	Fr	09:45 - 09:54	H4	2	3	Fishing	Rods w/ line in water	Unknown		
06/30/05	Th	11:30 - 11:40	H1	0	0					Crab pots set b/w H1, H3, & H4
06/30/05	Th	11:30 - 11:40	H4	0	0					
06/30/05	Th	11:30 - 11:40	H3	0	0					
06/30/05	Th	14:45 - 14:50	H1	0	0					Crab pots set b/w H1, H3, & H4
06/30/05	Th	14:45 - 14:50	H4	0	0					
06/30/05	Th	14:45 - 14:50	H3	0	0					

07/22/05	Fr	8:40 - 9:40	H1	0	0					
07/22/05	Fr	8:40 - 9:40	H3	1	2	Fishing	Rods w/ line in water	Unknown		Crab pots set b/w H1,H3 & H4
07/22/05	Fr	8:40 - 9:40	H4	0	0					
07/22/05	Fr	10:15 - 10:30	H1	2	2	Fishing	Rods w/ line in water	Unknown		
07/22/05	Fr	10:15 - 10:30	H3	2	1	Fishing	Rods w/ line in water	Unknown		
07/22/05	Fr	10:15 - 10:30	H4	2	3	Fishing	Rods w/ line in water	Unknown		
07/26/05	Tu	8:09 - 8:15	H1	1	2	Fishing	Rods w/ line in water	Unknown		Crab pots set b/w H1, H3 & H4
07/26/05	Tu	8:09 - 8:15	H3	0	0					
07/26/05	Tu	8:09 - 8:15	H4	1	4	Fishing	Rods w/ line in water	Unknown		
08/03/05	We	11:59 - 14:10	H1	0	0					
08/03/05	We	11:59 - 14:10	H3	0	0					
08/03/05	We	11:59 - 14:10	H4	0	0					
08/04/05	Th	9:09 - 9:15	H1	0	0					Crab pots set b/w H1, H3 & H4
08/04/05	Th	9:09 - 9:15	H3	0	0					
08/04/05	Th	9:09 - 9:15	H4	0	0					
08/04/05	Th	10:32 - 10:40	H1	0	0					
08/04/05	Th	10:32 - 10:40	H3	0	0					
08/04/05	Th	10:32 - 10:40	H4	0	0					
08/05/05	Fr	9:15 - 9:30	H1	1	2	Fishing	Rods w/ line in water	Unknown		Crab pots set b/w H1, H3 & H4
08/05/05	Fr	9:15 - 9:30	H3	0	0					
08/05/05	Fr	9:15 - 9:30	H4	0	0					
08/05/05	Fr	9:50 - 10:10	H1	0	0					
08/05/05	Fr	9:50 - 10:10	H3	0	0					
08/05/05	Fr	9:50 - 10:10	H4	0	0					
08/16/05	Mo	8:50 - 9:20	H1	0	0					
08/16/05	Mo	8:50 - 9:20	H3	0	0					
08/16/05	Mo	8:50 - 9:20	H4	2	4	Fishing	Rods w/ line in water	Unknown		Crab pots set near H1
08/16/05	Mo	10:09 - 10:15	H1	0	0					
08/16/05	Mo	10:09 - 10:15	H3	0	0					
08/16/05	Mo	10:09 - 10:15	H4	0	0					
08/18/05	We	19:10 - 19:30	H1	1	2	Fishing	Rods w/ line in water	Unknown		Crab pots set near H1
08/18/05	We	19:10 - 19:30	H3	0	0					
08/18/05	We	19:10 - 19:30	H4	0	0					
08/18/05	We	19:45 - 20:50	H1	0	0					
08/18/05	We	19:45 - 20:50	H3	0	0					
08/18/05	We	19:45 - 20:50	H4	0	0					
08/21/05	Su	10:15 - 10:45	N1	2	4	Fishing	Rods w/ line in water	No		North shore reef

Appendix G. Responses collected from the Lake Pontchartrain Recreational Fishing and Diving Survey in 2004 and 2005.

2004

Respondent #	1. Date	2. Site	3. Activity	4. Hours	5. People in boat		6. People in other boats		7. Gear	8. Target species	
					Adults	Children	Adults	Children		1st	2nd
1	9/12/2004	St. Tammany reef (N1)	Hook & line	0.5	1	0	0	0	Hook & line	Speckled trout	Flounder
2	9/29/2004	Jefferson reefs (H1)	Hook & line	2	3	0	15	0	Hook & line	Trout	Redfish

