A comparison of finfish assemblages on subtidal oyster shell (cultched oyster lease) and mud bottom in Barataria Bay, Louisiana

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A COMPARISON OF FINFISH ASSEMBLAGES ON SUBTIDAL OYSTER SHELL (CULTCHED OYSTER LEASE) AND MUD BOTTOM IN BARATARIA BAY, LOUISIANA

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS…………………………………………………………....ii

LIST OF TABLES…………………………………………………………………...v

LIST OF FIGURES…………………………………………………………………vi

ABSTRACT…………………………………………………………………………...ix

INTRODUCTION…………………………………………………………………...1
Crassostrea virginica in Louisiana……………………………………………..3
Oyster Shell Habitat as EFH: The Current State of Research……………………5
Study Objectives…………………………………………………………………12

METHODS…………………………………………………………………………13
Study Area ………………………………………………………………………13
Sampling Techniques……………………………………………………………14
Gill Nets…………………………………………………………………14
Substrate Trays…………………………………………………………...17
Transient Fish Diet Analysis……………………………………………………..18
Prey Importance…………………………………………………………19
Percent Frequency of Occurrence………………………………..19
Percent Composition by Weight(g)...……………………………19
Indices of Diversity and Community Similarity…………………………………20
Margalef's D……………………………………………………………..20
Shannon Index…………………………………………………………...20
Simpson's Index…………………………………………………………21
Sorenson's Community Similarity Index………………………………...21
Statistical Analyses………………………………………………………………21
Comparison of Transient Fish Assemblage to Louisiana Department of
Wildlife and Fisheries Data……………...23
Comparison of Resident Fish Data to Drop Sampler Data……..………………..23

RESULTS……………………………………………………………………………..25
Summary of the Faunal Assemblage…………………………………………….25
Gill Nets…………………………………………………………………………25
Transient Fish Abundance……………………………………………….25
Transient Fish Diversity……………………………………………….…26
Description of the Transient Fish Assemblage…………………………..26
Substrate Trays…………………………………………………………………...32
Benthic Community Abundance…………………………………………32
Benthic Community Diversity…………………………………………...32
Description of the Benthic Community………………………………….32
Similarity Percentages and Species Contribitions to Assemblage Differences….40
Environmental Data……………………………………………………………...40

Transient Fish Diet Characterization……………………………………………42
Overall Diet Characterization……………………………………………42
Percent Frequency of Occurrence………………………………..42
Percent Composition by Weight…………………………………43
Diversity……………………………………………………………44
Diet Characterization by Species……………………………………...44
Hardhead Catfish…...……...……………………………………44
Gafftopsail Catfish...…………………………………………….44
Spot…………………………………………………………………45
Kingfish…………………………………………………………..45
Seatrout…………………………………………………………..45
Croaker…………………………………………………………...45
Black Drum…………………………………………………………46
Comparison of Transient Fish Assemblage to Louisiana Department of Wildlife and Fisheries Data…………………………………………………...46
Comparison of Resident Fish Data to Drop Sampler Data………….………..46

DISCUSSION………………………………………………………………………54
Study Limitations: Small Sample Sizes and Gear Issues………………………..54
Small Sample Sizes……………………………………………………54
Gill Net Sampling- Suggestions for Improvement………………………55
Substrate Tray Sampling- Possible Biases and Suggestions for Improvement…………………………………………………………..55
Transient Fish Assemblages……………………………………………………..56
Comparison of Transient Fish Assemblage to Louisiana Department of Wildlife and Fisheries Data…………………………………………………...58
Transient Fish Diet Characterization……………………………………………59
Benthic Fish and Macroinvertebrate Abundance and Diversity…………………62
Benthic Fishes……………………………………………………………62
Benthic Macroinvertebrates……………………………………………...63
Conclusions- Benthic Fishes and Macroinvertebrates…………………...64
Comparison of Resident Fish Data to Drop Sampler Data…..…………………..64
Cultched Oyster Bottoms as EFH………………………………………………..65
Conclusions……………………………………………………………………66
Suggestions for Future Research………………………………………………...67

LITERATURE CITED……………………………………………………………..68

APPENDIX A: GUT CONTENTS……...……………………………………….....78

APPENDIX B: FISH SPECIES COLLECTED..…………………………………….82

VITA…………………………………………………………………………………..84

LIST OF TABLES

Table 1. Total abundance, percentage of total catch, CPUE (# fish/hr), and standard length range (mm) for transient fish species collected with gill nets at oyster and mud bottom sites in Barataria Bay, Louisiana, from October 2001 to October 2002. Species with an * for length range were not measured……………………….............................30

Table 2. Total number and mean number (fish/tray) ± S.E. of fish species collected with substrate trays at oyster bottom and mud bottom sites from October 2001 to October 2002……………………………………………………………………………………37

Table 3. List of invertebrate taxa collected in substrate trays from a- oyster and b-mud bottom sites in Barataria Bay, Louisiana, October 2001 to October 2002. Also indicated are seasonal occurrence, total abundance, mean abundance (organisms/tray) ± S.E., and length range (mm). Length is carapace length for shrimp, carapace width for crabs, and longest dimension for mollusks………………………………………………………….38

Table 4. Results of SIMPER analysis for the entire faunal assemblage at oyster and mud bottoms, showing percent contribution to average dissimilarity between habitats……...41

Table 5. Results of SIMPER analysis for transient fishes at oyster and mud bottoms, showing percent contribution to average dissimilarity between habitats………………..41

Table 6. Results of SIMPER analysis for resident fishes and macroinvertebrates at oyster and mud bottoms, showing percent contribution to average dissimilarity between habitats…………………………………………………………………………………...42

LIST OF FIGURES

Figure 1. Location of the oyster lease sampled in Barataria Bay……………………….15

Figure 2. Side-scan sonar image of the oyster lease used in this study; high shell concentrations are indicated by darker areas on image. Areas sampled in this study are marked with an O (oyster bottom sites) or M (mud bottom sites)……………………….16

Figure 3. Substrate tray used to sample benthic fish and invertebrates at oyster and mud sites in Barataria Bay, Louisiana…………………………………………………...18

Figure 4. Monthly catch per unit effort (CPUE) of total transient fishes collected by gill net at (a) oyster and (b) mud sites between October 2001 and October 2002. Error bars represent standard error…………………………………………………………..27

Figure 5. Total catch per unit effort (CPUE) for gill net sets taken in morning (M), morning and afternoon (M/A), and afternoon (A). CPUE was not significantly different between times of day…………………………………………………………….28

Figure 6. Total catch per unit effort (CPUE) of transient fishes from gill net sets taken during flood and ebb tides at oyster and mud bottoms. CPUE was not significantly different between tidal stages ($p > 0.05$)…………………………………………28

Figure 7. Abundance of total transient fishes and common transient fish families collected by gill net at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in abundance between oyster and mud within each fish group ($p < 0.05$)…..29

Figure 8. Mean diversity (D_s) for transient fishes collected by gill net at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters were significantly different ($p = 0.0412$)………………………..31

Figure 9. Abundance of total resident fish, *Gobiosoma bosc*, *Opsanus beta*, *Gobiesox strumosus*, and *Gobionellus boleosoma* collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in abundance between oyster and mud within each fish group ($p < 0.05$)………………………………………………...34

Figure 10. Abundance of total decapods, total xanthid crabs, and grass shrimp Palaemonetes sp. collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in abundance between oyster and mud within each group ($p < 0.05$)……………………………………………………………………………35

Figure 11. Abundance of total bivalves, total mussels, and *Mulinia lateralis* collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in abundance between oyster and mud within each group ($p < 0.05$)…………………35

Figure 12. Mean diversity (D_s) for benthic fishes and invertebrates collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters were significantly different ($p < 0.05$)……………………………………………………………………………………36

Figure 13. Estimated density (# m^{-2}) for (a) resident fishes, (b) decapod crustaceans, and (c) bivalve mollusks at oyster and mud bottoms. Error bars represent standard error. Bars with different letters represent significant differences at oyster and mud within each group (p = 0.0004, 0.0001, 0.0704, respectively)………………………………………..39

Figure 14. Mean water quality for Barataria Bay study sites from October 2001 to October 2002: (a) salinity (ppt), (b) water temperature (°C), and (c) dissolved oxygen (%) values (±S.E.)……………………………………………………………………..43

Figure 15. (a) percent frequency of occurrence, (b) percent composition by weight, for three major prey categories in guts from all fish species at oyster and mud bottom……47

Figure 16. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of hardhead catfish, *Arius felis*, at oyster and mud bottoms……………………………………………………………………………48

Figure 17. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of gafftopsail catfish, *Bagre marinus*, at oyster and mud bottoms……………………………………………………………………48

Figure 18. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of spot, *Leiostomus xanthurus*, at oyster and mud bottoms……………………………………………………………………………49

Figure 19. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of kingfish, *Menticirrhus americanus*, at oyster and mud bottoms……………………………………………………………………49

Figure 20. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of sand seatrout, *Cynoscion arenarius*, at oyster bottoms……………………………………………………………………………50

Figure 21. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of Atlantic croaker, *Micropogonias undulatus*, at oyster bottoms………………………………………………………………..50

Figure 22. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of black drum, *Pogonias cromis*, at oyster bottoms……………………………………………………………………………51

Figure 23. Comparison of relative abundance of common finfish species from (a) LDWF surveys at Manila Village and (b) the present study (oyster and mud habitat combined)…………………………………………………………52

Figure 24. Average total abundance of finfish collected by LDWF at Manila Village from 1986-2002. Error bars represent standard error…………………………………...53

ABSTRACT

Recent research suggests that oyster reefs provide unique three-dimensional hard bottom habitat for many fish species. Along the northern shore of the Gulf of Mexico, oyster shell bottoms are predominantly flat, subtidal and cultched, lacking the vertical relief and spatial heterogeneity provided by natural reefs. This study compared finfish assemblages, gut contents, and macroinvertebrate assemblages at subtidal oyster shell (cultched oyster lease) and mud bottoms in Barataria Bay, Louisiana. Three mud and three shell sites were sampled on seven dates from October 2001 to October 2002, using gill nets and substrate trays. Data from the gill nets were used to compare fish assemblages, as well as to document feeding habits through gut content analysis. Data from the substrate trays were used to document benthic fish and invertebrate communities associated with the two bottom types. Finfish abundance was greater at shell (N = 234) than mud (N = 179) bottoms. Substrate trays collected significantly greater numbers of benthic fishes ($p = 0.001$) and decapod crustaceans ($p = 0.001$) at shell bottoms. Gut contents showed predation on fishes, bivalves, and decapod crustaceans. These results show that cultched shell bottoms support a more abundant finfish assemblage than mud bottoms, and provide a potentially important food source for transient fishes due to abundant benthic fishes and decapod crustaceans.

INTRODUCTION

The Sustainable Fisheries Act (SFA) amendment to the Magnuson-Stevens Fishery Conservation Act, passed by Congress in 1996, mandates a fishery management approach that focuses on protection and conservation of habitat important to marine, estuarine, and anadromous finfish and shellfish. This “essential fish habitat” (EFH) is defined as “those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity” (Fluharty 2000). Given this definition, it would seem that virtually every portion of aquatic habitat could be defined as EFH for some species at some stage of life; therefore, implementation of the SFA requires a detailed understanding of the function and relative value of habitats available to fisheries species and to organisms which play a role in their life history. The National Marine Fisheries Service has listed 4 levels of information needed for identification of EFH. These include estimates of species density and abundance (level 1), evidence of habitat association (level 2), information on differential survival, growth, and trophic dynamics (level 3), and lastly an estimate of the differential contribution of each habitat type to year class strength (level 4) (NMFS 1997). The majority of studies have focused on the first two levels, and there is a need for information on the functional relationships between species and their habitats. Still, for many species, specific habitat use within estuaries has not been comprehensively defined (Minello 1999).

Estuarine ecosystems provide food, refuge from predation, and important habitat for fish and invertebrates of ecological, commercial, and recreational importance. For many species, preference for and relative value of estuarine habitat types has yet to be defined (Minello 1999). In addition to extensive mud bottom, estuarine habitat types include submerged aquatic vegetation (SAV), salt marsh edge and interior, and bivalve assemblages such as clam and mussel beds and oyster reefs.

In particular, oyster reefs have been hypothesized to be cornerstones of estuarine ecosystems (Peterson et al. 2000). Oysters provided a wide variety of ecosystem services, including: (1) filtration of water, thereby controlling dynamics of phytoplankton, particulate organic carbon, and other materials in the water column (Dame and Patten 1981, Newell 1988); (2) output of nutrients such as ammonia (Dame et al. 1984); and, (3) alteration of hydrodynamic flow (Dame et al. 1984). Perhaps their most important role from the standpoint of the SFA is the provision of three-dimensional hard bottom habitat which supplies settlement substrate, shelter, and food for a wide variety of fish and invertebrate species (including oysters) (Coen and Luckenbach 2000, Harding and Mann 2001, Kilgen and Dugas 1989, Meyer and Townsend 2000, Zimmerman et al. 1989). Due to this role, oyster reefs have been called the temperate-zone analog of tropical coral reefs (Ebeling and Hixon 1991).

The eastern oyster, *Crassostrea virginica*, is distributed from Canada to Argentina, a range of over 8,000 km (Kilgen and Dugas 1989). However, the extent of oyster reef communities and their fishery has declined drastically in the past century over much of *C. virginica*'s range (MacKenzie et al. 1997). In the United States, overall landings for the oyster fishery peaked at 160 million pounds of meat between 1880 and 1910, and have declined to present levels of approximately 40 million pounds (MacKenzie 1996). Endemic diseases such as the protozoan parasites *Perkinsus marinus* ("Dermo") and *Haplosporidium nelsoni* ("MSX") have caused significant mortality

(Craig et al. 1989, Ford 1996). Environmental degradation in the form of variable salinities, increased sedimentation, and other hydrologic modifications may stress stocks (Meyer and Townsend 2000). In most instances, overharvesting coupled with a failure to replace harvested shell is likely a primary cause of the fishery's decline (Coen and Luckenbach 2000). Harvesting techniques such as hand- and hydraulic tongs, but particularly dredges are highly destructive to the reefs (Rothschild et al. 1994). Planktonic oyster larvae settle gregariously on hard substrate, and without shell replacement such substrate becomes scarce.

***Crassostrea virginica* in Louisiana**

Unlike other oyster-producing states (e.g. Maryland, Rothschild et al. 1994), Louisiana has maintained a fairly consistent harvest throughout the past century. The oyster fishery in Louisiana harvests over 10 million pounds of oyster meat each year, consistently ranking as the first or second highest contributor to the total U.S. oyster harvest, producing 42% of the nation's oyster landings in 1995. For the four-year period between 1989 and 1992, the Barataria-Terrebonne estuarine complex accounted for an average of 86% of Louisiana's total oyster landings (McKenzie et al. 1997).

Despite consistently high harvests, Louisiana's oyster stocks have suffered the same insults as those on the Atlantic coast, albeit to a lesser degree. Dredging and siltation, caused primarily by the oil industry, have affected beds. Up to half of Barataria Bay's oyster beds are closed each year because of sewage-related contamination. Overharvesting and past failure to replace shell has drastically reduced oyster coverage. Changes in salinity are an item of special concern in Louisiana's waters. Although Louisiana's oyster beds are found in salinities ranging from 5 to 20 ppt, *C. virginica* flourishes between 10-15 ppt (Perret and Chatry 1988). Coastal erosion has led to increased saltwater input; higher salinities increase the rates of "Dermo" infection and predation from the oyster drill, *Stramonita haemastoma* (Melancon et al. 1998). As favorable salinities have moved landward, large, historically productive reefs have been abandoned, and the optimal salinities for oyster survival are now in areas which were formerly freshwater, lacking the extensive shell substrate built by hundreds of years of settling oysters. Substrate ("cultch") in the form of shell or limestone is often added to leases and public beds. Since 1926, the state has added at least 764,000 m^3 of shell (primarily common rangia, *Rangia cuneata*) to public beds (MacKenzie 1996). Consequently, the large oyster population in Barataria Bay is composed of relatively small, flat aggregations rather than large reefs (Conner and Day 1989).

In an effort to combat the erosion problem, the state has implemented a freshwater diversion program to allow sediment-laden river water into the estuary. In some areas this has lowered salinities below the optimal range for oysters, inhibiting spawning and reducing the survival rate of larvae (Perret and Chatry 1988). Of particular importance for Barataria Bay is the Davis Pond diversion project, completed in March 2002, which may help to reestablish the large, historically productive oyster beds in the southern portions of the bay.

The Barataria estuary also supports many finfish of commercial and recreational importance, including Gulf menhaden, *Brevoortia patronus*, black drum, *Pogonias cromis*, and spotted sea trout, *Cynoscion nebulosus*, all of which depend upon estuaries for at least one stage of their life cycles. Brown shrimp, *Farfantepenaeus aztecus*, white shrimp, *Litopenaeus setiferus*, and blue crab, *Callinectes sapidus*, comprise the leading crustacean fisheries in the system (Conner and Day 1987).

Oyster Shell Habitat as EFH: The Current State of Research

Oyster reefs may certainly be considered EFH for oysters. Services provided include settlement substrate for oyster larvae (which are attracted to oyster exudates and/or presence of microbial biofilms) (Bonar et al. 1990, Crisp 1967), aggregation of spawning stock, partial refugia from predation in interstitial reef spaces, and avoidance of siltation due to reef height (Coen and Luckenbach 2000). Recent research has highlighted the importance of oyster reefs to ecosystem-level processes and as habitat for fishes and macroinvertebrates other than oysters (reviewed in Coen et al. 1999).

Sampling on oyster reefs can be difficult due to reef structural characteristics. Oyster reef fishes and/or macroinvertebrates have been sampled using gill nets (Harding and Mann 1999, 2001a, 2001b, Lenihan et al. 2001), lift nets (Crabtree and Dean 1982, Stunz et al. 2002, Wenner et al. 1996), trawls (Harding and Mann 1999), drop samplers (Zimmerman et al. 1989), throw traps (Glancy 2000), fish traps (Arve 1960, Griffet et al 1999, Harding and Mann 1999, Lenihan et al. 2001), substrate trays or crates (Coen et al. 1999, Larsen et al. 2001, Lehnert and Allen 2002, Lenihan et al. 2001, Perry et al. 2001), quadrat samples (Breitburg 1998, Meyer and Townsend 2000), and visual censuses (Harding and Mann 2000).

Many of these methods have drawbacks in any environment. Trawls and traps have low, variable catch efficiency and drop samplers or throw traps sample a small area (Rozas and Minello 1997). Gill nets can be size or species selective (Nielsen and Johnson 1983). Lift nets and drop samplers are limited to intertidal or shallow subtidal zones (Rozas 1992). Visual censuses are difficult due to limited visibility in many coastal areas (Wenner et al. 1996). At oyster reefs, trawls and gill nets are often used around rather than directly on the reef to avoid snagging (Harding and Mann 1999). Drop samplers rarely seal properly on shell bottom (D. Baltz, LSU Coastal Fisheries Institute, personal communication, May 28, 2003). Substrate trays have unknown catch efficiencies. In addition, for studies comparing nekton abundance at oyster reefs and other estuarine habitat types, it may be difficult to select a gear which effectively samples all the habitats under investigation.

