BULLETIN OF MARINE SCIENCE, 77(1): 155–164, 2005

NOTES

OYSTER BEDS AS FISH AND MACROINVERTEBRATE HABITAT IN BARATARIA BAY, LOUISIANA

John Plunket and Megan K. La Peyre

Extensive research along the east coast of the U.S. provides evidence that three-dimensional natural and created oyster reefs are important habitat for many estuarine fishes (i.e., Breitburg, 1999; Posey et al., 1999; Coen and Luckenbach, 2000; Meyer and Townsend, 2000; Harding and Mann, 2001a,b, 2003; Lenihan et al., 2001). In contrast, little research exists documenting the use of oyster reefs by fish assemblages in the northern Gulf of Mexico (but see Zimmerman et al., 1989; Glancy et al., 2003). Existing studies in this region, focused on intertidal oyster reefs, suggest that these reefs provide habitat for some invertebrate and fish species (Zimmerman et al., 1989), and potentially provide better habitat than similar environments along the Atlantic coast (Minello, 1999). However, most Gulf coast oyster reefs are subtidal due to the narrow tidal range (Kilgen and Dugas, 1989). In Louisiana, the oyster industry's practice of planting shell (cultching) in relatively small, flat aggregations results in oyster beds that lack the three-dimensional relief associated with natural oyster reefs.

Despite a lack of significant three-dimensional structure, these flat oyster bottoms may provide valuable refuge or foraging habitat for fishes and decapod crustaceans. Description of fish and invertebrate assemblages over these flat oyster bottoms, and comparison to adjacent mud bottom habitat, provide a means to identify the potential importance of these reefs as fish habitat. Given that cultched oyster bottoms comprise, in some areas, over 10% of the bottom habitat (i.e., Barataria Bay, Louisiana), and given the increased interest in identifying important estuarine fish habitats, the use of these reefs and their relative importance as habitat are of significant interest to both ecologists and managers. The objectives of this study were to compare abundance and diversity of transient fishes, resident fishes, and benthic macroinvertebrates at subtidal cultched oyster and mud bottoms in Barataria Bay, Louisiana.

Methods

Study Area.—The study was conducted in Barataria Bay, Louisiana, a shallow, turbid estuary with diurnal tides averaging 0.3 m and salinities from 6 to 22 depending on freshwater input (Conner and Day, 1987; Fig. 1). Substrate is predominately clay, with an estimated 10% of the bottom covered by shell. The study area is surrounded by salt marsh dominated by smooth cordgrass, *Spartina alterniflora* (Loisel). Sampling took place on a private 336 ha oyster lease (N 29°26′18.3″, W 89°58′09.8″), with an average depth of 1.5 m. The lease has been cultched annually with oyster, *Crassostrea virginica* (Gmelin, 1791), hard clam, *Mercenaria mercenaria* (Linnaeus, 1758), and common rangia, *Rangia cuneata* (G. B. Sowerby I, 1831) shells since the 1940s.

Sampling Design.—The study was conducted using a stratified random sampling design. Samples were collected from six sites located in the study area. Distances between sites were approximately 0.5 km. Shell and mud bottoms on the lease were determined with side-scan sonar images (C. Wilson, Louisiana State University, unpubl. data), allowing random selection of three shell and three mud sites for sampling. Sampling occurred seven times over the