2005

Respondent #	1. Date	2. Site	3. Activity	4. Hours	5. People in boat		6. People in other boats		7. Gear	8. Target species	
					Adults	Children	Adults	Children		1st	2nd
1	5/15/2005	Jefferson reefs (H1, H3, H4)	Hook & line	3.5	2	0	30	0	Hook & line	Speckled trout	none
2	5/22/2005	Jefferson reefs (H1, H3, H4)	Hook & line	5	1	1	35	5	Hook & line	Speckled trout	none
3	5/21/2005	Jefferson reefs (H1, H3, H4)	Hook & line	4	2	0	20	7	Hook & line	Speckled trout	Croaker
4	5/14/2005	Jefferson reefs (H1, H3, H4)	Hook & line	1	1	0	1	0	Hook & line	Trout	none
5	6/9/2005	Jefferson reefs (H1, H3, H4)	Hook & line	4	3	0	15	0	Hook & line	Speckled trout	Redfish
6	6/4/2005	Jefferson reefs (H1, H3, H4)	Hook & line	4	2	0	30	0	Hook & line	Trout	none
7	6/24/2005	Jefferson reefs (H1, H3, H4)	Spear fishing	0.5	0	0	0	0	Spear	none	none
8	6/26/2005	St. Tammany reef (N1)	Spear fishing	0.5	2	0	0	0	Spear	Catfish	Drum
9	6/9/2005	Orleans reef (L1)	Hook & line	0.1	0	1	0	1	Hook & line	Speckled trout	Flounder, redfish, black drum
10	6/28/2005	Jefferson reefs (H1, H3, H4)	Hook & line	4	2	0	6	0	Hook & line	Speckled trout	Redfish
11	7/9/2005	Jefferson reefs (H1, H3, H4)	Hook & line	1	1	0	0	0	Hook & line	Speckled trout	none
12	5/26/2005	Jefferson reefs (H1, H3, H4)	Hook & line	2	3	0	15	2	Hook & line	Speckled trout	Flounder
13	5/27/2005	Jefferson reefs (H1, H3, H4)	Hook & line	2	2	0	18	0	Hook & line	Speckled trout	Redfish
14	5/28/2005	Jefferson reefs (H1, H3, H4)	Hook & line	2	2	0	50	15	Hook & line	Speckled trout	Redfish
15	7/31/2005	Jefferson reefs (H1, H3, H4)	Hook & line	3	1	0	5	0	Hook & line	Speckled trout	none
16	7/28/2005	Orleans reef (L1)	Hook & line	0.5	4	0	0	0	Hook & line	Trout	none
17	7/2/2005	Jefferson reefs (H1, H3, H4)	Diving	2	2	0	1	1	Did not fish	none	none
18	8/13/2005	Jefferson reefs (H1, H3, H4)	Spear fishing	3	2	0	2	0	Spear	Redfish	Sheepshead
19	8/20/2005	St. Tammany reef (N1)	Hook & line	2.5	1	1	2	0	Hook & line	Speckled Trout	Sheepshead

10. Fish caught/seen						11. Days fished at reefs			12. Past 2 months at reefs			13. Past 2 months	14. Enhanced
Species	Number	Length/Weight	Gear	Bait	Taken/Released	Jefferson	St. Tammany	Orleans	Jefferson	St. Tammany	Orleans	Lake P anywhere	opportunities?
None	0					0	6	0	0	2	0	8	No
Speckled trout	30	14" to 22"	Spin	Soft plastic	0	5	0	0	5	0	0	5	Yes - enhanced fishing