A number of studies have indicated that oyster reef communities are highly diverse, including species not found in adjacent areas of soft bottom (e.g. Wells 1961; Dame 1979). Zimmerman et al. (1989) compared abundance and diversity of fish and invertebrates at intertidal oyster reefs, salt marsh, and subtidal mud bottom in a Texas estuary, using drop samplers and bottom cores. This study found that both oyster reefs and salt marsh supported more organisms than mud bottom, with unique community assemblages. Oyster reefs attracted fewer juvenile transient fish and decapod crustaceans than salt marsh. The authors suggested that these differences were due to degrees of prey availability and predation risk, with lesser prey availability and less shelter from predators for these groups at oyster reefs. A mesocosm experiment (Posey et al. 1999) demonstrated the value of oyster reefs as refugia for daggerblade grass shrimp, *Palaemonetes pugio*. In the presence of finfish predators, grass shrimp preferred to shelter among oysters rather than seagrass or shallow water.

Finfish associated with oyster reefs have been divided into three broad categories: reef residents, for which the reef is primary habitat; facultative residents, which are generally associated with structured habitats; and transient fishes, which visit reefs but are wide-ranging (Breitburg 1999). Surveys of oyster reefs in Maryland, Virginia, North Carolina, South Carolina, and Texas found a total of 79 finfish species (Coen et al. 1999). Of these, only seven could be clearly identified as reef residents: naked goby, *Gobiosoma bosc*, striped blenny, *Chasmodes bosquianus*, feather blenny, *Hypsoblennius hentz*, freckled blenny, *H. ionthas*, skilletfish, *Gobiesox strumosus*, oyster toadfish, *Opsanus tau*, and Gulf toadfish, *O. beta*. Oysters are generally considered essential habitat for these species, which breed, feed, and shelter on the reefs. While not themselves important commercially or recreationally, resident species serve, along with invertebrates, as a food source for at least some of the 72 other wide-ranging (transient) species visiting oyster reefs (Harding and Mann 2000), which include species of commercial and recreational interest such as snapper (Fam. Lutjanidae), red drum, *Sciaenops ocellatus*, black drum, spotted seatrout, and sheepshead, *Archosargus probatocephalus* (Coen et al. 1999, Nestlerode et al. 1998, Harding and Mann 1999, Minello 1999, Posey et al. 1999).

Little is known about the use of these reefs by transient species, and it has been suggested that reefs may be important long-term habitat for juveniles of some “transient” species (Coen et al. 1999, Luckenbach et al. 1999). Despite the contention that oyster reefs are critical to numerous fish and invertebrate species, relatively little is known about the actual role oyster reefs play in supporting transient fish.

Recent studies on the Atlantic Coast have begun to demonstrate the trophic connections between oyster reefs and transient fish. Breitburg (1999) documented predation by juvenile striped bass, *Morone saxatilis*, on large numbers of naked goby larvae at an oyster reef. Harding and Mann (2001) found that bluefish, *Pomatomus saltatrix*, were more abundant at restored Chesapeake Bay oyster reefs than non-reef sites, and that those caught in association with reefs consumed a wider variety of teleost prey items than fish from other sites. Lenihan et al. (2001) compared fish and invertebrate utilization of natural and restored oyster reefs and sand bottom sites, using gill nets, fish traps, and open top 'habitat trays', finding that oyster reefs had vastly higher densities of amphipods, decapods, benthic fishes, decapods, and recruited bivalves (including oysters and several mussel species), than did sand bottom. Only two of 13 species of crustaceans and resident fishes at the reefs were also found on sand bottom sites. Non-resident fish were significantly more abundant and diverse at oyster reefs than sand bottom sites, with a total of 17 species caught. Examination of gut contents from gill-netted fish showed predation on reef-associated fish and invertebrates.

To date, Harding and Mann (2001b) have most explicitly addressed the role of oyster habitat as EFH for transient fish species, comparing abundance, species richness, and size of eight transient species (Atlantic menhaden, *Brevoortia tyrannus*, Atlantic croaker, *Micropogonias undulatus*, spot, *Leiostomus xanthurus*, weakfish, *Cynoscion regalis*, spotted seatrout, striped bass, silver perch, *Bairdiella chrysoura*, and bluefish), on sand bottom, oyster bar, and oyster reef habitat in the Chesapeake Bay. The species were found at all three bottom types, but were more abundant and larger with increasing habitat complexity. The authors suggest that this is related to feeding, with greater food availability, prey abundance, or presence of higher quality prey at oyster bottom sites. They conclude that oyster habitat is important for these generalist species, but not exclusively utilized and therefore not "essential".

The EFH function of oyster reefs is pertinent to the habitat function of artificial reefs, since estuarine artificial reefs placed within an appropriate salinity range are likely to develop an epifaunal assemblage over time which includes oysters. Oysters settling and maturing on artificial reef substrate may provide an additional source of food and shelter, enhancing the habitat value of artificial reefs. There are numerous studies showing that fish congregate at artificial reefs (Bohnsack and Sutherland 1985), but why this is the case (e.g. additional food, increased feeding efficiency, shelter from predation, habitat for recruitment) and whether fish production is increased remain unclear (Bohnsack 1989, Grossman et al. 1997). This same "attraction vs. production" debate is also applicable to natural oyster reefs.

Little research exists on the importance of oyster reefs as EFH in the northern Gulf of Mexico. A study in Texas reported that macroinvertebrates, particularly decapod crustaceans, are found in high numbers at intertidal oyster reefs (Zimmerman et al. 1989). While these studies provide evidence that the oyster reefs are important, relative habitat value in comparison to adjacent habitats (emergent vegetation, SAV, and sand or mud bottom) is largely unknown. In an analysis of fishes and decapod crustacean densities reported in 22 enclosure-sampler studies of estuarine habitats (including oyster reef, marsh edge, inner marsh, SAV, and shallow nonvegetated bottom) from Texas and Louisiana, Minello (1999) found that oyster reefs had the highest mean densities of mud crabs (Fam. Xanthidae), porcelain crabs, *Petrolisthes* sp., bay anchovy, *Anchoa mitchilli*, skilletfish, and naked goby (however, oyster reef data was taken only from Zimmerman et al. 1989). Stunz and Minello (2001) have indicated that oyster reef structure in laboratory experiments offers protection from predation for young red drum; however, a comparison of habitat types in Galveston Bay (Stunz et al. 2002) found that juvenile drum were absent from intertidal oyster reefs but present in relatively large numbers at adjacent seagrass beds and marsh edge.

Along the southeastern Atlantic Coast, most reefs are restricted to the intertidal zone because of high predation in subtidal areas (Bahr and Lanier 1981, Dame et al. 1984). The majority of workers have examined intertidal oyster reefs, in part because of the relative ease of sampling these areas (e.g. using lift nets, Rozas 1992, Wenner et al. 1996). Comparisons of the two habitats are rare (e.g. Lehnert and Allen 2002), but it is likely that intertidal reefs are not completely analogous to subtidal shell bottoms in terms of habitat function.

Most Gulf Coast oyster reefs are subtidal due to the narrow tidal range (Kilgen and Dugas 1989). Of particular importance in Louisiana are subtidal shell bottoms, often cultched, which lack the amount of three-dimensional relief created by true oyster reefs but provide more structural complexity than mud bottom. Few studies have examined nekton use of subtidal shell bottoms.

Arve (1960) cultched 2-acre subtidal plots in a Maryland estuary with oyster shell, creating a layer averaging 3 shells deep, and evaluated finfish use with traps on cultched and mud bottom. Species diversity was higher and abundance was approximately 3 times greater on cultched bottom. Arve (1960) suggested that fish were attracted to cultched sites by an increase in prey availability, although this was not quantified.

Lehnert and Allen (2002) used substrate trays and trawl samples to compare nekton use of subtidal shell bottom, subtidal mud bottom, and intertidal oyster reef in a

South Carolina estuary. Abundance and diversity were much greater at shell than mud sites. Many fish species were found to remain at the subtidal shell bottom even when intertidal reefs were inundated, and significantly more fish were collected at subtidal than intertidal shell. The authors suggested that subtidal shell bottom is EFH for some fish species, and may be “more critical” habitat than intertidal shell reefs.

Paynter (2000) investigated the effects of high (2 million/acre) and low (250,000/acre) density oyster plantings in Chesapeake Bay, finding that the high density planting attracted significantly higher abundance and diversity of gobies and blennies. In a laboratory study, Flynn and Paynter (2001) found that resident fishes including naked gobies, blennies, and skilletfish preferentially selected clumps of oyster shell over piles of loose shell.

These four studies suggest that the structure provided by low-profile oyster shell rubble provides important estuarine habitat for transient and resident fishes, presumably by increasing prey abundance. Surveys of fauna associated with oyster habitat have been conducted in Louisiana (Mackin and Hopkins 1962a and b, Mackin and Sparks 1962) but there are no published quantitative comparisons of faunal assemblages at oyster bottoms and other estuarine habitats in the state. The lack of quantitative studies of faunal assemblages at subtidal oyster reefs and cultch in Louisiana and the northern Gulf Coast may be due in part to the sampling difficulties previously discussed. Given the large amounts of cultch deposited in Louisiana estuaries, whether these cultched bottoms have superior habitat value in comparison to other estuarine bottom types is an important question.

Study Objectives

My thesis research was initiated in Fall 2001 with the following objectives: 1) compare abundance and diversity of transient fishes, resident fishes, and benthic macroinvertebrates at subtidal cultched oyster and mud bottom in Barataria Bay, and 2) compare transient fish gut contents and prey availability at oyster and mud bottom. Growing evidence of the complex ecological communities supported by oyster shell habitat, combined with past destruction of oyster reefs in Louisiana, present threats to oyster stocks, a proliferation of interest in creating artificial shell reefs, and the current focus on EFH, makes the issue of identifying and quantifying the role of oyster shell habitat in supporting fish communities a pertinent one.

METHODS

Study Area

Barataria Bay is a turbid, shallow estuary, with an average depth of 1.25 m (Day et al. 1973). Tides are diurnal and small, averaging 0.3 m, and salinity ranges from 6 to 22 ppt (Conner and Day 1987). Due to relatively high salinity in most of the bay, the fish community is dominated by marine species. In the lower bay, dominant species ranked by relative abundance and biomass are bay anchovy, Gulf menhaden, spot, croaker, and rough silverside, *Membras martinica* (Conner and Day 1987).

Substrate is predominately clayey silt, with approximately 10-12% of the bottom covered by shell (C. Wilson, LSU Coastal Fisheries Institute, personal communication, January 27, 2003). The total area of oyster leases (not necessarily in production) is estimated at 5,000 ha (Conner and Day 1987). Few, if any, natural oyster reefs exist due to extensive dredging and trawling (C. Wilson, LSU Coastal Fisheries Institute, personal communication, January 27, 2003).

Sampling took place at three subtidal cultched oyster shell and three subtidal mud bottom sites (average depth approximately 1.5 m) on a private oyster lease near the Manila Village area, directly east of the Barataria Waterway (N 29°26'18.3", W 89°58'09.8", Figure 1). The study area is surrounded by salt marsh (primarily smooth cordgrass, *Spartina alterniflora*). The lease was established on the remains of a natural clam reef, and has been cultched frequently since the 1940's, using oyster shell as well as shell from hard clam, *Mercenaria mercenaria*, and common rangia. Oyster harvest has ranged from 1,000 to 36,750 sacks year^{-1}, with 1,220 sacks harvested in 2002 (R. Pausina, personal communication, March 19, 2003).

Bottom topography was previously documented by C. Wilson of the Louisiana State University Coastal Fisheries Institute using side-scan sonar and shell volume counts. Oyster sites for this study were selected based in part on high shell volume counts from this research; mud bottom sites were selected based in part on shell volume counts of zero. Three shell and three mud sites were randomly chosen for sampling. I also used a push-pole to confirm the extent of shell or mud coverage at each site, and marked sites with labeled PVC poles (Figure 2). Although monthly sampling was planned, weather delays confined sampling to seven dates between October 2001 to October 2002 (October and November 2001, January, March, May, June, and October 2002).

Sampling Techniques

Gill Nets

To compare pelagic finfish use of oyster and mud bottoms, I used experimental monofilament gill nets 30.5 m long by 2.4 m deep, consisting of four 7.6 m panels with stretch-mesh sizes of 25.4 mm, 38.1 mm, 50.8 mm, and 63.5 mm. The range of mesh sizes reduced size selectivity of the nets (Nielsen and Johnson 1983). Gill nets were set parallel to the direction of the current and anchored at both ends with Danforth anchors, fishing the entire water column at all sites. Gill nets were fished during daylight hours. Fish were identified, measured (SL, mm), and preserved on ice for laboratory analysis of gut contents (guts of large fish were removed in the field and frozen separately). Sampling trips in October and November 2001 used 1-hr gill net sets at each site

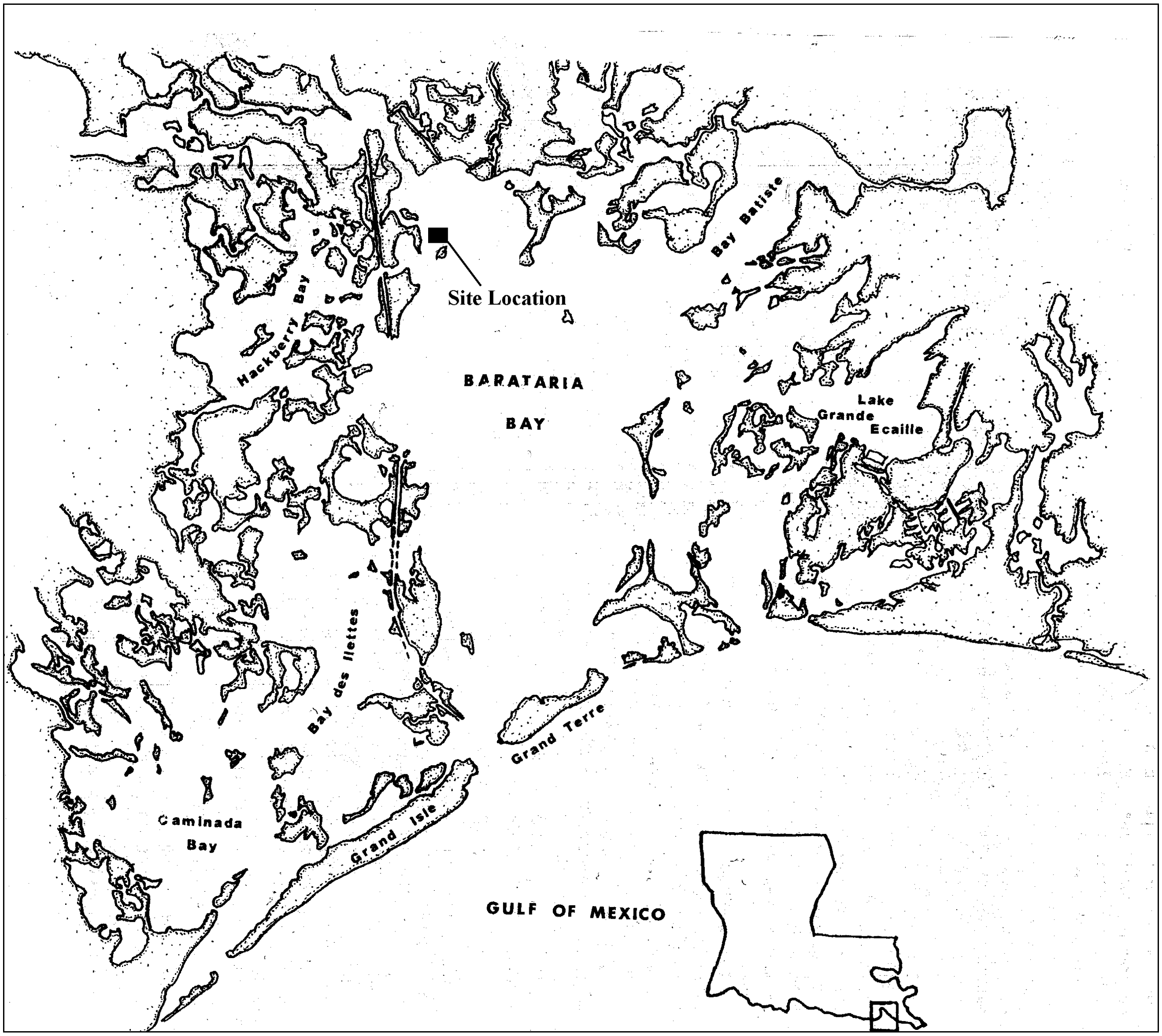

Figure 1. Location of the oyster lease sampled in Barataria Bay.

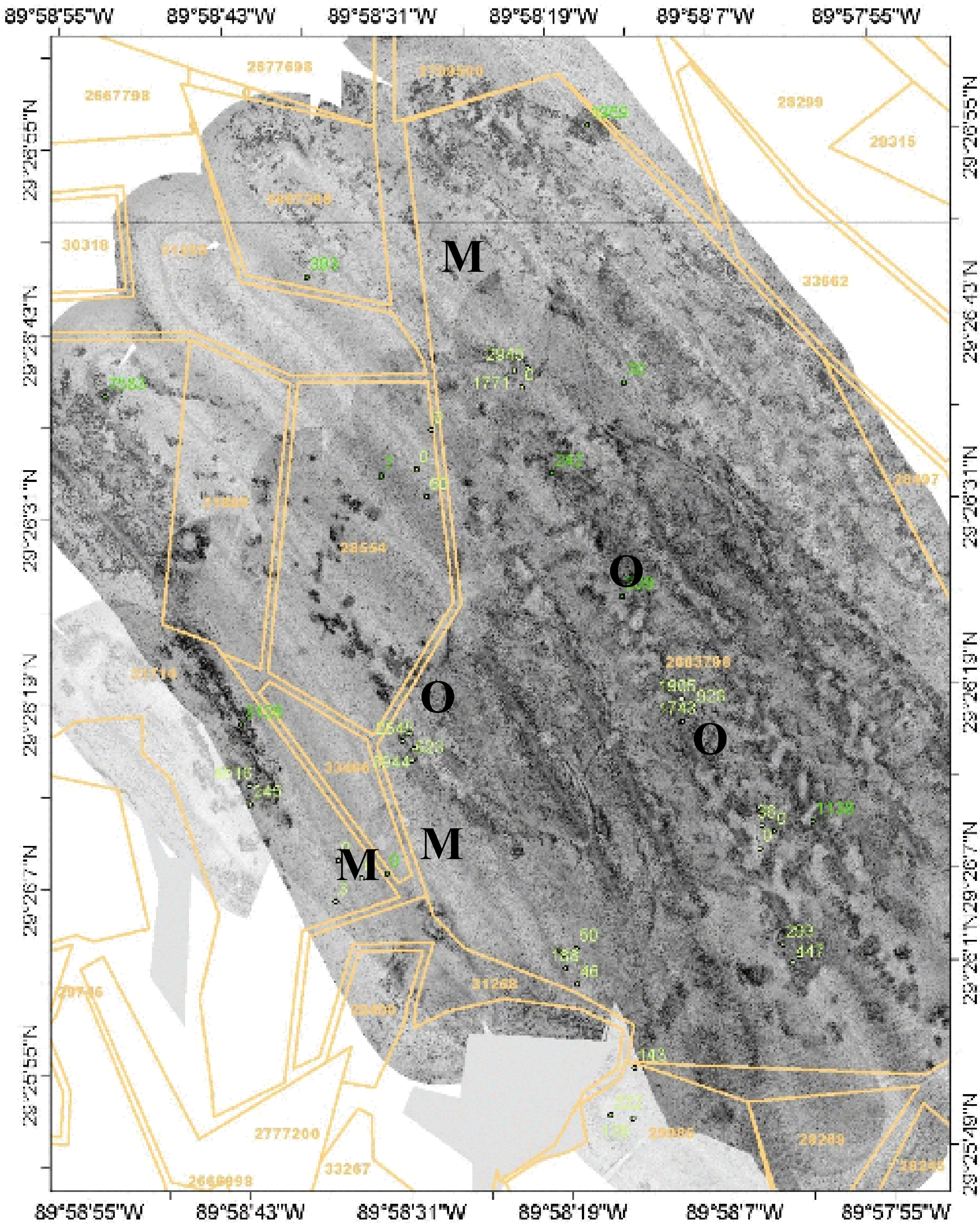

Figure 2. Side-scan sonar image of the oyster lease used in this study; high shell concentrations are indicated by darker areas on image. Areas sampled in this study are marked with an O (oyster bottom sites) or M (mud bottom sites).

and caught few fish. For the remaining trips, gill nets were set for 2 hours at each site. After setting each net, a YSI Multiprobe (Model 556) was used to measure water quality parameters, including temperature (°C), salinity (ppt), and dissolved oxygen (% and g/l).