Bulletin of Marine Science

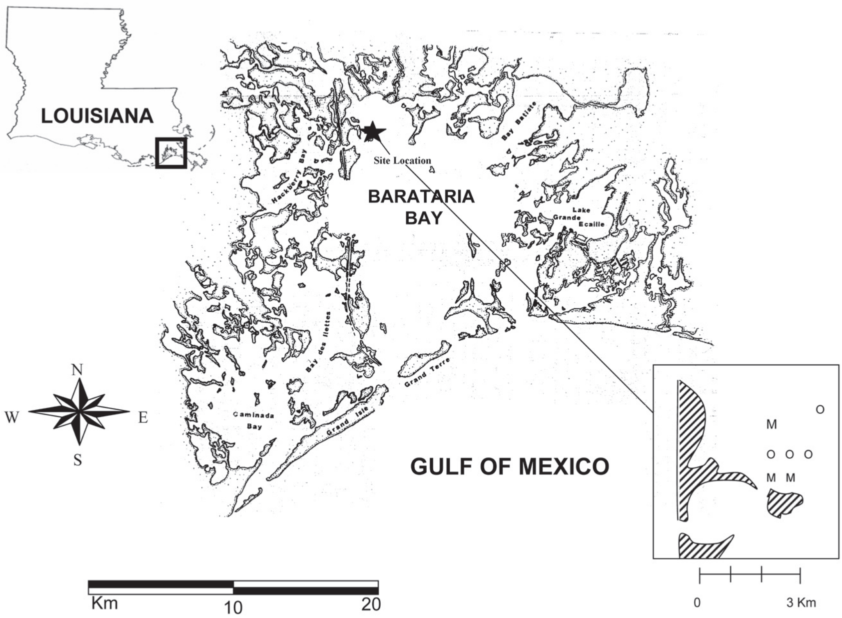

Figure 1. Map of Barataria Bay, Louisiana in relation to the Gulf of Mexico showing study site location (N 29°26′18.3″, W 89°58′09.8″). Sample stations were randomly located using side-scan sonar images delineating shell (o) and mud (m) bottoms and ground-truthed using a pole.

course of 1 yr (October and November 2001, January, March, May, June, and October 2002). Sampling occurred only during daylight hours due to logistical difficulties in reaching the sites at night.

Sampling Methods.—Plastic substrate trays (60 × 51 × 3 cm; 0.31 m^2) lined with 0.5 mm mesh screening were used to quantify the abundance and diversity of resident fishes and benthic macroinvertebrates. Substrate in trays located on oyster bottoms consisted of a single layer of disarticulated oyster shell, dried and replaced at each sampling period. Substrate in trays located on mud bottoms consisted of a layer of unsieved mud. Trays were deployed in triplicate at each site, on each sample date, lowered to the bottom beside site marker poles with bridle ropes attached to the pole each sample time, and quickly raised the following sample trip. Contents of each tray were rinsed, sieved, bagged, placed on ice, and returned to the lab for later identification and measurement. Similar trays containing oyster shell have been used for collection of benthic fishes and invertebrates (e.g., Breitburg, 1999; Lenihan et al., 2001; Lehnert and Allen, 2002), although their catch efficiency is unknown.

To compare transient fish use of oyster and mud bottoms, we used monofilament gill nets 30.5 m long × 2.4 m deep, with four 7.6 m panels (stretch-mesh sizes 25.4, 38.1, 50.8, and 63.5 mm). Gill nets were set during daylight hours, parallel to the current, fishing the entire water column. Sets were run for 1 hr in October and November 2001 and for 2 hrs thereafter due to low catches in October and November. A YSI Model 556 Multiprobe was used to record water temperature (°C), salinity, and dissolved oxygen (%) at each site during each sample. Fishes were identified and measured (standard length, SL, in mm, biomass in g) in the field.

Statistical Analyses.—All statistical analyses were performed using SAS (SAS Institute, Inc. 1999). Tray and gill net data were analyzed separately. Tray data were analyzed for diversity (H’), total faunal assemblage, and by fishes, invertebrates, bivalves, mussels, and clams separately using a two-way ANOVA (habitat and date). Soak time of the trays was accounted for in the random statement of the mixed ANOVA. A randomization technique was used to analyze smaller taxonomic groupings. Few assumptions about the data exist as this method relies on permutation tests (Edington, 1995). The Type III sum of squares of the real data was selected as the test statistic. This statistical approach was used due to the small sample sizes and the lack of normality. For tray data, ANOVA was used to generate the test statistic, specifically testing for differences in abundance of the dominant resident fishes in our catch by habitat.