10. Fish caught/seen						11. Days fished at reefs			12. Past 2 months at reefs			13. Past 2 months	14. Enhanced
Species	Number	Length/Weight	Gear	Bait	Taken/Released	Jefferson	St. Tammany	Orleans	Jefferson	St. Tammany	Orleans	Lake P. anywhere	opportunities?
Speckled trout Flounder	16 1	12" to 4.5 lbs 13"	Hook & Line Hook & Line	Plastic lures Plastic lures	15 T/ 1 R 1 T/ 0 R	2	0	0	2	0	0	10	Yes - enhanced fishing
Speckled trout	15	13" to 24", 1 to 4 lbs	Pole	Beetle	15 T	2	0	0	1	0	0	4	Yes - enhanced fishing
White trout	2	22", ~2 lbs	Sliding cork rig	Market shrimp	Released	6	0	0	4	0	0	6	Yes - enhanced fishing
Flounder	1	15"	Spinning	Jig	Released	1	0	0	1	0	0	1	Yes - enhanced fishing
Speckled trout	14	1lb to 3 lb		Live shrimp		25	0	0	25	0	0	28	Yes - enhanced fishing
Speckled trout	10	2.5 to 3 lbs	Rod & reel	Shrimp	10 T	8	0	0	8	0	0	3	Yes - enhanced fishing
Sheepshead	7	8'-12'	Spear	none	2 T	8	0	0	8	0	0	12	Yes - enhanced fishing Yes - enhanced diving
none	0					0	2	0	0	2	0	5	Yes - enhanced fishing Yes - enhanced diving
none	0					0	0	0	0	0	0	30	Don't know
Catfish	6	small	Hook & line	Plastic/cut	6 T	? Many	0	0	6	0	0	12	Yes - enhanced fishing
none	0					2	0	0	1	0	0	1	Yes - enhanced fishing
Speckled trout Sheepshead Croaker	35 3 2	16-20 in. / 2-4 lbs. 20 in. / 3 lbs. 15-16 in. / 1 lb.	Bottom Bottom Bottom	Live shrimp Live shrimp Live shrimp	25 T / 10 R 2 T / 1 R 2 T / 0 R	20	0	0	10	0	0	15	Yes - enhanced fishing
Speckled trout	21	14-20 in. / 1-3 lbs.	Bottom	Live shrimp	16 T / 5 R	20	0	0	10	0	0	15	Yes - enhanced fishing
Speckled trout Flounder Croaker	24 1 10	12-19 in. / 1-3 lbs. 16 in. / 1 lb. 6 in.	Bottom Bottom Bottom	Live shrimp Live shrimp Live shrimp	17 T / 7 R 1 T / 0 R 0 T / 10 R	20	0	0	10	0	0	15	Yes - enhanced fishing
none	0					12	0	0	12	0	0	15	Yes - enhanced fishing Yes - enhanced diving
none	0			Live shrimp/ sliding cork		0	0	1	0	0	1	15	No
Naked gobies Sheepshead						1	0	0	1	0	0	3	Yes - enhanced diving
none						5	0	0	2	0	0	2	Yes - enhanced fishing Yes - enhanced diving
Hardhead catfish Gafftop catfish	1 1					0	1	0	0	1	0	4	Yes - enhanced fishing

15. Fished/dived more often?	16. Problems	17. State, county of residence	18. Log	19. Respondent Contact Info.
Yes - fished more	None	Louisiana, St. Tammany	Yes	(removed)
Yes - fished more	Lost fishing tackle	Louisiana, Jefferson	Yes	

15. Fished/dived more often?	16. Problems	17. State, county/parish of residence	18. Log	
No	Lost fishing tackle Could not find edges of reefs	Louisiana, Orleans	Yes	(removed)
Yes - fished more	Lost fishing tackle	Louisiana	No	
Yes - fished more	Other - see Comments	Louisiana, Orleans	Yes	
Yes - fished more	None	Louisiana, Orleans	No	
Yes - fished more	Lost fishing tackle	Louisiana, Jefferson		
Yes - fished more	Trouble anchoring	Louisiana, Jefferson	Yes	
Yes - dived more	Had other boats tied up to buoy	Louisiana, Orleans	No	
Yes - dived more	A little deep would like to see one shallower	Louisiana, East Baton Rouge	Yes	
No	Difficulty finding reefs due to format of coordinates	Louisiana, Orleans	Yes	
Yes - fished more	Difficulty finding reefs due to format of coordinates	Louisiana, Jefferson	Yes	
Yes - fished more		Louisiana, Orleans	Yes	
Yes - fished more	Lost fishing tackle Too crowded with boats	Louisiana, Orleans	Yes	
Yes - fished more	Lost fishing tackle Too crowded with boats	Louisiana, Orleans	Yes	
Yes - fished more	Lost fishing tackle Too crowded	Louisiana, Orleans	Yes	
Yes - fished more Yes - dived more	Lost fishing tackle	Louisiana, Metairie	Yes	
No	Very, very, very small in size	Louisiana, St. Tammany	Yes	
	SE buoy drifted off site, spent lot of time swimming over muddy bottom looking for reef	Louisiana, Jefferson	Yes	
Yes - fished more Yes - dived more	None	Lousisiana, St. Charles	No	
No	Difficulty finding reefs due to format of coordinates Found buoy but not reef	Louisiana, St. Tammany	No	

VITA

Kelly A. Whitmore was born in Easthampton, Massachusetts and graduated from Easthampton High School in Easthampton, Massachusetts. She attended Union College in Schenectady, New York where she received her B.S. in Biology in June 2000. Kelly conducted research on Chesapeake Bay water quality at the University of Maryland's Horn Point Laboratory in Cambridge, Maryland and later became a field biologist with NOAA Fisheries in Woods Hole, Massachusetts, conducting offshore surveys of North Atlantic right whales. To further her educational background in conservation and ecology she entered the Graduate School at the University of New Orleans in January 2004, where she is currently a candidate for the degree of Master of Science in Biology at the University of New Orleans. She and her husband William Whitmore were married in August 2004 and have greatly enjoyed living in New Orleans and studying at the University of New Orleans.