Substrate Trays

Substrate trays were used to quantify abundance, density, and diversity of finfish prey items (benthic macroinvertebrates and resident fishes) at mud and oyster bottom. Open plastic bread containers measuring 60 cm x 51 cm x 3 cm (0.31 m^2) and lined with 0.5 mm mesh black fiberglass screening were used. A rope bridle for lifting the trays was attached to all four corners of the tray (Figure 3). Substrate at oyster sites consisted of a single layer of disarticulated oyster shell, dried and replaced at each sampling period. Substrate at mud sites consisted of a 3 cm layer of mud (to the top of each tray). Trays were deployed in triplicate at each site (for a total of 18 trays), lowered to the bottom beside the site marker poles with bridle ropes attached to the poles above water level. Trays were left between sampling sessions (ranging from 23 to 120 d, with an average of 60 d), then quickly raised. Contents were sieved, rinsed, and bagged for identification, enumeration and measurement of fauna in the laboratory. Similar trays containing oyster shell have been used successfully in a variety of studies for collection of benthic fish and invertebrates (e.g. Breitburg 1991, Lenihan et al. 2001, Lehnert and Allen, 2002), although their catch efficiency is unknown. To my knowledge they have not previously been used at mud bottoms. Due to wave action at the sampling area, many trays were overturned between sampling sessions, losing their contents. Rebar was attached to the underside of each tray in an effort to weigh the trays down. Additional trays were lost due to the effects of Tropical Storm Isidore in September 2002.

Figure 3. Substrate tray used to sample benthic fish and invertebrates at oyster and mud sites in Barataria Bay, Louisiana.

Transient Fish Diet Analysis

Gut contents were taken from all fish caught with gill nets in order to evaluate fish diet on oyster and mud bottom and to compare prey items ingested with prey items present at the two habitats. In the laboratory, contents of the entire digestive tract were fixed in 10% formalin and transferred to 70% ethanol. Gut contents were identified to the nearest possible taxon, oven dried separately by taxon at 60°C for 24 h, and weighed to the nearest 0.01 g.

Prey Importance

To evaluate prey importance, a variety of diet measures should be used (Bowen 1996). Diet composition for each species caught with food in guts was evaluated by percent frequency of occurrence and percent composition by (dry) weight.

Percent Frequency of Occurrence

To obtain percent frequency of occurrence, I calculated the number of stomachs containing individuals from each prey category and divided this by the total number of stomachs with food to obtain a percentage. This method provides a "crude qualitative picture of the food spectrum" (Hyslop 1980), describing the uniformity with which groups of fish select their diet, but providing no information on the relative importance of prey types in overall diet.

Percent Composition by Weight (g)

To obtain percent composition by weight, I calculated the percentage of the weight of each prey category in each stomach and then summed these percentages for each prey category and divided by the total number of stomachs with food. Since food value is roughly proportional to weight for most prey types (excluding mollusks), this method gives a better idea of the relative importance of individual prey types in fish diet (Bowen 1996), although the relative importance of larger prey items increases. It should be noted that differential digestion of prey items is a problem in evaluating their relative importance to diet. Soft prey such as fishes are digested quickly and may leave little trace, while prey with hard parts such as bivalves are digested more slowly, so their importance may be over-estimated (Bowen 1996, Hyslop 1980).

Gut contents analysis was not performed on Gulf menhaden, as identification of phytoplankton from numerous menhaden guts was beyond the scope of this study or the ability of the author.

Indices of Diversity and Community Similarity

Diversity and community similarity were evaluated separately for transient fishes and for the "benthic community" consisting of resident fishes and macroinvertebrates. I used a variety of measures of richness and diversity: Margalef's D, the Shannon Diversity Index, and Simpson's Diversity Index. I also used the above indices with gut contents data (presence/absence of major prey taxa). I used Pearson correlations to determine relationships between indices, and refer only to Simpson's Diversity Index where indices were significantly correlated. Sorenson's Community Similarity Index was used to compare transient fish assemblages and the benthic community at oyster and mud bottom.

Margalef's D

Margalef's D is a measure of species richness, the total number of species in a community, calculated as:

$$D_{mg} = (S-1)/\ln N$$

where S is the number of species recorded and N is the total number of individuals summed over all S species.

Shannon Index

The Shannon and Simpson indices are based on the proportional abundance of species, combining richness and evenness into a single number (Magurran 1988). The Shannon Index is calculated as:

$$H = -\Sigma p_i \log p_i$$

where p_i is the proportion of the total number of individuals occurring in species *i*. This index is most affected by species richness.

Simpson's Index

Simpson's Index is calculated as:

$$D_s = 1-\Sigma n_i^2-N / N(N-1)$$

where *N* is the total number of individuals of all species and *n* is the total number of individuals of a particular species. This index is most affected by dominance (changes in abundance of the most common species).

Sorenson's Community Similarity Index

Sorenson's Community Similarity Index was used to compare transient fish assemblages and the benthic community between oyster and mud bottom. This index compares species compositions of different communities (Magurran 1988) and is calculated as:

$$2c / s1 + s2$$

where *c* is the number of species the two communities have in common, and *s1* and *s2* are the number of species in the respective communities. Index values range from 0 to 1, with higher values indicating more similar communities.

Statistical Analysis

Statistics were calculated using PRIMER v5 (Plymouth Routines in Multivariate Ecological Research). This software package consists of a wide range of univariate, graphical and multivariate procedures for analyzing species/samples abundance matrices.

Few assumptions regarding the form of the data are needed for these procedures, which rely on ‘non-metric’ ordination and permutation tests.

To test for differences in abundance and diversity for the entire faunal assemblage (transient fishes, resident fishes, and macroinvertebrates), transient fishes, resident fishes, and decapod crustaceans between habitats, by date, and by tidal stage, I used the ANOSIM procedure, which is an analog of ANOVA, performing randomization tests on similarity matrices. Randomization tests involve calculation of a test statistic for the data, followed by repeated (in this case, 999) permutations of the data, with a test statistic value calculated for each permutation. The resulting p-value for the randomization test is the proportion of data permutations in the set that have test statistic values greater than or equal to the value for the experimentally obtained results (Edgington 1995, Manly 2001). Significance levels were established at $p = 0.05$ *a priori*.

To identify the faunal groups primarily responsible for differences in species assemblages between oyster and mud samples, I used the SIMPER procedure, which provides the overall percent contribution each species or faunal group makes to the average dissimilarity between two groups.

I used the BVSTEP procedure, analogous to stepwise multiple regression (except that in this case the residual sum of squares function is guaranteed to decrease as more variables are added), to find the smallest possible subset of species or faunal groups which, in combination, accounted for most of the difference in assemblages between oyster and mud bottom in the full data set.

To examine relationships between environmental variables (temperature, salinity, dissolved oxygen) and catch per unit effort (CPUE) of transient fishes, the BIOENV procedure was used. The procedure calculates Spearman rank correlations elements in similarity matrices for biotic and abiotic variables to reflect the degree to which environmental variables 'explain' biological variables.

Comparison of Transient Fish Assemblage to Louisiana Department of Wildlife and Fisheries Data

To compare my transient fish data set collected over the course of one year to a long-term data set from the same area, I used data from the Louisiana Department of Wildlife and Fisheries (LDWF), which has conducted finfish surveys at Manila Village (29°25'50" x 89°58'25") using a variety of gear types since 1967. The LDWF gill net sampling program was initiated in 1986 and takes place monthly from October to March and bimonthly from April to September. A 228.6 m long, 2.4 m deep experimental monofilament gill net is used, consisting of five 45.7 m long panels with mesh sizes of 25 mm, 32 mm, 38 mm, 45 mm, and 51 mm. Fish are sampled via strike netting, in which the net is deployed and the boat is circled around the net several times, in theory forcing fish into the net. Although this sampling is not habitat specific, LDWF data were analyzed to compare species composition and seasonal abundance with the present study.

Comparison of Resident Fish Data to Drop Sampler Data

I compared finfish data from my study sites to data collected with drop samplers in Barataria Bay from 1987-1991 (Baltz et al. 1993, Baltz unpublished data). Samples were taken along two transects running inland from the Gulf of Mexico using 0.5 m^2 drop samplers in water depths of less than 1 m. Dominant and subdominant substrate types were recorded for each sample, including mud, sand, shell, and emergent vegetation. The subset of data I analyzed included 16 samples collected from sites with substrate composed entirely of mud and 58 samples collected from sites with shell as the dominant or subdominant substrate.

RESULTS

Summary of the Faunal Assemblage

Sample sizes were small: A total of 717 fishes and 1,866 macroinvertebrates were collected over the course of the study. Fish species were classified as transients (pelagic fishes collected primarily by gill nets) and residents (demersal fishes collected only by substrate trays). Four hundred thirteen transient and 304 resident fishes from 28 species were collected overall. Two hundred thirty-four transient fishes from 16 species were collected at oyster bottom and 179 transient fishes from 13 species were collected at mud bottom, although there was no significant difference in abundance between the two habitats ($p > 0.05$). Resident fishes were significantly more abundant at oyster bottom ($p = 0.001$). Two hundred twenty-six resident fishes from 8 species were collected at oyster bottom and 77 resident fishes from 8 species were collected at mud bottom. Decapod crusteaceans were significantly more abundant at oyster bottom ($p = 0.001$). One thousand, one hundred forty-eight decapod crustaceans and 87 bivalves were collected at oyster bottom and 203 decapods and 428 bivalves were collected at mud bottom.

Gill Nets

Transient Fish Abundance

From October 2001 to October 2002, 18 gill net sets were conducted at oyster bottom and 19 gill net sets were conducted at mud bottom, for a respective total of 32 and 33 hours fishing time. There was no significant difference in total fish abundance between the two habitats ($p > 0.05$), although total catch was greater at oyster bottom ($N = 234$) than mud bottom ($N = 179$). Overall CPUE was highest during summer months at both habitats. At oyster, CPUE was not significantly different between months ($p > 0.05$). At mud, CPUE was significantly higher in May than in any other month (Figure 4). Overall CPUE was higher for samples taken before noon (CPUE = 15.7) than for samples which encompassed morning and afternoon (CPUE = 10.0) and samples taken after noon (CPUE = 9.0), although the difference was not significant ($p > 0.05$) (Figure 5). Overall CPUE was highest on flood tide at oyster and highest on ebb tide at mud, but was not significantly different between tidal stages ($p > 0.05$) (Figure 6).

Transient Fish Diversity

Only Simpson's Diversity Index (D_s) was used for fishes collected by gill net, since all indices were highly correlated ($r^2 = 0.98$). Mean D_s values were 1.65 ± 0.21 at oyster bottom and 1.04 ± 0.22 at mud bottom. Diversity was not significantly different between habitats ($p > 0.05$) (Figure 8). The value for Sorenson's Community Similarity Index was 0.38, indicating relative dissimilarity between oyster and mud transient fish assemblages.

Description of Transient Fish Assemblage

Overall, gill nets caught 18 species of fishes from 9 families (413 individuals, Table 1). Of these, 16 species were caught at oyster bottom (234 individuals) and 13 species were caught at mud bottom (179 individuals). Five species were caught only at oyster bottom (Atlantic spadefish, *Chaetodipterus faber,* N = 2; cownose ray, *Rhinoptera bonasus,* N = 1; pinfish, *Lagodon rhomboides,* N = 1; sand seatrout, *Cynoscion arenarius,* N = 7; and silver perch, N = 2); 2 species were caught only at mud bottom (blacktip shark, *Carcharhinus limbatus*, N = 2, and skipjack herring, *Alosa chrysochloris,* N = 2).

Gulf menhaden dominated the catch at both bottom types and were more abundant at oyster bottom (N = 162; CPUE = 5.06 fish/hr; 69% of the total oyster catch) than at mud bottom (N = 145; CPUE = 4.39 fish/hr; 80% of the total mud catch). The second most abundant fish species at oyster bottom was black drum (N = 15; CPUE = 0.47 fish/hr; 6% of the total oyster catch). Other common species at oyster bottom (N > 5) included hardhead catfish, *Arius felis*, spot, kingfish, *Menticirrhus americanus*, Spanish mackerel, *Scomberomorus maculatus*, and croaker. At mud bottom, the second most abundant species was hardhead catfish (N = 11; CPUE = 0.33 fish/hr; 6% of the total mud catch). No more than 4 members of any other species were caught at mud. Those with N > 2 included gafftopsail catfish, *Bagre marinus*, spotted seatrout, kingfish, and Spanish mackerel.

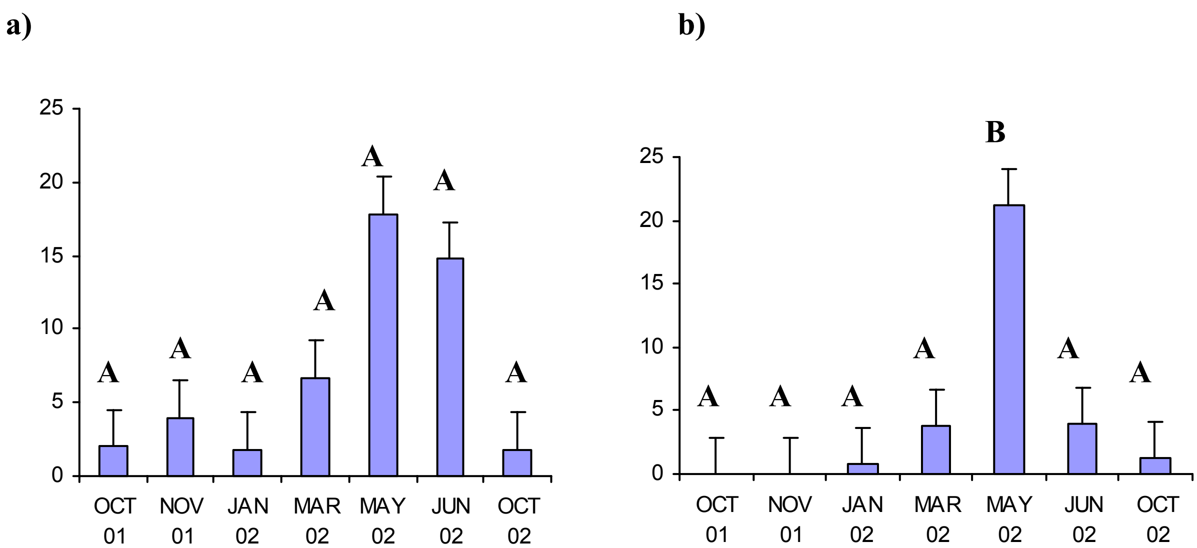

Figure 4. Monthly catch per unit effort (CPUE) of total transient fishes collected by gill net at (a) oyster and (b) mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in CPUE between months ($p < 0.05$).

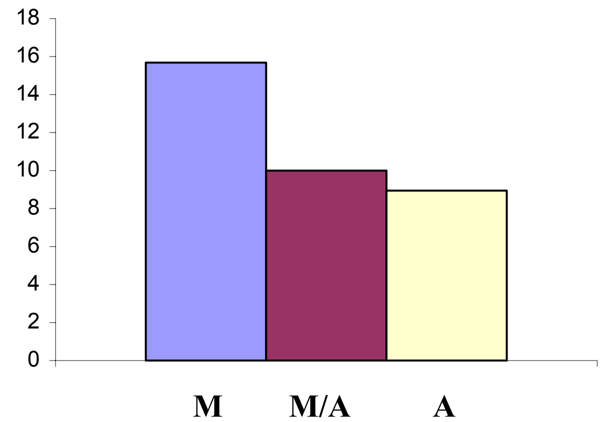

Figure 5. Total catch per unit effort (CPUE) of transient fishes from gill net sets taken in morning (M), morning and afternoon (M/A), and afternoon (A). CPUE was not significantly different between times of day ($p > 0.05$).

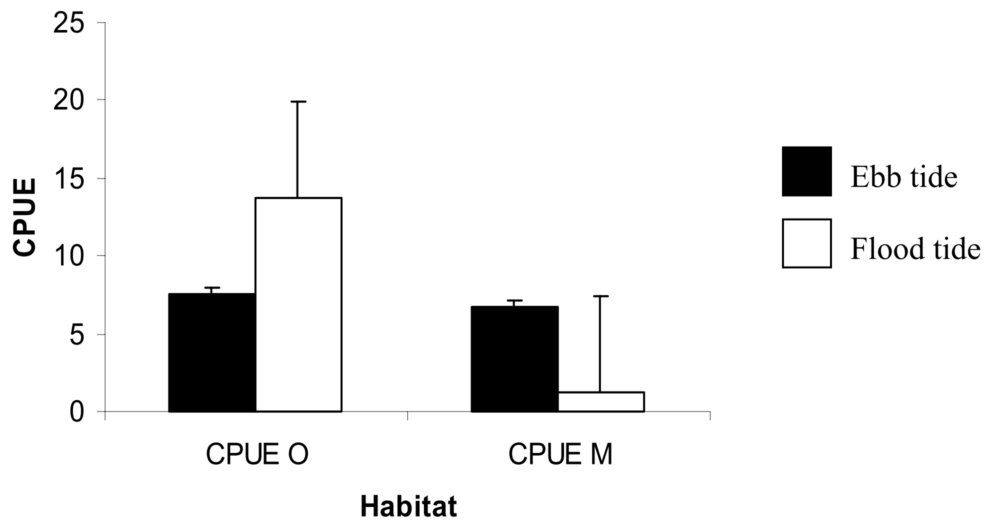

Figure 6. Total catch per unit effort (CPUE) of transient fishes from gill net sets taken during flood and ebb tides at oyster and mud bottoms. CPUE was not significantly different between tidal stages ($p > 0.05$).