Gill net catch per unit effort (CPUE ; #fish hr^{-1}) of total catch, transient fish, the dominant fish *Brevoortia patronus* Goode, 1878, and total diversity (Shannon-Wiener Diversity Index, H′) were analyzed using a mixed model analysis of variance (ANOVA) with habitat (mud, oyster bottom) and date (month) as the two fixed factors. Time of day, tidal stage, and environmental variables (temperature, salinity, dissolved oxygen), were accounted for in the random statement of the mixed ANOVA. Data were log transformed where necessary to achieve normality and homogeneity of variance. Results are presented as mean ± standard error (SE) unless otherwise indicated. As described above for tray data, a randomization technique was used for smaller taxonomic groupings. For gill net data, two-way ANOVA was used to generate the test statistic, specifically testing for differences in abundance of total catch minus *B. patronus*, and fishes characterized as bottom-feeding fish by habitat (oyster, mud) and date.

Results

Salinity during the study averaged 12.6 ± 7.1 (range 4.3–22.1), temperature averaged 21.9 ± 5.3 °C (range 13.7–28.8) and dissolved oxygen averaged 5.9 ± 3.0 (range 3.3–10.2; Fig. 2). Environmental variables followed an expected seasonal cycle and did not differ by site.

Substrate Trays.—Twenty-two oyster and 18 mud substrate trays were retrieved intact over the course of the study. Soak times ranged from 23 to 130 d (average = 60) due to difficulties with the weather in getting to the sites regularly. Soak time was a significant factor affecting invertebrate numbers, but not fish numbers. Ten fish species and nine macroinvertebrates were collected in association with the trays (Table 1). Resident fishes and decapod crustaceans were significantly more abundant on shell bottoms (33.2 ± 4.5 resident fishes m^{-2}; 168.4 ± 16.1 decapod crustaceans m^{-2}) as compared to mud bottoms (13.9 ± 1.6 resident fishes m^{-2}, ANOVA: P = 0.0004; 41.8 ± 26.5 decapod crustaceans m^{-2}, ANOVA: P = 0.0001, while bivalves were more

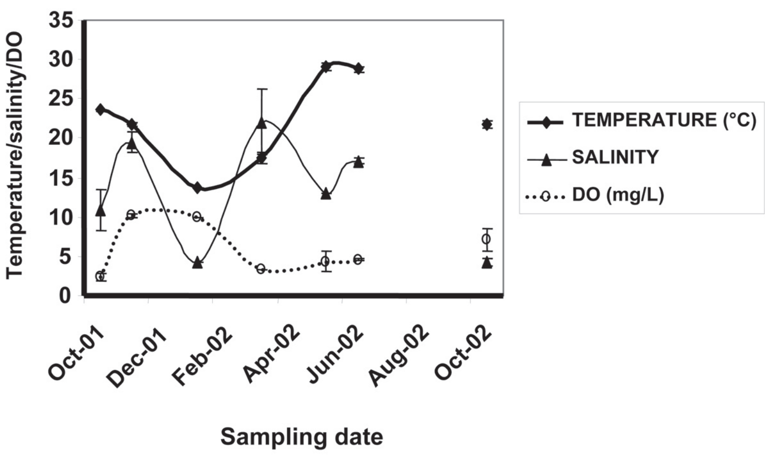

Figure 2. Mean temperature, salinity, and dissolved oxygen at all six sites (± SE). Environmental parameters did not vary by site, but showed expected seasonal trends. Sampling did not occur in August 2002 due to difficulties in reaching the sites as a result of storm events.

Table 1. Fish and invertebrate taxa collected with substrate trays at shell and mud sites in Barataria Bay, Louisiana from October 2001 to October 2002. Total number and mean number (organisms/tray) ± SE are reported. Oyster sites had significantly higher fish and invertebrate abundances relative to mud bottoms (ANOVA, $P < 0.05$).

		Oyster			Mud		
Common name	Scientific name	Total	Mean	SE	Total	Mean	SE
FISH							
Atlantic spadefish	*Chaetodipterus faber* (Broussonet, 1782)	2	0.1	0.1	1	0.1	0.1
Striped blenny	*Chasmodes bosquianus* (Lacepède, 1800)	1	0.1	0.9	-	-	-
Skilletfish	*Gobiesox strumosus* Cope, 1870	55	2.5	0.4	13	0.7	0.2
Darter goby	*Gobionellus boleosoma* (Jordan & Gilbert, 1882)	5	0.2	0.2	16	0.9	0.5
Naked goby	*Gobiosoma bosc* (Lacepède, 1800)	119	5.4	0.9	29	1.6	0.3
Crested blenny	*Hypleurochilus geminatus* (Wood, 1825)	1	0.1	0.1	-	-	-
Feather blenny	*Hypsoblennius hentzi* (Lesueur, 1825)	2	0.1	0.1	1	0.1	0.1
Gulf toadfish	*Opsanus beta* (Goode and Bean, 1880)	41	1.9	0.7	15	0.8	0.3
Mangrove snapper	*Lutjanus griseus* (Linnaeus, 1758)	-	-	-	1	0.1	0.1
Speckled worm eel	*Myrophis punctatus* Lütken, 1852	-	-	-	1	0.1	0.1
DECAPOD CRUSTACEANS							
Grass shrimp	*Palaemonetes* sp.	469	52.2	4.5	62	3.4	0.8
Snapping shrimp	*Alpheus* sp.	37	1.7	0.5	15	0.8	0.4
Porcelain crab	*Petrolisthes* sp.	7	0.3	0.1	-	-	-
Blue crab	*Callinectes sapidus* M. J. Rathbun, 1896	46	2.1	0.9	25	1.4	0.8
Mud crab	Xanthidae	701	31.9	3.3	100	5.6	1.9
Brown shrimp	*Penaeus aztecus* (Ives, 1891)	-	-	-	1	0.1	0.1
BIVALVE MOLLUSKS							
Ribbed mussel	*Beukensia demissa* (Dillwyn, 1817)	54	2.5	1.0	19	1.1	0.4
Hooked mussel	*Ischadium recurvum* (Rafinesque, 1820)	32	1.5	0.8	2	0.1	0.1
Dwarf surf clam	*Mulinia lateralis* (Say, 1822)	1	0.1	0.1	407	22.6	7.8

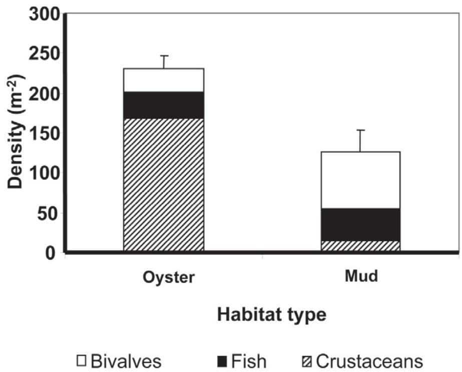

Figure 3. Tray catch density by habitat type. Overall catch density at oyster sites was significantly higher than density at mud sites.

abundant on mud bottoms (71.4 ± 12.2 bivalves m^{-2}) as compared to shell bottoms (29 ± 14.2 bivalves m^{-2}; ANOVA: P = 0.0002; Fig. 3). The higher abundance on mud bottoms was due to the surf clam, *Mulinia lateralis* (Say, 1822), which dominated (95%) the catch on mud bottoms. Mussels on the other hand, dominated (99%) the catch on oyster bottom. Both mussels and grass shrimp were more abundant on oyster bottom relative to mud bottom (ANOVA: P = 0.0498, P = 0.0001, respectively). Invertebrate numbers also varied significantly by date with January samples having highest numbers and May and June samples having lowest numbers (ANOVA: P = 0.0012). These high numbers were largely explained by January's soak time which was approximately double that for May and June. Diversity (H') was not significantly different between habitat types (ANOVA: P > 0.05).