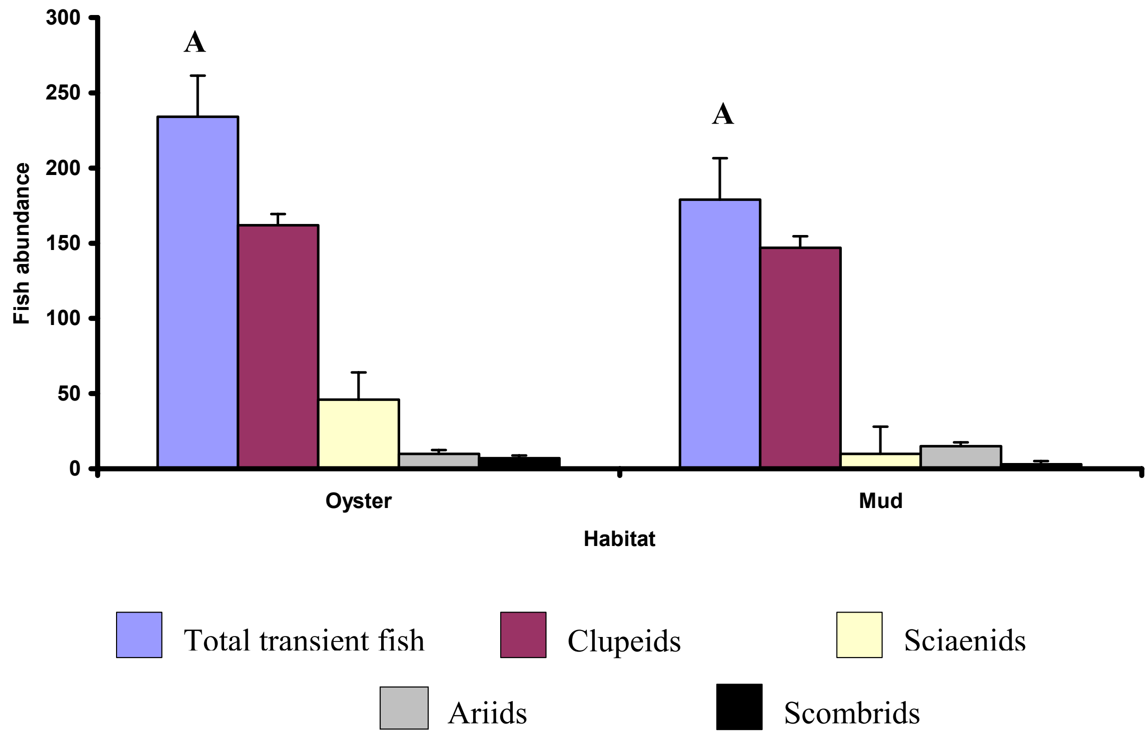

Figure 7. Abundance of total transient fishes and common transient fish families collected by gill net at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in abundance between oyster and mud within each fish group ($p < 0.05$).

Table 1. Total abundance, percentage of total catch, CPUE (# fish/hr), and standard length range (mm) for transient fish species collected with gill nets at oyster and mud bottom sites in Barataria Bay, Louisiana, from October 2001 to October 2002. Species with an * for length range were not measured.

Common Name	Scientific Name	Oyster total catch (#)	Oyster total catch (%)	Oyster CPUE (#/hr)	Length range (mm SL)	Mud total catch (#)	Mud total catch (%)	Mud CPUE (#/hr)	Length range (mm SL)
Atlantic croaker	*Micropogonias undulatus*	6	2.6	0.19	130-165	1	0.6	0.03	159
Atlantic spadefish	*Chaetodipterus faber*	2	0.9	0.06	41-112				
Black drum	*Pogonias cromis*	15	6.4	0.47	309-880	1	0.6	0.03	450
Blacktip shark	*Carcharhinus limbatus*	-	-	-	-	2	1.1	0.06	*
Bluefish	*Pomatomus saltatrix*	1	0.4	0.03	190	1	0.6	0.03	189
Cownose ray	*Rhinoptera bonasus*	1	0.4	0.03	*	-	-	-	-
Gafftopsail catfish	*Bagre marinus*	2	0.9	0.06	183-255	4	2.2	0.12	141-171
Gulf menhaden	*Brevoortia patronus*	162	69.2	5.06	90-220	145	81.0	4.39	90-203
Hardhead catfish	*Arius felis*	8	3.4	0.25	175-379	11	6.1	0.33	259-402
Pinfish	*Lagodon rhomboides*	1	0.4	0.03	120	-	-	-	-
Sand seatrout	*Cynoscion arenarius*	7	3.0	0.22	196-310	-	-	-	-
Sheepshead	*Archosargus probatocephalus*	2	0.9	0.06	229-364	1	0.6	0.03	362
Silver perch	*Bairdiella chrysoura*	2	0.9	0.06	145-150	-	-	-	-
Skipjack herring	*Alosa chrysochloris*	-	-	-	-	2	1.1	0.06	194-231
Southern kingfish	*Menticirrhus americanus*	7	3.0	0.22	172-287	3	1.7	0.09	181-221
Spanish mackerel	*Scomberomorus maculatus*	7	3.0	0.22	319-425	3	1.7	0.09	385-487
Spot	*Leiostomus xanthurus*	8	3.4	0.25	122-150	2	1.1	0.06	116-123
Spotted seatrout	*Cynoscion nebulosus*	3	1.3	0.09	220-319	3	1.7	0.09	233-275
TOTAL		234				179			

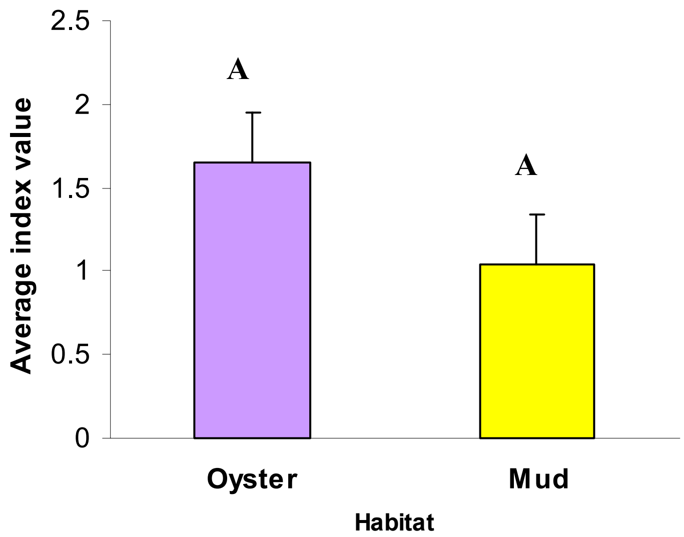

Figure 8. Mean diversity (D_s) for transient fishes collected by gill net at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters were significantly different.

Substrate Trays

Benthic Community Abundance

Twenty-two oyster and 18 mud substrate trays were retrieved intact over the course of the study. Total abundance of fish captured in substrate trays was significantly greater at oyster bottoms ($p = 0.001$) (Figure 9).

Abundance of total decapod crustaceans was significantly greater ($p = 0.001$) in oyster trays than in mud trays (Figure 10). Mollusk abundance was not significantly different between habitats (Figure 11).

Benthic Community Diversity

Since all indices were highly correlated ($r^2 = 0.98$), only results from Simpson's Index are reported (Figure 12). Mean D_s values were 2.84 ± 0.15 at oyster bottom and 3.24 ± 0.26 at mud bottom, but were not significantly different between habitats for the benthic community ($p>0.05$). The value for Sorenson's Community Similarity Index was 0.81, indicating relative similarity between the benthic community at oyster and mud.

Description of Benthic Community

Overall, substrate trays captured 10 fish species (N = 303). Eight fish species (N = 226) were collected at oyster bottom, and 8 fish species (N = 77) were collected at mud bottom (Table 2). Oyster trays caught 10.28 ± 1.38 fish per tray, while mud trays caught 4.28 ± 0.54 fish per tray (Table 2). Two species (striped blenny, N = 1; crested blenny, *Hypleurochilus geminatus*, N = 1) were collected only at oyster bottom, and two species (speckled worm eel, *Myrophis punctatus*, N = 1; mangrove snapper, *Lutjanus griseus*, N = 1) were collected only at mud bottom. Naked goby was the most abundant species at oyster bottom (N = 119; 5.13 ± 0.96 fish/tray; 53% of the total oyster catch), and at mud bottom (N = 29; 0.88 ± 0.26 fish/tray; 38% of the total mud catch). Other commonly encountered species at both bottom types were Gulf toadfish, skilletfish, and darter goby.

Substrate trays captured a variety of macroinvertebrates, predominately consisting of mud crabs (primarily common mud crab, *Panopeus herbstii*, and flat-back mud crab, *Eurypanopeus depressus*), grass shrimp, and small bivalve mollusks such as dwarf surf clam, ribbed mussel, *Geukensia demissa*, and hooked mussel, *Ischadium recurvum* (Table 3). Oyster trays, on average, caught nearly twice as many invertebrates (N = 1,235; 61.22 ± 4.99 invertebrates/tray) as mud trays (N = 635; 35.05 ± 8.21 invertebrates/tray). Decapods were approximately five times as abundant at oyster bottom (N = 1,148; 52.18 ± 4.53 decapods/tray) as at mud bottom (N = 203; 11.27 ± 2.65 decapods/tray) including large numbers of mud crabs (N = 701; 31.86 ± 3.31 crabs/tray) and grass shrimp (N = 469; 21.31 ± 2.67 crabs/tray). The dominant invertebrate in mud trays was the dwarf surf clam (N = 407; 22.6 ± 7.75 clams/tray). Due to the large numbers of dwarf surf clam burrowing into the mud, total mean abundance of bivalve mollusks was greater in mud trays (N = 428; 23.77 ± 7.98 mollusks/tray) than oyster trays (N = 87; 3.95 ± 1.21 mollusks/tray).

Based on the tray data, resident fish densities were estimated at a mean of 33.6 resident fishes m^{-2} at oyster bottom and 13.3 resident fishes m^{-2} at mud bottom (Figure 13a). Estimated means for invertebrates were 170.6 decapods m^{-2} and 29.4 bivalves m^{-2} at oyster bottom and a mean of 36.9 decapods m^{-2} and 78.1 bivalves m^{-2} at mud bottom (Figure 13b, c).

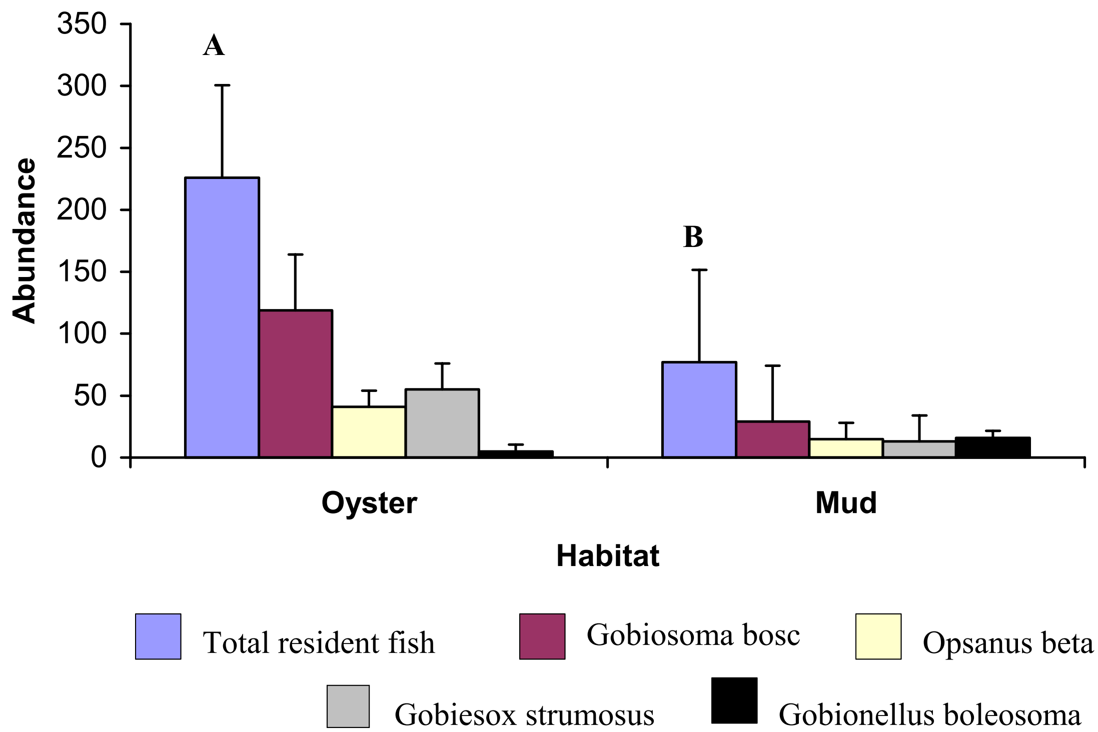

Figure 9. Abundance of total resident fish, *Gobiosoma bosc*, *Opsanus beta*, *Gobiesox strumosus*, and *Gobionellus boleosoma* collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in abundance between oyster and mud within each fish group ($p < 0.05$).

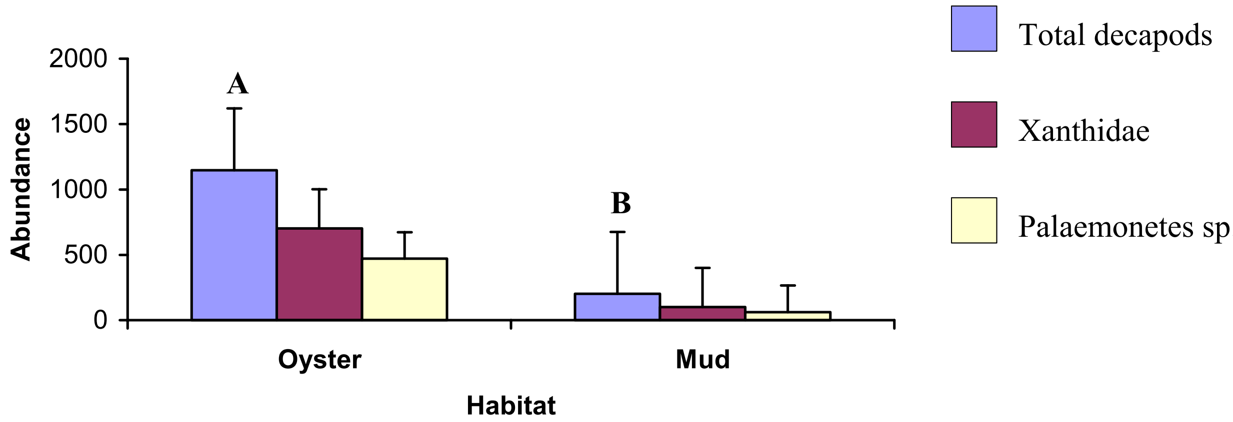

Figure 10. Abundance of total decapods, total xanthid crabs, and grass shrimp Palaemonetes sp. collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters represent significant differences in abundance between oyster and mud within each group ($p < 0.05$).

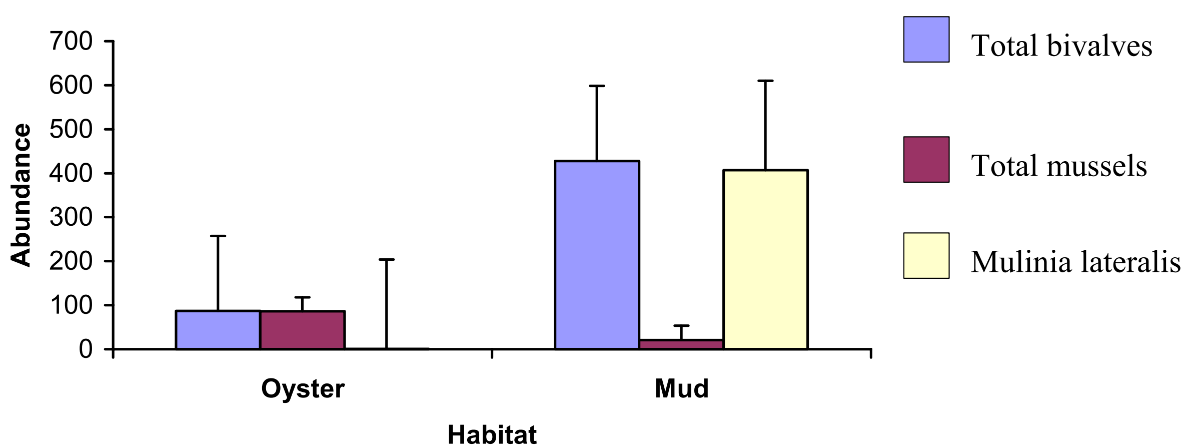

Figure 11. Abundance of total bivalves, total mussels, and *Mulinia lateralis* collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error.

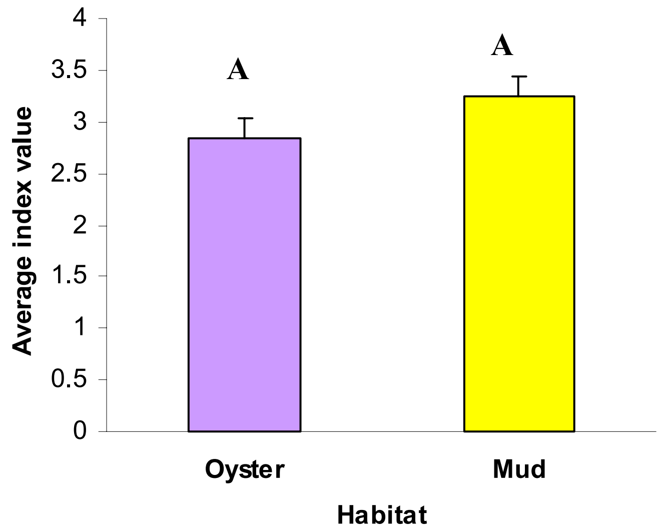

Figure 12. Mean diversity (D_s) for benthic fishes and invertebrates collected by substrate tray at oyster and mud sites between October 2001 and October 2002. Error bars represent standard error. Bars with different letters were significantly different ($p < 0.05$).

Table 2. Total number and mean number (fish/tray) ± S.E. of fish species collected with substrate trays at oyster bottom and mud bottom sites from October 2001 to October 2002.