Naked goby, *Gobiosoma bosc* (Lacepède, 1800), was the most abundant fish species over both substrates, comprising 53% of resident fishes at shell and 38% of resident fishes at mud sites. Other common species on both substrate types were Gulf toadfish, *Opsanus beta* (Goode and Bean, 1880), skilletfish, *Gobiesox strumosus* Cope, 1870, and darter goby, *Gobionellus boleosoma* (Jordan and Gilbert, 1882). Of the four dominant species, three were significantly more abundant at shell bottoms as compared to mud bottoms (ANOVA; *G. bosc*: P = 0.004, *O. beta*: P = 0.005, *B. strumosus*: P = 0.0002), while *G. boleosoma*, was more abundant over mud bottom as compared to shell bottoms.

Gill Nets.—From October 2001 to October 2002, 18 gill net sets were made over oyster bottom and 19 gill net sets were made over mud bottom, for a total of 32 and 33 hrs of fishing time. Transient fish CPUE did not differ significantly by habitat (ANOVA: P = 0.1), but did differ significantly by date (ANOVA: P < 0.001). Overall, CPUE was higher in our samples over oyster habitat (6.4 ± 1.9) than over mud bottom (4.7 ± 1.9). CPUE was highest in the warmest months (i.e., May and June) and lowest in the cooler months (i.e., January; Fig. 4). Transient fish CPUE did not vary by time of day or tidal stage sampled. Transient fish diversity (H') tended to be higher over oyster bottom versus mud, although not significantly (ANOVA: P = 0.07), and did not differ by date. Bottom-feeding fish, and total catch minus *B. patronus* were found to be significantly more abundant over oyster bottoms as compared to mud bottom (ANOVA: P = 0.0498, P = 0.02, respectively). CPUE of the dominant species

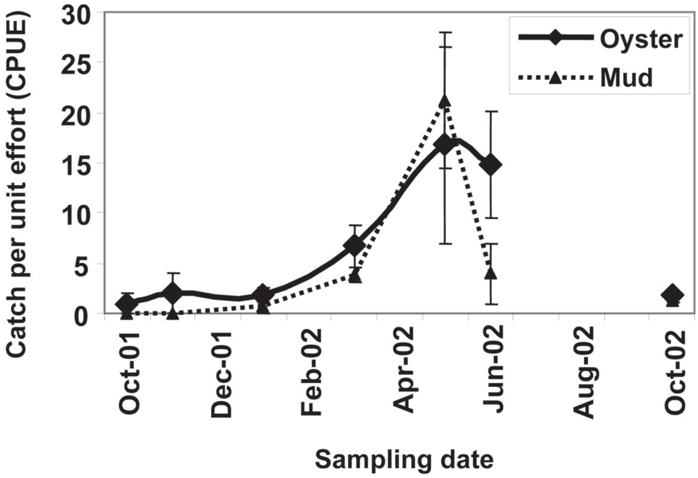

Figure 4. Habitat-specific catch per unit effort (CPUE) by month for gill net sampling of transient fish.

in the catch, Gulf menhaden, *B. patronus*, did not differ significantly between habitats (ANOVA: $P > 0.05$).

Eighteen species of transient fishes from nine families (413 individuals; Table 2) were caught during the study with 16 species collected over oyster bottom (234 individuals) and 13 species collected over mud bottom (179 individuals). Gulf menhaden dominated the catch at both bottom types, comprising 69% and 80% of the total number of fishes captured over shell and mud bottoms, respectively. The second most abundant species in our samples was black drum, *Pogonias cromis* (Linnaeus, 1766) at shell sites (6% of the total oyster catch) and hardhead catfish, *Arius felis* (Linnaeus, 1766) at mud sites (6% of the total mud catch).

Discussion

While numerous studies have examined nekton use of three-dimensional reefs (i.e., Zimmerman et al., 1989; Breitburg, 1999; Posey et al., 1999; Coen and Luckenbach, 2000; Meyer and Townsend, 2000; Harding and Mann, 2001a,b; Lenihan et al., 2001), few have examined sub-tidal cultched oyster shell in the Gulf of Mexico. In Barataria Bay, Louisiana, decapod crustaceans and mussels, potentially important prey for many transient fishes, were found to be approximately twice as abundant in oyster beds relative to mud bottoms. While transient fish overall were not significantly more abundant at subtidal cultched oyster bottoms relative to mud bottoms, bottom-feeding fish were more abundant at oyster bottoms as compared to mud bottoms.

Observed density estimates of crustaceans in subtidal, cultched oyster bottoms (168.4 ± 16.1 decapod crustaceans m^{-2}) were higher than density estimates made by Zimmerman et al. (1989) in an intertidal oyster reef in Texas (105 decapod crustaceans m^{-2}). The taxa collected were similar between studies, with mud crabs dominating the catch. Mud crabs preferentially associate with shell substrate (Day and Lawton, 1988) and prey on small bivalves (Dame and Patten, 1981). Grass shrimp, the second most abundant macroinvertebrate, are also common oyster reef residents

Table 2. Total abundance, percentage of total catch, CPUE (# fish/hr), and standard length range (mm) for transient fish species collected with gill nets at shell and mud sites in Barataria Bay, Louisiana, from October 2001 to October 2002. * = species classified as bottom feeding fish for analysis.

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* (Linnaeus, 1766)	6	2.6	0.19	130–165	1	0.6	0.03	159
Atlantic spadefish*	*Chaetodipterus faber* (Broussonet, 1782)	2	0.9	0.06	41–112				
Black drum*	*Pogonias cromis* (Linnaeus, 1766)	15	6.4	0.47	309–880	1	0.6	0.03	450
Blacktip shark	*Carcharhinus limbatus* (Müller & Henle, 1839)	-	-	-	-	2	1.1	0.06	*
Bluefish	*Pomatomus saltatrix* (Linnaeus, 1766)	1	0.4	0.03	190	1	0.6	0.03	189
Cownose ray	*Rhinoptera bonasus* (Mitchill, 1815)	1	0.4	0.03	-	-	-	-	-
Gafftopsail catfish*	*Bagre marinus* (Mitchill, 1815)	2	0.9	0.06	183–255	4	2.2	0.12	141–171
Gulf menhaden	*Brevoortia patronus* Goode, 1878	162	69.2	5.06	90–220	145	81.0	4.39	90–203
Hardhead catfish*	*Arius felis* (Linnaeus, 1766)	8	3.4	0.25	175–379	11	6.1	0.33	259–402
Pinfish	*Lagodon rhomboids* (Linnaeus, 1766)	1	0.4	0.03	120	-	-	-	-
Sand seatrout	*Cynoscion arenarius* Ginsburg, 1930	7	3.0	0.22	196–310	-	-	-	-
Sheepshead*	*Archosargus probatocephalus* (Walbaum, 1792)	2	0.9	0.06	229–364	1	0.6	0.03	362
Silver perch*	*Bairdiella chrysoura* (Lacepède, 1802)	2	0.9	0.06	145–150	-	-	-	-
Skipjack herring	*Alosa chrysochloris* (Rafinesque, 1820)	-	-	-	-	2	1.1	0.06	194–231
Southern kingfish	*Menticirrhus americanus* (Linnaeus, 1758)	7	3.0	0.22	172–287	3	1.7	0.09	181–221
Spanish mackerel	*Scomberomorus maculates* (Mitchill, 1815)	7	3.0	0.22	319–425	3	1.7	0.09	385–487
Spot*	*Leiostomus xanthurus* Lacepède, 1802	8	3.4	0.25	122–150	2	1.1	0.06	116–123
Spotted seatrout	*Cynoscion nebulosus* (Cuvier *in* Cuvier and Valenciennes, 1830)	3	1.3	0.09	220–319	3	1.7	0.09	
Total		234				179			