Common Name	Scientific Name	Oyster Total	Oyster Mean	Mud Total	Mud Mean
Atlantic spadefish	*Chaetodipterus faber*	2	0.09±0.05	1	0.06±0.06
Striped blenny	*Chasmodes bosquianus*	1	0.05±0.97	-	-
Skilletfish	*Gobiesox strumosus*	55	2.5±0.44	13	0.72±0.24
Darter goby	*Gobionellus boleosoma*	5	0.23±0.15	16	0.88±0.51
Naked goby	*Gobiosoma bosc*	119	5.41±0.96	29	1.61±0.26
Crested blenny	*Hypleurochilus geminatus*	1	0.05±0.05	-	-
Feather blenny	*Hypsoblennius hentz*	2	0.09±0.06	1	0.06±0.06
Gulf toadfish	*Opsanus beta*	41	1.86±0.67	15	0.83±0.31
Mangrove snapper	*Lutjanus griseus*	-	-	1	0.06±0.06
Speckled worm eel	*Myrophis punctatus*	-	-	1	0.06±0.06
TOTAL		**226**	**10.28±1.38**	**77**	**4.28±0.54**

Table 3. List of invertebrate taxa collected in substrate trays from a- oyster and b-mud bottom sites in Barataria Bay, Louisiana, October 2001 to October 2002. Also indicated are seasonal occurrence, total abundance, mean abundance (organisms/tray) ± S.E., and length range (mm). Length is carapace length for shrimp, carapace width for crabs, and longest dimension for mollusks.

a)

Taxon	Common Name	Seasonal Occurrence	Total Abundance	Mean abundance	Length range (mm)
DECAPOD CRUSTACEANS			**1148**	**52.18±4.53**	
Palaemonetes sp.	Grass shrimp	All year	469	21.31±2.67	4-18
Alpheus sp.	Snapping shrimp	All year	37	1.68±0.46	4-19
Petrolisthes sp.	Porcelain crab	Fa, Wi	7	0.32±0.13	4-5
Callinectes sapidus	Blue crab	All year	46	2.09±0.93	6-60
Xanthidae	Mud crab	All year	701	31.86±3.31	3-30
BIVALVE MOLLUSKS			**87**	**3.95±1.21**	
Geukensia demissa	Ribbed mussel	All year	54	2.45±1.04	4-18
Ischadium recurvum	Hooked mussel	Wi	32	1.45±0.83	5-20
Mulinia lateralis	Dwarf surf clam	Su	1	0.05±0.05	6

b)

Taxon	Common Name	Seasonal Occurrence	Total Abundance	Mean abundance	Length range (mm)
DECAPOD CRUSTACEANS			**203**	**11.27±2.65**	
Palaemonetes sp.	Grass shrimp	All year	62	3.44±0.81	3-15
Alpheus sp.	Snapping shrimp	All year	15	0.83±0.36	8-16
Callinectes sapidus	Blue crab	All year	25	1.38±0.82	5-50
Xanthidae	Mud crab	All year	100	5.55±1.86	3-43
Penaeus aztecus	Brown shrimp	Sp	1	0.05±0.05	25
BIVALVE MOLLUSKS			**428**	**23.77±7.98**	
Geukensia demissa	Ribbed mussel	Wi, Su	19	1.05±0.39	2-11
Ischadium recurvum	Hooked mussel	Wi	2	0.11±0.11	2-11
Mulinia lateralis	Dwarf surf clam	Wi, Su	407	22.6±7.75	2-7

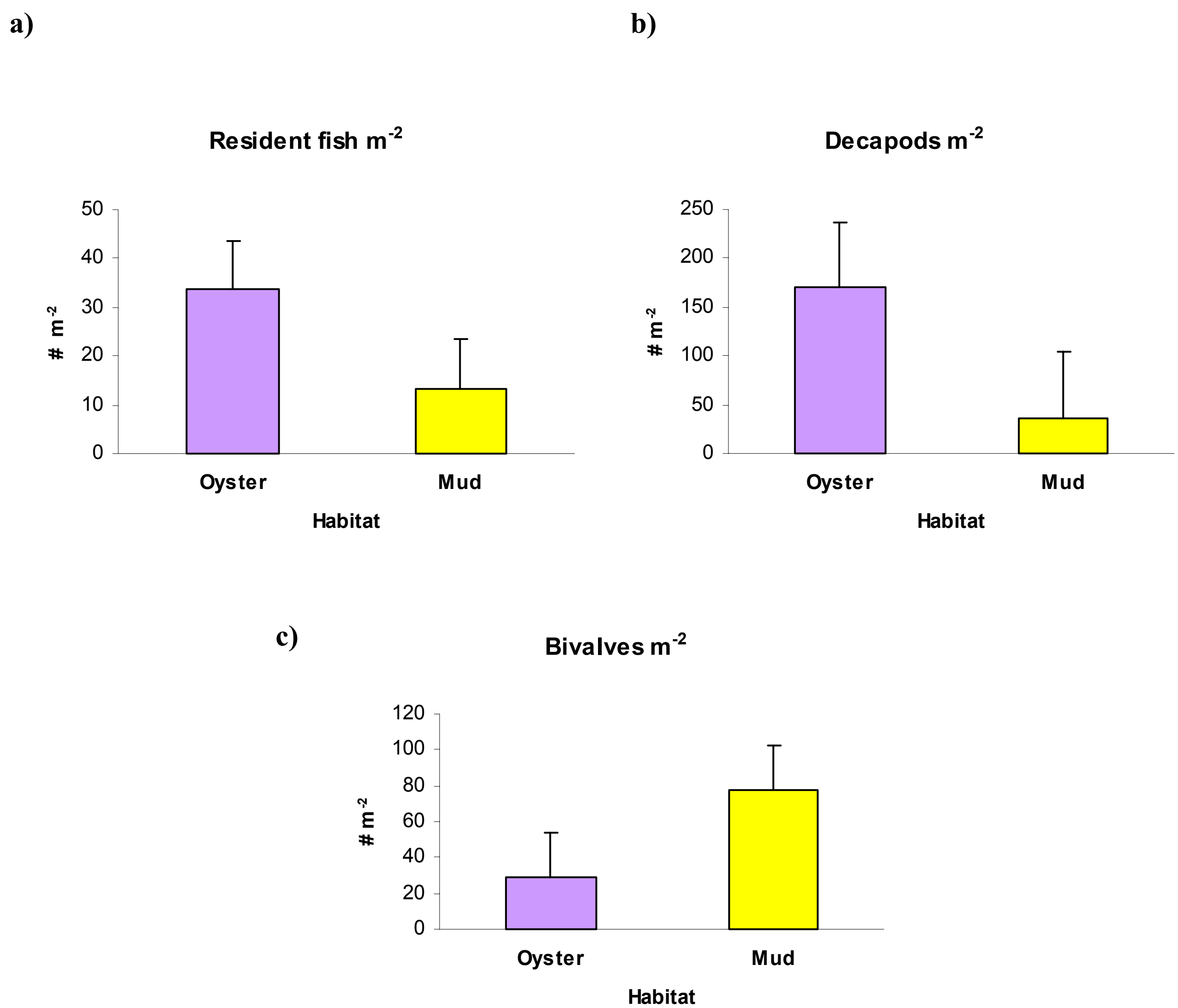

Figure 13. Estimated density (# / m^{-2}) for (a) resident fishes, (b) decapod crustaceans, and (c) bivalve mollusks at oyster and mud bottoms. Error bars represent standard error.

Similarity Percentages and Species Contribitions to Assemblage Differences

The SIMPER procedure, conducted for the entire faunal assemblage (transient fishes, resident fishes, and macroinvertebrates) at oyster and mud bottom, indicated 87.07% average dissimilarity between the two habitats. Species or faunal groups accounting for the highest percentages of the dissimilarity were mud crabs (23.34%), Gulf menhaden (15.49%), grass shrimp (15.35%), and dwarf surf clam (5.75%) (Table 4).

SIMPER also was conducted for the transient fish assemblage, indicating 71.80% average dissimilarity between the two habitats. Species accounting for the highest percentages of the dissimilarity were Gulf menhaden (40.63%), hardhead catfish (5.49%), and spot (4.17%) (Table 5).

SIMPER also was conducted for the benthic community assemblage, indicating 76.42% average dissimilarity between the two habitats. Species or faunal groups accounting for the highest percentages of the dissimilarity were mud crabs (29.21%), grass shrimp (19.45%), dwarf surf clam (7.51%), and naked goby (5.08%) (Table 6).

Results from the BVSTEP procedure (conducted on the entire faunal assemblage) suggested that 95% of the variation in assemblages between oyster and mud bottom was accounted for by 9 faunal groups: hardhead catfish, gafftopsail catfish, Gulf menhaden, sand seatrout, spot, kingfish, mud crabs, blue crabs, and grass shrimp.

Environmental Data

Neither salinity, water temperature, nor dissolved oxygen values differed significantly between sites ($p>0.05$). All parameters were significantly different between dates ($p<0.05$). During the course of the study, salinity ranged from 4.17 to 22.08 ppt, water temperature ranged from 13.74 to 28.96 °C, and dissolved oxygen ranged from

Table 4. Results of SIMPER analysis for the entire faunal assemblage at oyster and mud bottoms, showing percent contribution by species or faunal group to average dissimilarity between habitats.

Common Name	**Scientific Name**	**Average Dissimilarity (%)**
Mud crab	Family Xanthidae	23.34
Gulf menhaden	*Brevoortia patronus*	15.49
Grass shrimp	*Palaemonetes* sp.	15.35
Dwarf surf clam	*Mulinia lateralis*	5.75
Naked goby	*Gobiosoma bosc*	4.05
Ribbed mussel	*Geukensia demissa*	2.46
Blue crab	*Callinectes sapidus*	2.44
Gulf toadfish	*Opsanus beta*	2.17
Skilletfish	*Gobiesox strumosus*	2.12
Snapping shrimp	*Alpheus* sp.	1.80
Hardhead catfish	*Arius felis*	1.62
Spot	*Leistomus xanthurus*	1.33
Black drum	*Pogonias cromis*	1.09
Total Average Dissimilarity (%)		**87.07**

Table 5. Results of SIMPER analysis for transient fishes at oyster and mud bottoms, showing percent contribution by species to average dissimilarity between habitats.

Common Name	**Scientific Name**	**Average Dissimilarity (%)**
Gulf menhaden	*Brevoortia patronus*	40.63
Hardhead catfish	*Arius felis*	5.49
Spot	*Leiostomus xanthurus*	4.17
Black drum	*Pogonias cromis*	3.12
Croaker	*Micropogonias undulatus*	3.03
Kingfish	*Menticirrhus americanus*	3.01
Sand seatrout	*Cynoscion arenarius*	2.83
Spanish mackerel	*Scomberomorus maculatus*	2.56
Total Average Dissimilarity (%)		**71.80**

Table 6. Results of SIMPER analysis for resident fishes and macroinvertebrates at oyster and mud bottoms, showing percent contribution by species or faunal group to average dissimilarity between habitats.

Common Name	**Scientific Name**	**Average Dissimilarity (%)**
Mud crab	Family Xanthidae	29.21
Grass shrimp	*Palaemonetes* sp.	19.45
Dwarf surf clam	*Mulinia lateralis*	7.51
Naked goby	*Gobiosoma bosc*	5.08
Ribbed mussel	*Geukensia demissa*	2.83
Blue crab	*Callinectes sapidus*	2.72
Skilletfish	*Gobiesox strumosus*	2.34
Total Average Dissimilarity (%)		**76.42**

26.6 to 139.2 % (Figure 14). BIOENV showed little correlation between environmental parameters and CPUE ($\rho = -0.055$).

Transient Fish Diet Characterization

Overall Diet Characterization

Excluding menhaden, digestive tracts of 46 out of 66 fish captured by gill net over oyster bottom (70%) and 24 out of 32 fish captured by gill net over mud bottom (75%) contained identifiable food items. Due to mastication and digestion, many fishes and crabs recovered from guts were not identified to species level. Regurgitation of gut contents was observed in Spanish mackerel as the net was retrieved.

Percent Frequency of Occurrence

The top three prey categories by percent frequency of occurrence were mud crabs, which occurred in 36% of full guts from oyster bottom and 50% of full guts from mud bottom, teleost fishes (primarily bay anchovy and speckled worm eel), which occurred in 30% of full guts from oyster and 50% from mud, and bivalves (primarily shells of dwarf surf clam and mussels), which occurred in 32% of full guts from oyster and 13% from mud (Figure 15a).

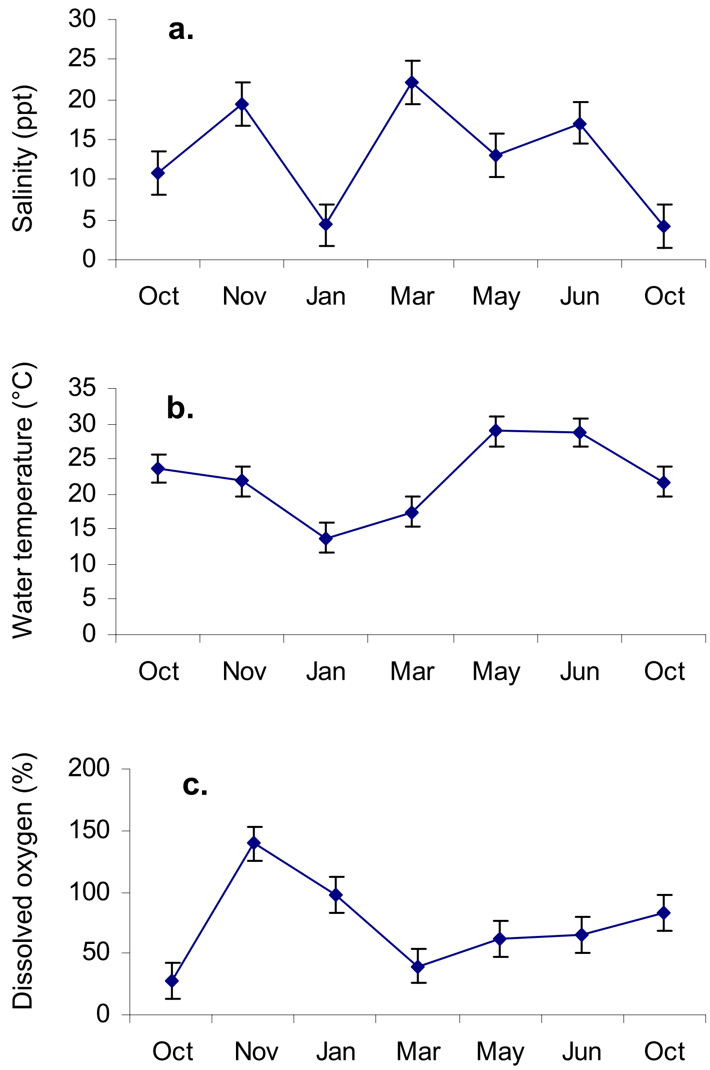

Figure 14. Mean water quality for Barataria Bay study sites from October 2001 to October 2002: (a) salinity (ppt), (b) water temperature (°C), and (c) dissolved oxygen (%) values (±S.E.).

Percent Composition by Weight

Mud crabs, teleost fishes, and bivalves also were the top three categories for percent composition by weight. Mud crabs made up 30% of diet by weight at oyster and 44% at mud. Teleost fishes made up 30% of diet by weight at oyster and 10% at mud, and bivalves made up 30% of diet by weight at oyster and 39% at mud (Figure

15b). Other relatively common prey items included blue crabs (*Callinectes* sp.) and penaeid shrimp. Infrequently occurring gut items included polychaetes, fish scales, grass shrimp, and plant material (Appendix A).

Diversity

Due to significant correlations among diversity indices, only Simpson's Index is reported. D_s values for gut contents, using presence/absence data for the top three prey categories (mud crabs, fishes, and bivalves), were not significantly different between habitats ($p > 0.05$). Mean D_s values were 1.27 ± 0.32 at oyster bottom and 1.29 ± 0.30 at mud bottom.

Diet Characterization by Species

Prey items of commonly caught transient fish species were combined into general taxonomic groups and are discussed below in terms of percent frequency of occurrence and percent composition by weight.

Hardhead Catfish

For hardhead catfish at oyster bottom (N = 8), mud crabs were the most important prey item by frequency of occurrence (75%) and by weight (58%). At mud bottom (N = 9), mud crabs were also the most important prey item by percent frequency of occurrence (67%), while blue crabs were the most important prey item by weight (33%) (Figure 16).

Gafftopsail Catfish

Fishes were the most important prey item by frequency of occurrence (100%) and by weight (53%) for gafftopsail catfish at oyster (N = 2). For gafftopsail catfish at mud bottom (N = 5), mud crabs were the most important prey item by percent frequency of occurrence (82%) and by weight (67%) (Figure 17).

Spot

Spot gut contents at oyster bottom (N = 5) included copepods, mud crabs, and dwarf surf clam; the latter item was found in all guts of spot at oyster bottom and accounted for 80% of diet by weight. Gut contents of the single feeding spot at mud bottom consisted only of dwarf surf clam (Figure 18).

Kingfish

Kingfish gut contents at oyster bottom (N = 5) included blue crabs, mud crabs, and penaeid shrimp, with mud crabs accounting for 60% of the diet by percent frequency of occurrence and percentage by weight. Gut contents of the single feeding kingfish at mud bottom consisted only of mud crabs (Figure 19).

Seatrout

Sand seatrout guts at oyster bottom (N = 3) contained fish and mud crabs, with bay anchovy occurring most frequently in the diet (67%) and making up the greatest percentage by weight (67%) (Figure 20). Gut contents of the single feeding spotted seatrout at mud bottom consisted entirely of mud crabs.

Croaker

Mud crabs comprised the majority of the diet for croaker at oyster bottom (N = 1), with 83% frequency of occurrence and 59% of the diet by weight (Figure 21); gut contents of this species also included ribbed mussel, dwarf surf clam, and plant material.

Black Drum

Black drum gut contents at oyster bottom (N = 7) included blue crabs and mud crabs, but the majority of the diet consisted of bivalves; ribbed mussel made up 30% of diet by weight and dwarf surf clam made up 41% of diet by weight. However, no identifiable oyster shell was recovered from drum guts (Figure 22).

Comparison of Transient Fish Assemblage to Louisiana Department of Wildlife and Fisheries Data

From 1986-2002, LDWF gill nets collected 8,296 finfish from 38 species at Manila Village, averaging 46 fish/month. Seven species made up 87% of the catch: Gulf menhaden (40%), spotted seatrout (16%), spot (15%), Atlantic croaker (6%), hardhead catfish (6%), striped mullet, *Mugil cephalus* (5%), and crevalle jack, *Caranx hippos* (2%). All other species each made up less than 1% of the total catch.

Gulf menhaden was the dominant species in both studies, making up a much greater percentage (74%) of my catch (for oyster and mud bottoms combined). Relative abundances of other species differed between studies and several of the abundant species (striped mullet, crevalle jack) in the LDWF data set were not present in my samples (Figure 23). Mean abundance of finfish caught by LDWF was lowest in winter months, a trend also shown in my data, and highest in September, a month during which I did not sample (Figure 24).

Comparison of Resident Fish Data to Drop Sampler Data

Drop samplers deployed by Baltz et al. at shell or partial shell substrate captured 1,231 fishes from 30 species (21.22 fish/sample). Drop samplers deployed at mud substrate captured 208 fishes from 15 species (13.0 fish/sample). As in tray results from

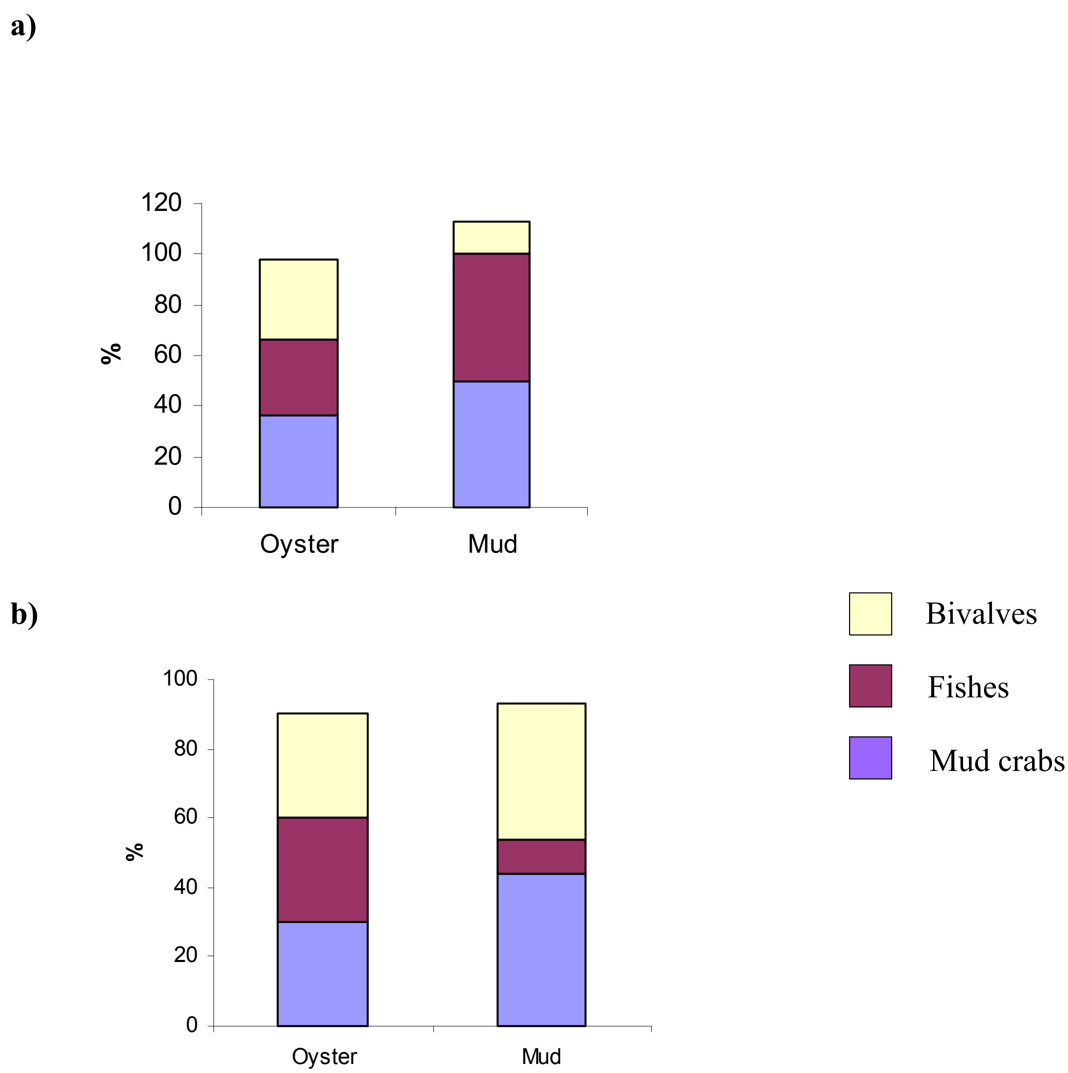

Figure 15. (a) percent frequency of occurrence, (b) percent composition by weight, for three major prey categories in guts from all fish species at oyster and mud bottom.