(Coen et al., 1999; Perry et al., 2001). 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, 1983). This is not to say that mud bottoms are unimportant as a food source for some fishes; spot, croaker, and catfish species often feed on infaunal invertebrates in soft sediments (Darnell, 1958; Diaz and Onuf, 1985; Muncy and Wingo, 1983), and dwarf surf clam was significantly more abundant in mud bottoms. Higher crustacean densities in our study compared to Zimmerman et al. (1989) may also be due to the use of different sampling techniques (trays versus drop net). Tray catches may be higher because fish and invertebrates may be attracted to the structure of the trays themselves, although this was not found by Lehnert and Allen (2002). This bias, however, should be similar for both cultched and mud trays in our study.

The greater abundance of bottom-feeding fish over shell bottoms likely relates to the observed greater abundance of benthic fishes and invertebrates. Benthic fishes caught at both bottom types were primarily species characterized as oyster reef residents. These species were more than twice as abundant in oyster beds than in mud bottoms. Shell habitat, even flat cultched reefs, appears to provide shelter, food, or spawning substrate for many species (Runyan, 1962; Wilson et al., 1982; Harding and Mann, 1999, 2000).

Low catch numbers using gill nets may be due to a number of factors, including a lack of summer samples (July–September) and a focus only on daytime sampling. Studies in other regions have used gill nets to sample subtidal reefs over diurnal periods in order to examine differences in reef use associated with time of day and tidal stage (e.g., Harding and Mann 2001b, 2003). In one study, tidal stage and time of day was found to impact the size of striped bass (*Morone saxitilis* Walbaum, 1792) in the Piankatank River, Virginia, a tributary of the Chesapeake Bay (Harding and Mann, 2003). Similarly, on the shallow inner continental shelf, patterns of fish habitat use were reversed at night with more fishes present in sandy bottoms as compared to more complex habitats during the night (Diaz et al., 2003). Studies in other habitats have found significantly higher night time catches of many larger transient fishes, possibly due to different feeding patterns, as well as gear avoidance during the day (e.g., Buckel and Conover, 1997; Rountree and Able, 1997; Prchalova et al., 2003). These and other studies indicate that both daytime sampling and a lack of summer samples (due to tropical storms) may have contributed to the conservative estimates of transient fish abundances observed in this study.

The large amounts of shell cultch deposited in Louisiana estuaries for oyster production play a secondary role as structured habitat for resident fishes and decapod crustaceans. The structure provided by these cultched oyster beds provides important habitat for benthic fish and decapod crustaceans; the abundant benthic fauna may make these areas valuable foraging sites for transient species as evidenced by our finding more bottom feeding fish at shell habitat as compared to mud habitat. These findings may have implications for restoration and/or enhancement efforts spurred by the degradation of estuarine habitat. By providing areas with concentrated abundant food sources for gamefish, cultched oyster beds may enhance the value of recreational fisheries and help support other members of the estuarine ecosystem.

Acknowledgments

The authors thank R. Pausina and R. "Buddy" Pausina for permission to sample their oyster lease. Special thanks are due to B. Milan, G. Peterson, B. Piazza, S. Kanouse, C. Bush, A. Podey, K. Boswell and others who volunteered their time in the field. Thanks to Mason Piehler for help with tables and figures. This study was part of a master's research project (J.P.) and was funded by the U.S. Geological Survey Louisiana Fish and Wildlife Cooperative Research Unit and the Louisiana Chapter of Sigma Xi.