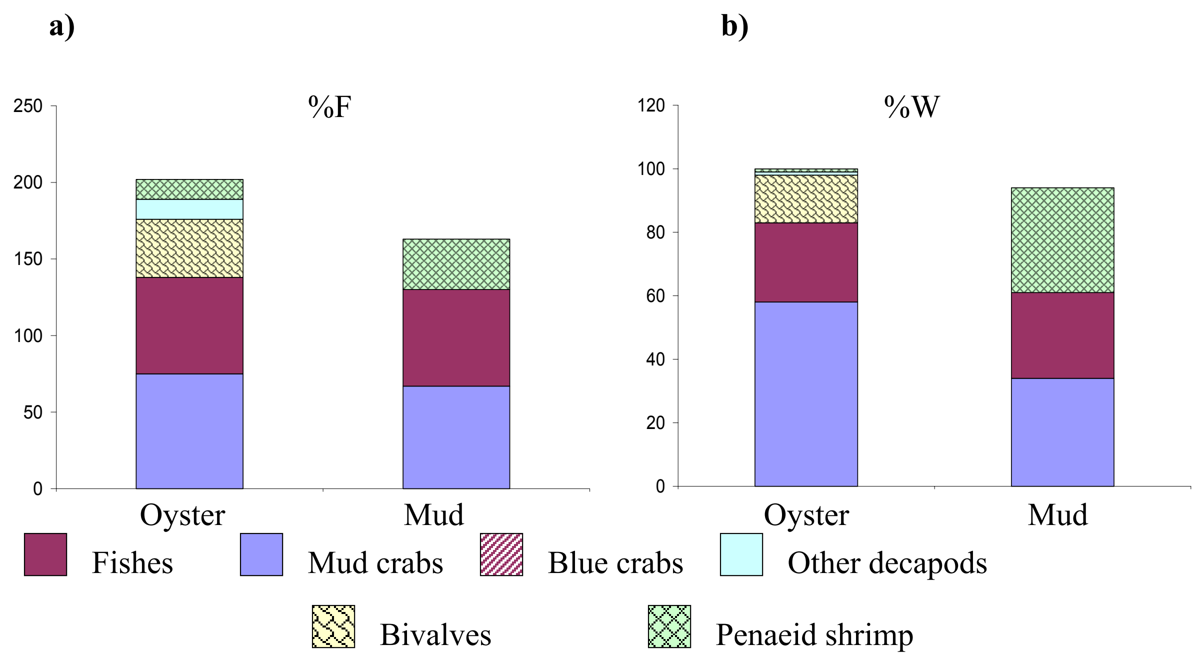

Figure 16. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of hardhead catfish, *Arius felis*, at oyster (N = 8) and mud (N = 9) bottoms.

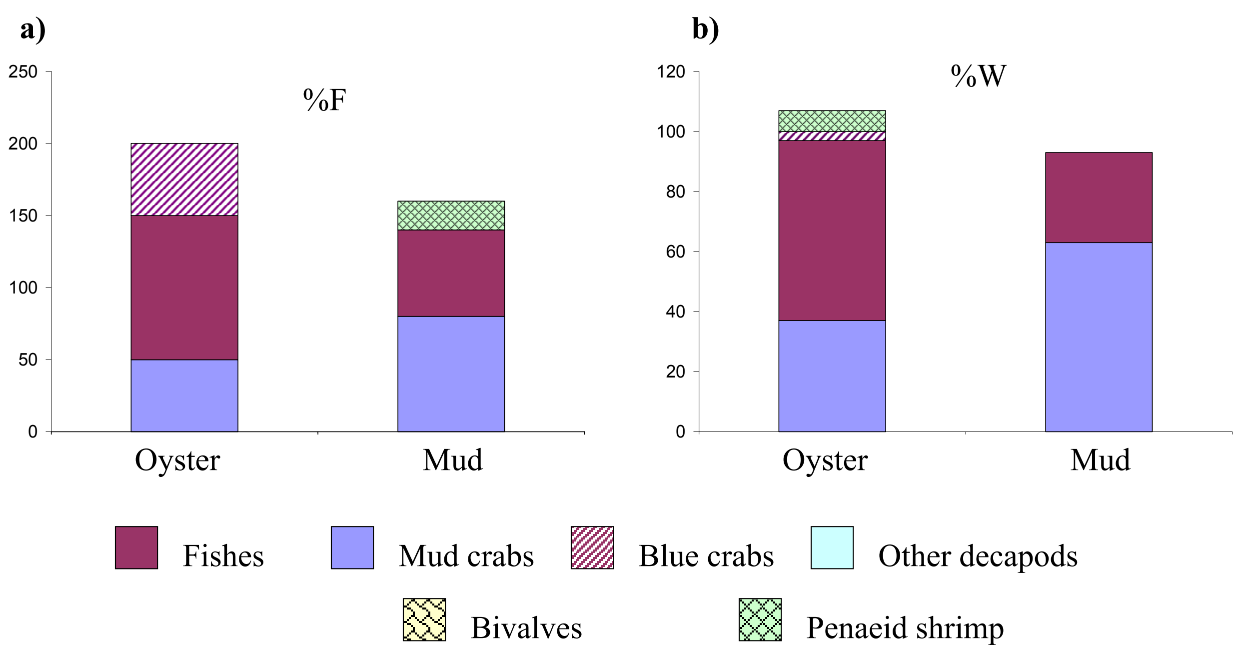

Figure 17. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of gafftopsail catfish, *Bagre marinus*, at oyster (N = 2) and mud (N = 5) bottoms.

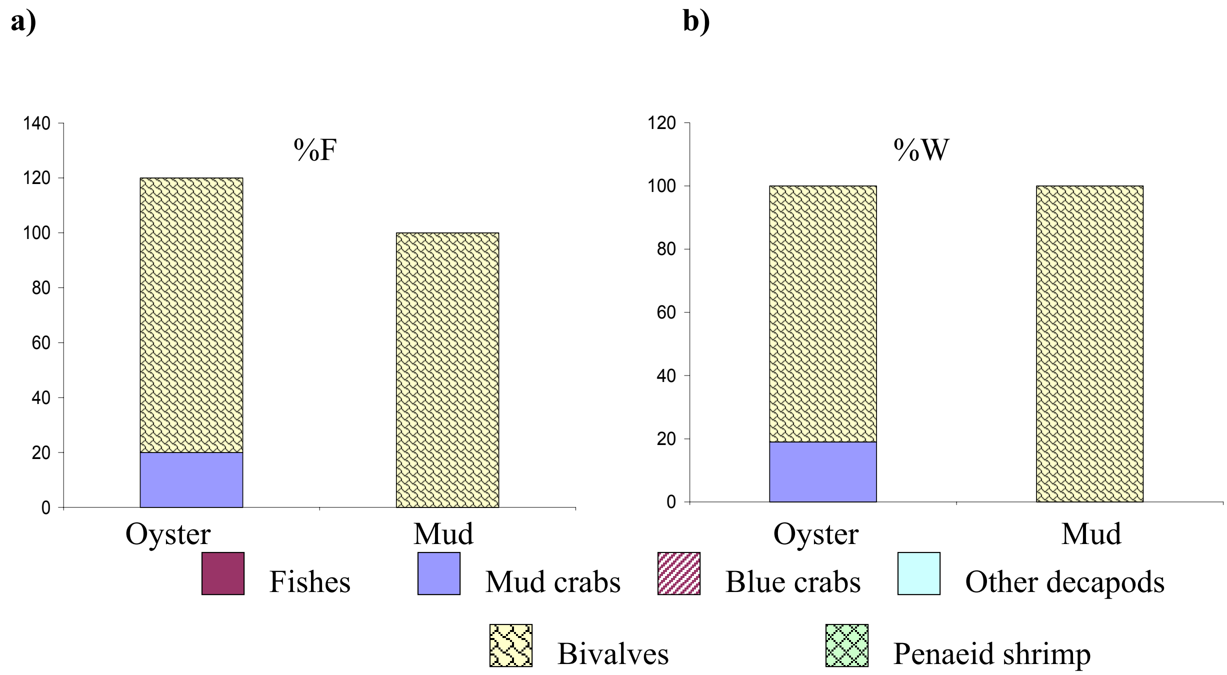

Figure 18. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of spot, *Leiostomus xanthurus*, at oyster (N = 5) and mud (N = 1) bottoms.

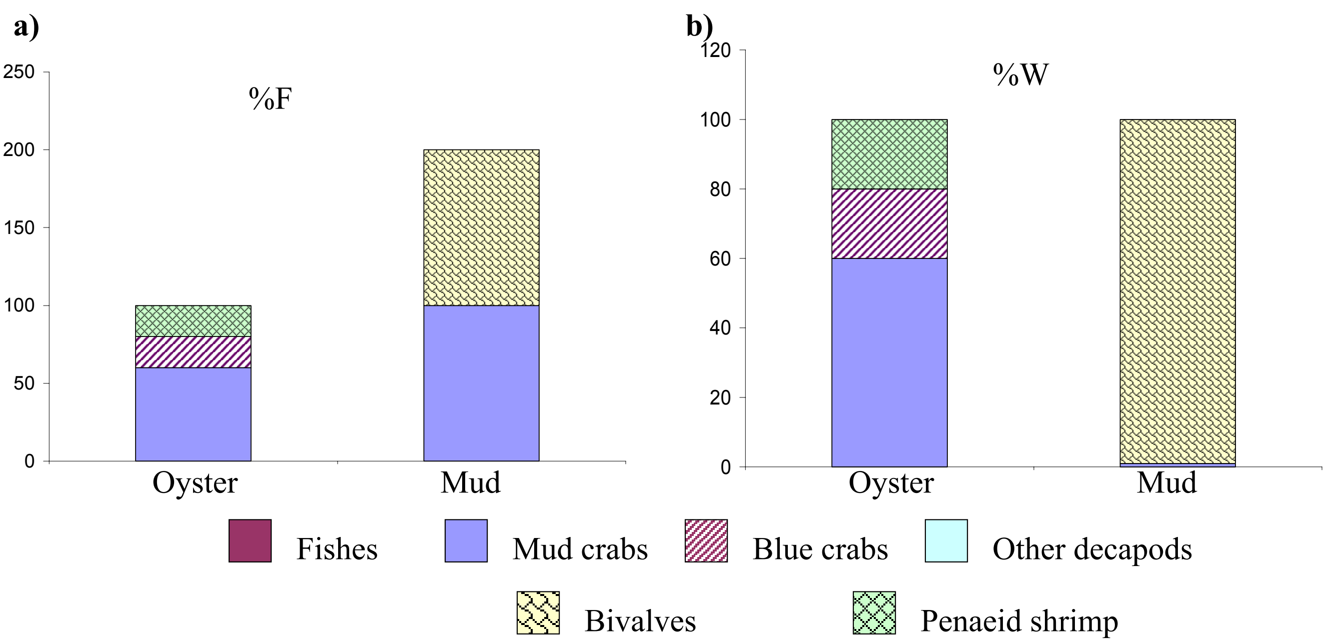

Figure 19. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of kingfish, *Menticirrhus americanus*, at oyster (N = 5) and mud (N = 1) bottoms.

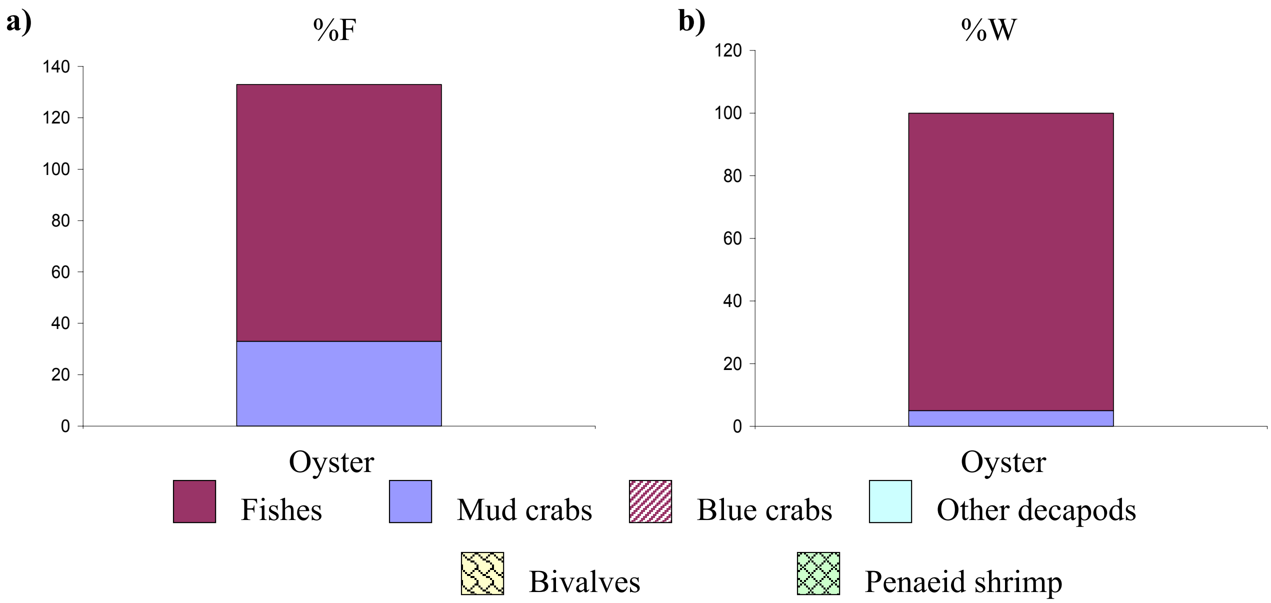

Figure 20. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of sand seatrout, *Cynoscion arenarius*, at oyster bottoms (N = 3).

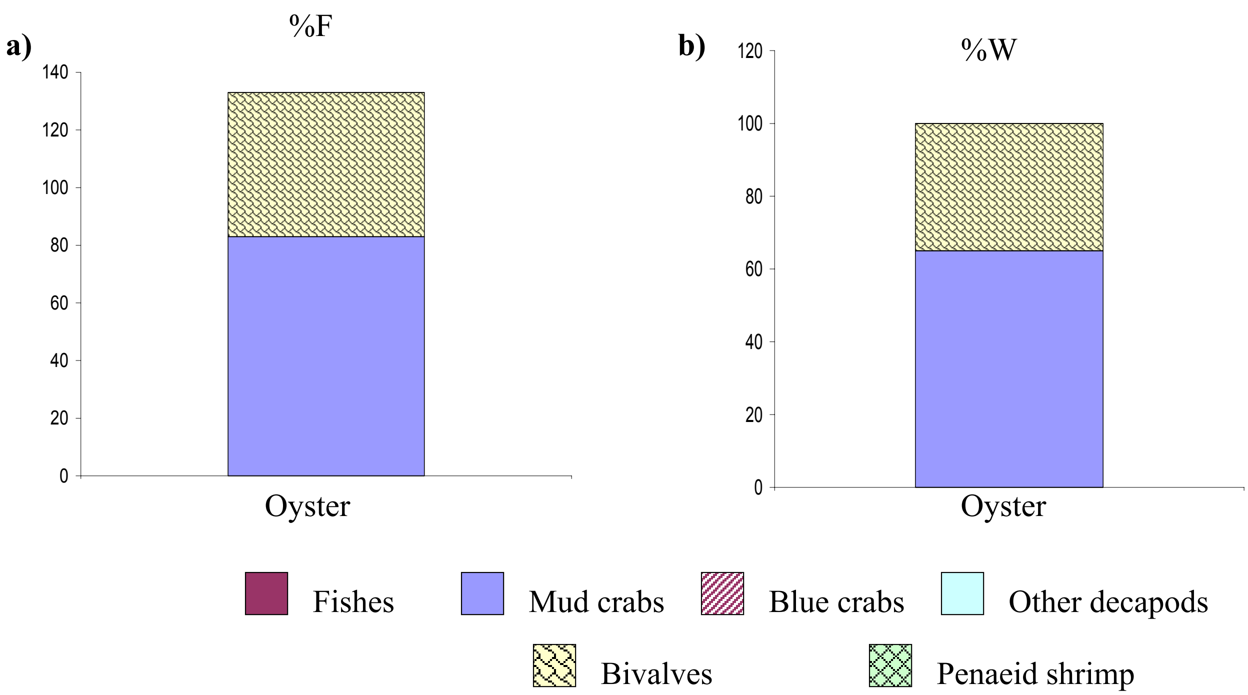

Figure 21. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from a single gut of Atlantic croaker, *Micropogonias undulatus*, at oyster bottoms (N = 1).

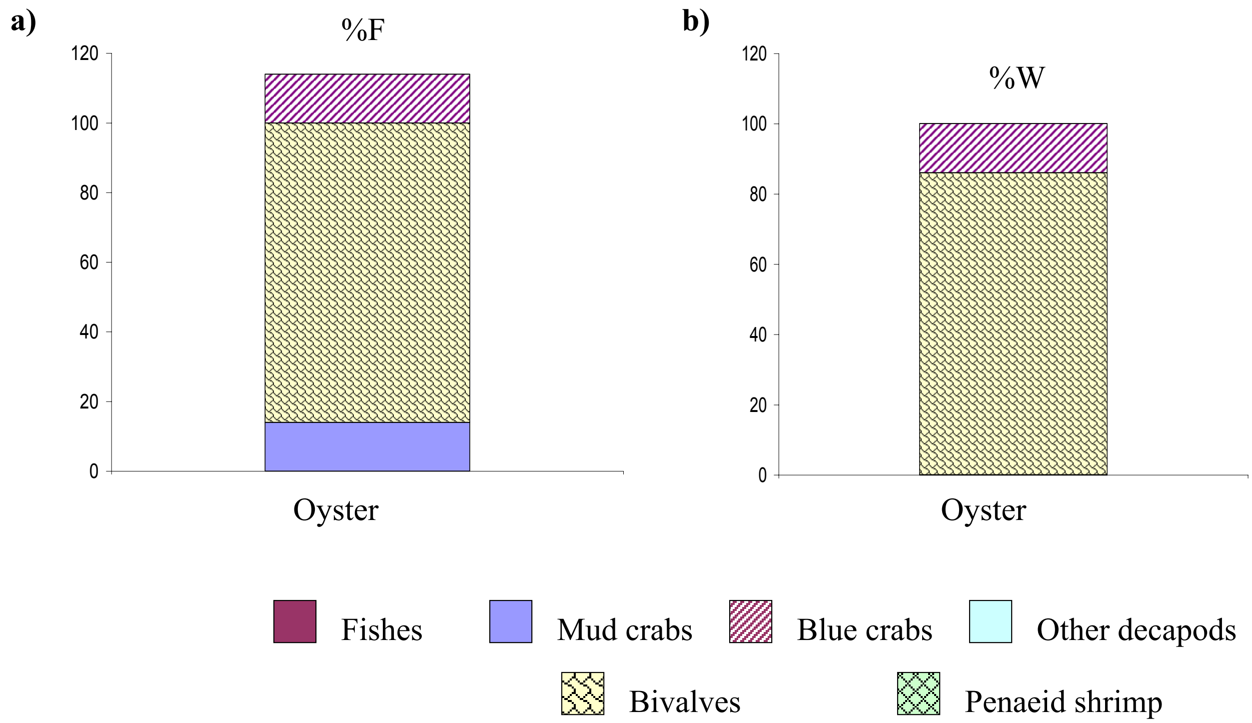

Figure 22. (a) Percent frequency of occurrence (%F) and (b) percent composition by dry weight (%W) of major prey categories from guts of black drum, *Pogonias cromis*, at oyster bottoms (N = 7).

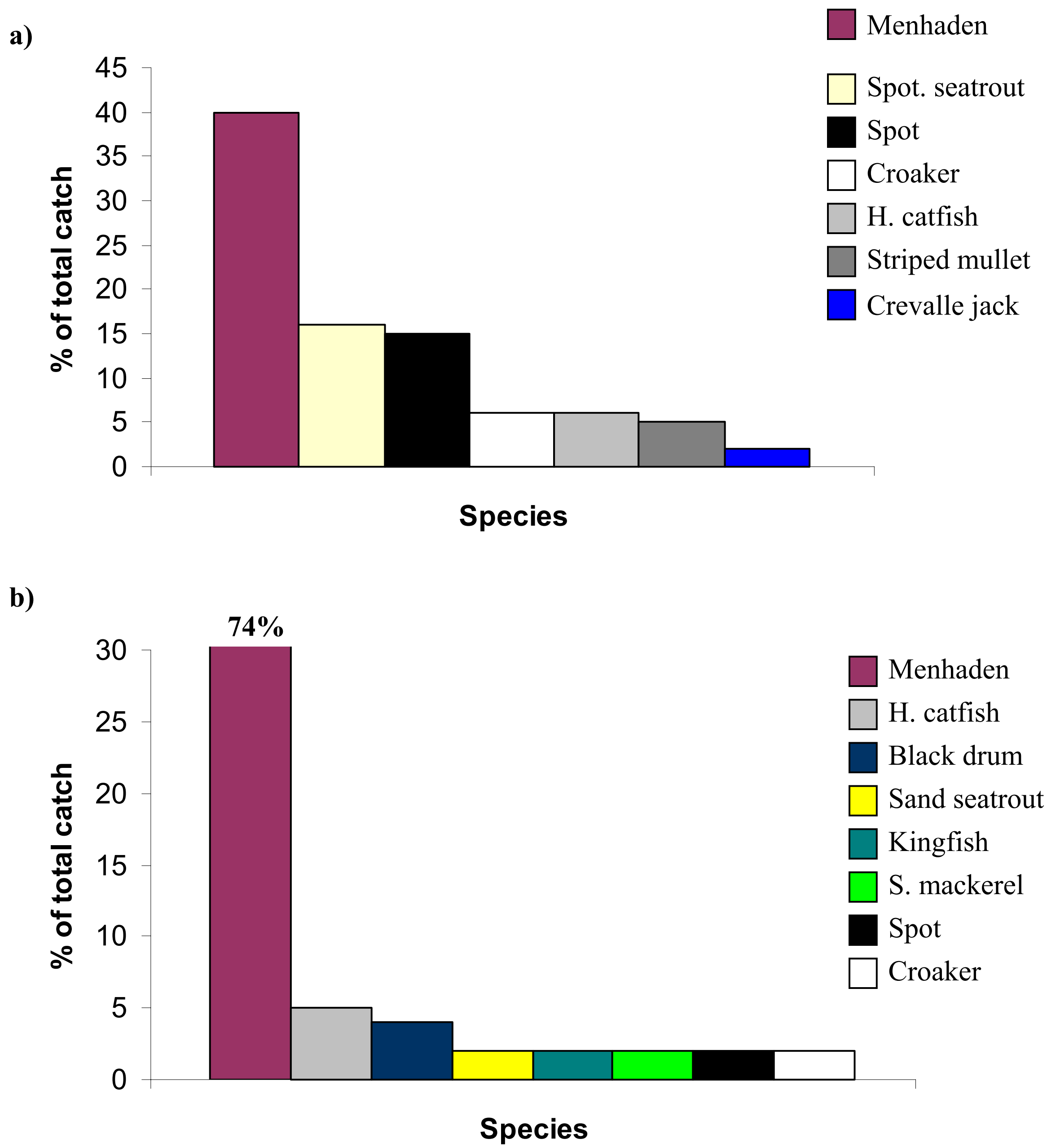

Figure 23. Comparison of relative abundance of common finfish species from (a) LDWF surveys at Manila Village and (b) the present study (oyster and mud habitat combined).

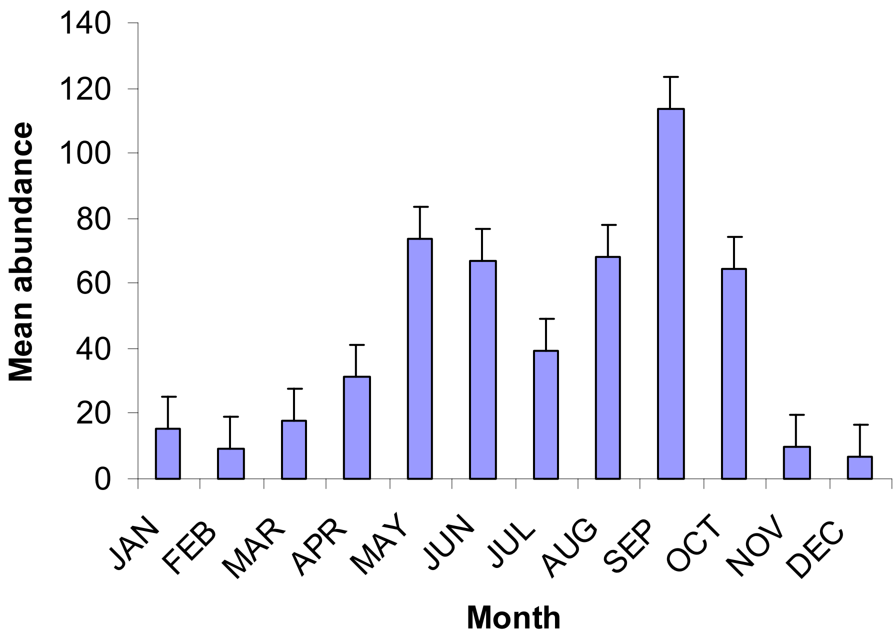

Figure 24. Mean monthly abundance of finfish collected by LDWF at Manila Village from 1986-2002. Error bars represent standard error.

my study, naked goby was the most abundant species at shell (N = 597; 10.3 fish/sample; 48% of total shell catch) and at mud bottom (N = 77; 4.8 fish/sample; 37% of total mud catch).At shell, other common species caught by drop samplers were Gulf menhaden (N = 167; 2.9 fish/sample; 14% of total shell catch), skilletfish (N = 129; 2.2 fish/sample; 10% of total shell catch), and darter goby (N = 126; 2.2 fish/sample; 10% of total shell catch). At mud, other common species were darter goby (N = 54; 3.4 fish/sample; 26% of total mud catch) and inland silverside (N = 42; 2.6 fish/sample; 20% of mud catch).

DISCUSSION

Past studies of oyster reefs indicate that, in addition to resident fishes and invertebrates, reefs attract numerous transient fish species (e.g. Coen et al. 1999, Harding and Mann 1999, Harding and Mann 2001, Lenihan and Peterson 1998, Lenihan et al. 2001, Wenner et al. 1996, Zimmerman et al. 1989). Transients often are assumed to congregate at oyster reefs due to the refuge or forage function provided, although direct support for these assumptions is scarce. The three-dimensional structure of oyster reefs has been considered a key feature in the value of reefs as habitat (e.g. Bartol et al. 1999). However, in estuaries along the northern Gulf of Mexico, the majority of oyster habitat consists of cultched subtidal beds lacking the three-dimensional structure of large oyster reefs. To my knowledge, no studies have examined the value of these cultched shell areas to transient fishes. This study compared transient fish use and feeding habits, as well as resident fish and macroinvertebrate assemblages, at mud and cultched shell bottoms. Results show that cultched oyster bottoms host significantly greater numbers of resident fishes and macroinvertebrates, and attract greater numbers and more species of transient fishes, comparable in terms of species richness to three-dimensional oyster reefs.

Study Limitations: Small Sample Sizes and Gear Issues

Small Sample Sizes

Given the small numbers of transient fishes in this study (excluding menhaden, 66 transients were caught at oyster bottom and 32 were caught at mud bottom), it is difficult to make conclusive statements regarding habitat preference or prey selection for individual finfish species. Meaningful comparisons of habitat use are impossible for virtually all the individual transient species caught in this study.

Gill Net Sampling- Suggestions for Improvement

Transient fish numbers and species diversity would probably have increased had I used a longer gill net with a wider range of mesh sizes and sampled nocturnally or during crepuscular periods, since many species exhibit activity peaks (e.g. feeding) at these times (Nielsen and Johnson 1983). Intensive sampling, e.g. running two hour sets for a period of 24 hours or more, would also have contributed to a larger data set, but was logistically impossible for this study.

Substrate Tray Sampling- Possible Biases and Suggestions for Improvement

Collection of tray contents was erratic; only 22 oyster and 18 mud trays were collected intact over the course of the study. Substrate, particularly mud, was frequently washed away between sampling sessions, and trays themselves often were overturned by rough weather or simply vanished in the interim, along with the site marker poles to which they were attached. A more sheltered study site would have improved results. Previous studies using substrate trays have taken place in intertidal areas (Coen et al. 1999), tidal creeks protected from wave energy (Lehnert and Allen 2002) or involved divers burying the trays flush with the bottom (Lenihan et al. 2001). Burying trays flush with the bottom might also have eliminated any bias from fish or invertebrate attraction to the structure of the trays themselves, although Lehnert and Allen (2002) found such attraction to be minimal.

I have previously mentioned difficulties in sampling oyster reefs and in selecting a sampling gear which performs well at multiple habitats. A particular issue which may bias tray results is the possibility of differential retention of motile fauna in mud and oyster trays during tray retrieval. It is likely that trays containing shell allow water to flow through them, while trays lined with mud do not, causing fauna to be washed off as mud trays are raised. Additionally, it is possible that motile fauna are more prone to remain sheltered under shell during tray retrieval, but actively depart mud trays. Tray design could be improved by adding a pop net around tray frames to prevent escape of motile fauna.

Transient Fish Assemblages

Cultched oyster shell bottom was utilized by a more abundant and diverse assemblage of transient fishes than mud bottom, the majority of which are of commercial or recreational value (Appendix B). Transient fishes on both bottom types consisted of pelagic species such as Gulf menhaden and Spanish mackerel and bottom-oriented species such as catfishes and sciaenids. Many of these species are generalist predators, which feed on a variety of prey items (Day et al. 1989). These fish may be attracted to oyster bottom due to high abundances of prey such as crabs, shrimp, and resident fishes.

Black drum were the most common sciaenid at oyster bottom. While adults of this species are found over a range of bottom types, including sand, mud, and oyster shell, black drum prey primarily on oysters and other bivalves (Sutter et al. 1986), and this is one possible reason for their greater abundance at oyster bottom.

Spot and croaker were more abundant at oyster bottom. These species are opportunistic bottom feeders (Chao and Musick 1977, Miller and Dunn 1980). Spot have been found over various habitats (Lassuy 1983c, Stickney and Cuenco 1982), but prefer muddy sediments where they feed on benthic fauna (Darnell 1958). Croaker also feed on benthic fauna in soft muddy bottom (Diaz and Onuf 1985) and are primarily found at this habitat. Given established habitat preferences of these species, the greater numbers at oyster bottom may seem counterintuitive, but are probably not meaningful considering the small sample size.

Sand seatrout were found only at oyster bottom. This species preys primarily on fish and crustaceans, and is found over a variety of substrates (Sutter and McIlwain 1987). Spotted seatrout were found in equal numbers at oyster and mud bottom. This species has been described as an opportunistic carnivore, and has been associated with structured habitat such as oyster reefs, seagrass beds, and marsh edge (Lassuy 1983b).

Gulf menhaden, one of the most abundant species in Barataria Bay (Conner and Day 1987) had the highest relative abundance at both bottom types. Menhaden are most often found over mud bottoms, but as filter-feeders substrate type is probably unimportant for this species (Lassuy 1983a). Hardhead and gafftopsail catfish were common at both bottom types; both species are opportunistic bottom feeders over mud and sand bottoms with high organic content (Muncy and Wingo 1983).

Studies of species richness on oyster reefs, using a variety of sampling methods, have found 10-30 transient fish species (Coen et al. 1999, Harding and Mann 1999, Harding and Mann 2001, Lenihan and Peterson 1998, Lenihan et al. 2001, Wenner et al. 1996, Zimmerman et al. 1989). I found 16 transient species at oyster bottom, indicating that cultched shell bottom supports a species richness similar to that supported by three-dimensional oyster reefs. However, when comparing these results to published studies of oyster reefs and shell bottoms, it is important to note the wide range of sampling gear types, geographical locations, and reef characteristics involved. For example, many studies have focused on intertidal reefs; the only published quantitative survey of oyster reef fauna in the Gulf of Mexico (Zimmerman et al. 1989) was conducted on an intertidal reef using drop samplers which captured few large transients. Other studies using gill nets at subtidal reefs (e.g. Harding and Mann 2001) sampled much more intensively and may have captured more species as a result.

Fish assemblages were relatively dissimilar between oyster and mud bottom (SIMPER, Sorenson's Community Similarity Index). On average, transient fish species richness, evenness, and diversity were higher at oyster bottom. These results indicate that cultched oyster bottom attracts a different, more diverse transient fish community than mud bottom. In terms of transient species richness, oyster bottoms are comparable to oyster reefs.

Comparison of Transient Fish Assemblage to Louisiana Department of Wildlife and Fisheries Data

The long-term LDWF data set provides a representation of seasonality and relative abundance of the finfish assemblage at Manila Village, with the exception of small species unlikely to be caught by gill nets. The high number of transient species caught by LDWF (N = 38) in comparison to my study (N = 18) is likely due to their greater sampling effort. Sampling by LDWF caught an average of 46 fish/month and the current study caught an average of 59 fish/month. However, differences between sampling methods should be noted when comparing the LDWF data set to my catch data. Unfortunately, LDWF sampling is not habitat specific. Nets used in the LDWF surveys are approximately 200 m longer than my nets. Rather than 2 h stationary sets, the LDWF method involves a quick set and active 'herding' of fish. These differences make in-depth comparisions difficult.

Transient Fish Diet Characterization

Transient fishes are generally assumed to occur in greater numbers at oyster reefs due to the abundant supply of prey items at this habitat, which include resident fishes, decapod crustaceans, polychaetes, and a wide variety of sessile organisms. Few differences in gut contents at oyster and mud bottom were detected in this study. For all transient species combined, mud crabs, fishes, and bivalves were the most important prey categories on mud and oyster bottoms by frequency of occurrence and by weight. Fish and mud crabs occurred more frequently in guts from mud bottoms. This seems counterintuitive if fish were foraging only at the habitat over which they were captured, since mud crabs were more abundant at oyster bottoms. However, mud crabs may have been more accessible at mud bottoms. The similarity in diversity of major prey categories from transient guts at oyster and mud bottom is unsurprising, since diversity of potential prey captured in substrate trays was also similar between habitats.

Most estuarine fish species are not specialist feeders, but consume a wide variety of prey items; diet may change depending on life history stage and the abundance or availability of food (Day et al. 1989). Feeding habits of individual species were generally similar to findings from previously published information. Surprisingly, although black drum is a known oyster predator (Sutter et al. 1986), and drum associated with oyster reefs prey preferentially on oysters (Cave and Cake 1980), no identifiable oyster shell was present in guts recovered from the oyster lease. Instead, this species ate large amounts (up to 40 g/gut) of small bivalves such as dwarf surf clam and ribbed mussel. Grass shrimp were abundant at oyster habitat but rare in the guts of any species. Grass shrimp are a common diet item for many of the transients caught (Anderson 1985, Overstreet and Heard 1982). Posey et al. (1999) found that, in mesocosms, grass shrimp sought refuge among oysters rather than seagrass or shallow water. Transient fish may have preferentially selected other prey items over grass shrimp or the shrimp may have been relatively inaccessible compared to mud crabs and other prey items.

Resident fishes associated with oyster habitat have been documented as prey for transient fish in some studies (Breitburg 1999, Harding and Mann 2001a) but not in others (Lenihan et al. 2001). I found no evidence of predation on these species. All identifiable fish present in guts at both habitats were either bay anchovy (the majority) or speckled worm eel, suggesting that resident fishes may not be a particularly important prey category for the transient species sampled. Alternatively, resident fishes may have been relatively inaccessible in comparison to bay anchovy. The sampling gear used did not target small pelagic species such as bay anchovy, so their relative numbers over oyster and mud bottom are unknown. While this species is not generally characterized as displaying a habitat preference (Norton 1989), Minello (1999) noted a greater mean density of anchovy at oyster reefs than other estuarine habitats and Coen et al. (1999) suggested that anchovy may congregate at oyster reefs due to their function as refuge from predators. However, the low profile of the cultched beds in comparison to natural oyster reefs probably makes them unimportant as refuge for anchovy or other pelagic, transient fishes.

One important consideration when comparing transient fish predation between structured and unstructured habitats is the issue of prey accessibility. Mud bottom provides little refuge for prey species, and this may lead to a higher degree of predation by transient fishes at mud than at structured habitats such as oyster bottom (Zimmerman et al. 1999). Whether the refuge provided to prey at oyster bottom interferes with transient fish feeding on benthic fauna such as mud crabs and grass shrimp or the vastly greater prey densities at oyster bottom counteract any such effect is an unresolved question. Habitat structural complexity can reduce predatory efficiency by reducing prey capture rates (Crowder and Cooper 1982). Several studies have shown that SAV reduces fish predation on crabs, shrimp, and amphipods (Minello and Zimmerman 1983, Stoner 1982, Heck and Thoman 1981, Rozas and Odum 1988), but little research exists on the role of oyster habitat complexity in fish-prey interactions. Stunz and Minello (2001) showed that, in the laboratory, predation on juvenile red drum was reduced at structured habitats, including oyster reefs; to my knowledge, there have been no studies of predation rates on invertebrate prey at oyster reefs.

The general assumption in studies of oyster reefs is that transient fishes are attracted due to the increased abundance of prey (Coen et al. 1999). This seems intuitive, but studies directly testing trophic linkages from oyster habitat residents to transient predators are rare. Only one study (Harding and Mann 2001a) has compared gut contents of a fish species (bluefish) at oyster reefs and unstructured (sand) bottom, finding that fish caught at oyster reefs consumed a wider diversity of prey items. However, Harding and Mann (2001a) found no significant difference in numbers of prey consumed between habitats. My data show that decapod crustaceans, a major prey category for many fishes, were significantly more abundant at oyster bottom. Transient fishes were generally more abundant, and many of the species present have been documented to feed on decapod crustaceans (Darnell 1958, Lassuy 1983b, Lassuy 1983c, Muncy and Wingo 1983, Overstreet and Heard 1982, Sutter et al. 1986, Sutter and McIlwain 1987). Guts from all

6 sciaenid species feeding at oyster bottom contained xanthid crabs, and 2 of 3 sciaenid species feeding at mud bottom ate xanthid crabs. It appears that cultched oyster bottom may be preferred habitat for some fishes due to increased abundance of decapod prey.

Benthic Fish and Macroinvertebrate Abundance and Diversity

Benthic Fishes

Benthic fishes collected from both bottom types were primarily species which are often characterized as oyster reef residents, such as naked goby, Gulf toadfish, and skilletfish (Kilgen and Dugas 1989). However, these species were nearly three times more abundant on oyster bottom. These results suggest that, for these fishes, cultched oyster bottom provides habitat that may be similar to oyster reefs despite the lack of vertical relief. Shell habitat provides shelter, food, or spawning substrate for these species (Harding and Mann 2000). Skilletfish use empty oyster shells for shelter and spawning (Runyan 1962). Gobies, blennies, and toadfish attach their eggs to oyster shells. Oyster toadfish feed primarily on mud crabs and grass shrimp (Wilson et al. 1982) which were abundant at cultched shell bottom. Gobies and blennies graze on infaunal and epibenthic invertebrates and in turn are prey items for transient fish (Harding and Mann 1999).

My density estimates of benthic fishes at cultched oyster bottom are similar to estimates made by Zimmerman et al. (1989), using drop samplers at an intertidal oyster reef in Texas. Zimmerman et al. found a mean of 34.0 fish m^{-2} (14 species) at intertidal oyster reefs. However, it may be difficult to make a direct comparison between the two studies due to differences in sampling gear (substrate trays are unlikely to catch fast-moving pelagic species found in drop samplers such as bay anchovy, *Anchoa mitchilli*).

Lehnert and Allen (2002) found a mean of only 5.7 fish m^{-2} in substrate trays set at subtidal shell rubble in South Carolina. Shorter tray deployment times (1 to 25 d) may have contributed to this lesser density estimate.

Benthic Macroinvertebrates

Taxonomic diversity was similar between habitat types. However, benthic macroinvertebrates were nearly twice as abundant at oyster bottoms due to large numbers of mud crabs and grass shrimp. Mud crabs preferentially associate with shell substrate (Day and Lawton 1988), prey on small bivalves (Dame and Patten 1981) and, along with grass shrimp (Perry et al. 2001, Thorp and Hoss 1976), are common oyster reef residents (Coen et al. 1999). These invertebrates have been documented as food for resident fishes such as oyster toadfish (Wilson et al. 1982) and transient fishes such as spotted seatrout (Lassuy 1983a) and croaker (Lassuy 1983b), and mud crabs were one of the most common prey categories in this study.

Bivalves were an important prey item for transient fishes caught at oyster and mud bottom. Mussels were more abundant at oyster bottom, recruiting from the water column onto the structure provided by shell. While mussels are a potential problem for living oysters in terms of competition for food and space (Stanley and Sellers 1986), they are also a source of food for blue crabs and mud crabs (Stiven and Gardner 1992) as well as fishes. The dwarf surf clam was present in large numbers at mud bottoms but virtually absent at oyster bottoms. This is an abundant species in mud bottoms of Gulf of Mexico estuaries (Armstrong 1987), and has been documented as an important diet item for black drum and other fishes (Sutter et al. 1986).

Zimmerman et al. (1989) found a mean of 105 decapod crustaceans m^{-2} (8 species) at intertidal oyster reefs in Texas. My density estimate for subtidal, cultched oyster bottom is higher than this estimate for a natural oyster reef. These numbers can be compared despite the difference in sampling gears since gear avoidance is not an issue with slow-moving invertebrates. The taxa I collected were similar to taxa found by Zimmerman et al (1989), with mud crabs dominating the catch.

Conclusions – Benthic Fishes and Macroinvertebrates

While taxonomic diversity was similar between the two habitats, cultched oyster bottom supports a greater abundance of benthic fish, decapods, and mussels than subtidal mud bottom, and is equivalent to oyster reefs in terms of resident fish species present. Although shell bottom may not be "essential" for these benthic fish and invertebrates, it does host greater numbers of individuals for the majority of species on which this study focused, many of which are an important source of food for a diverse group of fishes.

Comparison of Resident Fish Data to Drop Sampler Data

Drop sampler data was similar to some of my findings. In both studies, CPUE was higher at oyster bottom. Naked goby was the most abundant resident fish at shell and mud bottoms. Darter goby made up a larger proportion of the catch at mud bottom than oyster. However, differences in sampling technique should be considered when comparing the two studies. Comparisons of species diversity between the two studies cannot be made since drop samplers captured numerous pelagic species not likely to be captured by substrate trays.

Cultched Oyster Bottoms as EFH

Can cultched oyster bottoms be termed EFH? As noted by a number of authors (e.g. Harding and Mann 2001b), the definition of EFH invites criticism as unrealistic. Oyster bottoms are important habitat for resident fishes and decapod crustaceans, as evidenced by their vastly greater numbers in comparison with mud bottoms. Many of the transient fish species caught in this study are generalists, preying on a broad spectrum of food items (Gerking 1994). These species are not limited to a certain habitat, but display trophic adaptability, taking advantage of whatever prey are available. The prey items consumed by these species vary considerably both spatially and temporally (Day et al. 1989). The abundant decapod fauna of cultched oyster bottoms probably makes these areas important foraging sites for transient species. However, the same decapod fauna are available, albeit in lesser numbers, at adjacent mud bottoms and other estuarine habitats (Minello 1999). Therefore, oyster bottoms may be termed important, but not essential, in supporting transient fish species. This is not to say that mud bottoms are unimportant; dwarf surf clams were found in abundance at mud bottoms and in gut contents of many species. This prey species is common at mud bottoms in the Gulf of Mexico (Armstrong 1987) but has not been reported at oyster beds in Barataria Bay (Conner and Day 1987).

Although there are relatively few studies comparing nekton densities among habitats, other estuarine habitats such as SAV (Minello 1999) and marsh edge (Baltz et al. 1993) have been shown to be used extensively by many species. Bushek et al. (2001) found that the removal of oyster reefs from tidal creeks in South Carolina did not significantly change nekton utilization. It is likely that all estuarine habitats are important for some fish species at some stage of life history, and it may be that the entire suite of estuarine habitat types (cultched oyster bottom, mud bottom, marsh edge, etc) is utilized by the majority of transient fish species.

Conclusions

This study has produced evidence that cultched oyster shell hosts greater abundances of some transient fishes, resident fishes and decapod crustaceans, and that cultched shell bottoms are similar to three-dimensional oyster reefs in terms of species richness and benthic community composition. It is generally assumed, but rarely directly supported, that transient fishes are attracted to shell habitat because of high prey abundance and availability. This study shows that decapods and mussels, potential prey for transient fishes, are much more abundant at oyster than mud bottoms.

Due to the small sample size of this study, it is difficult to conclusively show differences in abundance or diversity of prey in guts from oyster and mud bottom. It can be stated, due to the much higher abundance of decapod crustaceans at oyster bottom, that this habitat is a potentially significant area of trophic exchange.

These results suggest that the large amounts of shell cultch deposited in Louisiana estuaries for oyster production plays a secondary role as habitat for a variety of fish and invertebrates, in a sense acting as artificial "reefs" despite a lack of vertical relief. This has important implications for restoration and/or enhancement efforts spurred by the degradation of estuarine habitat. By providing an abundant food source for gamefish, cultched oyster bottoms may enhance the value of recreational fisheries (a $200 million yr^{-1} industry in Louisiana) and play a role in supporting other members of the estuarine ecosystem. As is the case with true artificial reefs, whether this habitat actually increases fish production by increasing habitat or simply attracts fish from elsewhere is a matter of debate (Grossman et al. 1997).

Suggestions for Future Research

For a more comprehensive evaluation of transient fish assemblage differences at cultched and mud bottoms, a larger data set is necessary. To determine if the abundant decapod fauna at cultched oyster bottoms is readily available to transient fishes, further predation experiments are necessary. With a larger data set, differences in the abundance and diversity of prey items between cultched oyster and mud bottoms can be evaluated. Mesocosm experiments could elucidate differences in prey growth and survival, as well as predator success, at the two habitats.

I have made comparisons between transient fish, resident fish, and invertebrate abundance and diversity data from this study and studies of oyster reefs; it would be useful to make a direct comparison in a Gulf of Mexico estuary between relatively flat, cultched shell bottoms and true oyster reefs with greater heterogeneity and vertical relief. Louisiana's inshore artificial reef program has created reefs with oyster shell, crushed limestone, or crushed concrete, which are likely to be colonized by oysters over time. A comparison of these habitat types and other structured estuarine habitat (e.g. marsh edge) in terms of faunal abundance and diversity, trophic connections among faunal groups, function as refuge for prey species, and importance of structural characteristics (structural complexity, vertical relief, size, and perimeter/area ratio) could prove instructive in defining the relative value of the habitats for estuarine species.

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APPENDIX A. GUT CONTENTS

Gut contents of fish collected by gill net from October 2001 through October 2002 at a-oyster and b- mud bottom sites in Barataria Bay. Gut contents are presented as percent frequency of occurrence and percent composition by dry weight (g).

a)

	Species of fish (OYSTER)					
	Archosargus probatocephalus	*Arius felis*	*Bagre marinus*	*Bairdiella chrysoura*	*Cynoscion arenarius*	*Leiostomus xanthurus*
# fish	2	8	2	2	7	8
# fish with food	1	8	2	2	3	5
Food item	Percent frequency of occurrence / percent by weight					
Fishes						
Anchoa mitchilli	0	0	0	0	67/67	0
Brevoortia patronus	0	0	0	0	0	0
Myrophis punctatus	0	0	0	50/18	0	0
Scales	0	25/13	0	0	0	0
Unidentified teleost	0	63/13	100/53	50/18	33/25	0
Crustaceans						
Callinectes sp.	0	13/1	0	0	0	0
Copepoda	0	0	0	0	0	40/3
Palaemonetes sp.	0	0	0	0	0	0
Penaeidae	0	0	0	50/50	0	0
Xanthidae	0	75/58	50/37	50/14	33/8	20/17
Bivalves						
Geukensia demissa	100/100	0	50/3	0	0	0
Mulinia lateralis	0	0	0	0	0	100/80
Unidentified bivalve	0	38/15	0	0	0	0
Other						
Polychaeta	0	0	50/7	0	0	0
Plant material	0	0	0	0	0	0

a) -continued.

	Species of fish (OYSTER)				
	Menticirrhus americanus	*Micropogonias undulatus*	*Pogonias cromis*	*Pomatomus saltatrix*	*Scomberomorus maculatus*
# fish	7	6	15	1	7
# fish with food	5	6	7	1	3
Food item	Percent frequency of occurrence / percent by weight				
Fishes					
Anchoa mitchilli	0	0	0	0	0
Brevoortia patronus	0	0	0	0	0
Myrophis punctatus	0	0	0	0	0
Scales	0	0	0	0	0
Unidentified teleost	0	0	0	100/100	100/100
Crustaceans					
Callinectes sp.	20/20	0	14/14	0	0
Copepod	0	0	0	0	0
Palaemonetes sp.	0	0	0	0	0
Penaeidae	20/20	0	0	0	0
Xanthidae	60/60	83/59	14/1	0	0
Bivalves					
Geukensia demissa	0	17/17	43/30	0	0
Mulinia lateralis	0	17/9	43/41	0	0
Unidentified bivalve	0	0	29/14	0	0
Other					
Polychaeta	0	0	0	0	0
Plant material	0	33/15	0	0	0

b)

	Species of fish (MUD)				
	Alosa chrysochloris	*Archosargus probatocephalus*	*Arius felis*	*Bagre marinus*	*Cynoscion nebulosus*
# fish	2	1	11	5	3
# fish with food	2	1	9	5	1
Food item	Percent frequency of occurrence / percent by weight				
Fishes					
Anchoa mitchilli	50/50	0	0	0	0
Brevoortia patronus	50/48	0	0	0	0
Myrophis punctatus	0	0	11/7	40/2	0
Scales	0	0	0	0	0
Unidentified teleost	50/2	0	44/20	40/2	0
Crustaceans					
Callinectes sp.	0	0	33/33	0	0
Copepod	0	0	0	0	0
Palaemonetes sp.	0	0	11/2	0	0
Penaeidae	0	0	11/5	20/34	0
Xanthidae	0	100/50	67/29	80/62	100/100
Bivalves					
Geukensia demissa	0	100/39	0	0	0
Mulinia lateralis	0	100/11	0	0	0
Unidentified bivalve	0	0	0	0	0
Other					
Polychaeta	0	0	0	0	0
Plant material	0	0	0	0	0

b) -continued.

	Species of fish (MUD)			
	Leiostomus xanthurus	*Menticirrhus americanus*	*Pomatomus saltatrix*	*Scomberomorus maculatus*
# fish	2	3	1	3
# fish with food	1	1	1	2
Food item	Percent frequency of occurrence / percent by weight			
Fishes				
Anchoa mitchilli	0	0	0	50/1
Brevoortia patronus	0	0	0	50/49
Myrophis punctatus	0	0	0	0
Scales	0	0	0	0
Unidentified teleost	0	0	100/100	50/50
Crustaceans				
Callinectes sp.	0	0	0	0
Copepod	0	0	0	0
Palaemonetes sp.	0	0	0	0
Penaeidae	0	0	0	0
Xanthidae	0	100/100	0	0
Bivalves				
Geukensia demissa	0	0	0	0
Mulinia lateralis	100/100	0	0	0
Unidentified bivalve	0	0	0	0
Other				
Polychaeta	0	0	0	0
Plant material	0	0	0	0

APPENDIX B. FISH SPECIES COLLECTED

Fish species collected from a- subtidal oyster shell and b- mud bottom habitat in Barataria Bay, October 2001 to October 2002. Also indicated are seasonal occurrence, total abundance, standard length range (mm), life history stage based on standard length (J = juvenile, A = adult) resident/transient status (R = resident, T = transient), fishery status (C = commercial, R = recreational) and gear type used in collection (G = gill net, T = substrate tray).

a)

Species	Common Name	Seasonal Occurrence	Total Abundance	SL Range	Life history stage	Residency Status	Fishery status	Gear type
Archosargus probatocephalus	Sheepshead	Fa, Wi	2	229-364	A	T	C, R	G
Arius felis	Hardhead catfish	Sp, Su	8	175-379	J, A	T	-	G
Bagre marinus	Gafftopsail catfish	Sp	2	183-255	J, A	T	-	G
Bairdiella chrysoura	Silver perch	Sp	2	145-150	J	T	C	G
Brevoortia patronus	Gulf menhaden	All year	162	90-220	J(?), A	T	C	G
Chaetodipterus faber	Atlantic spadefish	Sp, Fa	2	41-112	J, A	T	R	G, T
Chasmodes bosquianus	Striped blenny	Wi	1	42		R	-	T
Cynoscion arenarius	Sand seatrout	Sp, Su, Fa	7	196-310	A	T	R	G
Cynoscion nebulosus	Spotted seatrout	Sp, Su	3	220-319	A	T	C, R	G
Gobiesox strumosus	Skilletfish	All year	55	11-69		R	-	T
Gobionellus boleosoma	Darter goby	Wi	5	29-39		R	-	T
Gobiosoma bosc	Naked goby	All year	119	9-45	J, A	R	-	T
Hypleurochilus geminatus	Crested blenny	Fa	1	29		R	-	T
Hypsoblennius hentz	Feather blenny	Wi	2	12-68		R	-	T
Lagodon rhomboides	Pinfish	Fa	1	120	A	T	-	G
Leiostomus xanthurus	Spot	Sp, Fa, Wi	8	122-150	J, A	T	C, R	G
Menticirrhus americanus	Southern kingfish	Sp, Fa	7	172-287	A	T	R	G
Micropogonias undulatus	Atlantic croaker	Su, Fa	6	130-165	J	T	C, R	G
Opsanus beta	Gulf toadfish	Sp, Su, Fa	41	8-128	J, A(?)	R	-	T
Pogonias cromis	Black drum	Sp, Su, Wi	15	309-880	A	T	C, R	G
Pomatomus saltatrix	Bluefish	Sp	1	190	J	T	C, R	G
Rhinoptera bonasus	Cownose ray	Sp	1	*	?	T	-	G
Scomberomorus maculatus	Spanish mackerel	Su	7	319-425	A	T	C, R	G

b)

Species	Common Name	Seasonal Occurrence	Total Abundance	SL Range	Life history stage	Residency Status	Fishery status	Gear type
Alosa chrysochloris	Skipjack herring	Sp, Wi	2	194-231	A	T	C, R	G
Archosargus probatocephalus	Sheepshead	Sp	1	362	A	T	C, R	G
Arius felis	Hardhead catfish	Sp, Su	11	259-402	A	T	-	G
Bagre marinus	Gafftopsail catfish	Sp	4	141-171	J	T	-	G
Brevoortia patronus	Gulf menhaden	All year	145	90-203	J(?), A	T	C	G
Carcharhinus limbatus	Blacktip shark	Sp	2	*	J	T	R	G
Chaetodipterus faber	Atlantic spadefish	Sp	1	83	J	T	R	T
Cynoscion nebulosus	Spotted seatrout	Sp	3	233-275	A	T	C, R	G
Gobiesox strumosus	Skilletfish	Sp, Su, Wi	13	19-55		R	-	T
Gobionellus boleosoma	Darter goby	Wi	16	15-39		R	-	T
Gobiosoma bosc	Naked goby	Sp, Su, Wi	29	10-35	J, A	R	-	T
Hypsoblennius hentz	Feather blenny	Su	1	12		R	-	T
Leiostomus xanthurus	Spot	Su	2	116-123	J	T	C, R	G
Lutjanus griseus	Mangrove snapper	Fa	1	55	J	T	C, R	T
Menticirrhus americanus	Southern kingfish	Sp, Su	3	181-221	A	T	R	G
Micropogonias undulatus	Atlantic croaker	Wi	1	159	J	T	C, R	G
Myrophis punctatus	Speckled worm eel	Fa	1	85		T	-	T
Opsanus beta	Gulf toadfish	Sp, Su	15	13-183	J, A(?)	R	-	T
Pogonias cromis	Black drum	Sp	1	450	A	T	C, R	G
Pomatomus saltatrix	Bluefish	Sp	1	189	J	T	C, R	G
Scomberomorus maculatus	Spanish mackerel	Su	3	385-487	A	T	C, R	G

VITA

John Thompson Plunket, IV was born in Sarasota, Florida, on March 23, 1978, the son of John and Barbara Plunket and the brother of Orion Plunket. He was home-schooled, attended Hood College in Frederick, Maryland, part-time from 1993-1995, and received a Bachelor of Science in Marine Science in May 1998 from Eckerd College in Saint Petersburg, Florida. He spent two years as a research associate under the direction of Doctor Richard Shaw at the Louisiana State University Coastal Fisheries Institute, entering the Department of Oceanography and Coastal Sciences in August 2001 as a candidate for the degree of Master of Science.