Literature Cited

Breitburg, D. L. 1999. Are three dimensional structure and healthy oyster populations the keys to an ecologically interesting and important fish community? Pages 239–250 *in* M.W. Luckenbach, R. Mann, and J.A. Wesson, eds. Oyster reef habitat restoration: a synopsis and synthesis of approaches. Virginia Institute of Marine Science Press, Gloucester Point.

Buckel, J. A. and D. O. Conover. 1997. Movements, feeding periods, and daily ration of piscivorous young-of-the-year bluefish, *Pomatomus saltatrix*, in the Hudson River estuary. Fish. Bull. 95: 665–679.

Coen, L. D. and M. W. Luckenbach. 2000. Developing success criteria and goals for evaluating oyster reef restoration: ecological function or resource exploitation? Ecol. Eng. 15: 323–343.

__________, ____________________, and D. L. Breitburg. 1999. The role of oyster reefs as essential fish habitat: a review of current knowledge and some new perspectives. Am. Fish. Soc. Symp. 22: 438–454.

Conner, W. H., and J. W. Day, Jr. (eds.). 1987. The ecology of Barataria Basin, Louisiana: an estuarine profile. USFWS Biol. Rep. 85 (7.13). 165 p.

Dame, R. F., and R. Patten. 1981. Analysis of energy flows in an intertidal oyster reef. Mar. Ecol. Prog. Ser. 5: 115–124.

Darnell, R. M. 1958. Food habits of fishes and large invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Pub. Inst. Mar. Sci. U. TX. 5: 353–416.

Day, E. A., and P. Lawton. 1988. Mud crab (Crustacea: Brachyura: Xanthidae) substrate preference and activity. J. Shellfish Res. 7: 421–426.

Diaz, R. J. and C. P. Onuf. 1985. Habitat suitability index models: Juvenile Atlantic croaker (revised). USFWS Biol. Rep. 82/10.98. 23 p.

________, G. R. Cutter, and K.W. Able. 2003. The importance of physical and biogenic structure to juvenile fishes on the shallow inner continental shelf. Estuaries 26: 12–20.

Edington, E. S. 1995. Randomization tests, 3rd ed. Marcel Dekker, Inc. New York. 409 p.

Glancy, T. P., T. K. Frazer, C. E. Cichra, and W. J. Lindberg. 2003. Comparative patterns of occupancy by decapod crustaceans in seagrass, oyster, and marsh-edge habitats in a Northeast Gulf of Mexico estuary. Estuaries 26: 1291–1301.

Harding, J. M. and R. Mann. 1999. Fish species richness in relation to restored oyster reefs, Piankatank River. Bull. Mar. Sci. 65: 289–300.

___________ and ________. 2000. Estimates of naked goby (*Gobiosoma bosc*), striped blenny (*Chasmodes bosquianus*) and eastern oyster (*Crassostrea virginica*) larval production around a restored Chesapeake Bay oyster reef. Bull. Mar. Sci. 66: 29–45.

___________ and ________. 2001a. Diet and habitat use by bluefish, *Pomatomus saltatrix*, in a Chesapeake Bay estuary. Env. Biol. Fish. 60: 401–409.

___________ and ________. 2001b. Oyster reefs as fish habitat: opportunistic use of restored reefs by transient fishes. J. Shellfish Res. 20: 951–959.

___________ and ________. 2003. Influence of habitat on diet and distribution of striped bass (*Morone saxatilis*) in a temperate estuary. Bull. Mar. Sci. 72: 841–851.

Kilgen, R. H. and R. J. Dugas. 1989. The ecology of oyster reefs of the northern Gulf of Mexico: an open file report. NWRC open file rep. 89-02. 113 p.

Lassuy, D. R. 1983. Species profiles: life histories and environmental requirements (Gulf of Mexico)-spotted seatrout. USFWS, Division of Biological Services. FWS/OBS-82/11.4 U.S. Army Corps of Engineers, TR EL-82-4. 14 p.

Lehnert, R. L. and D. M. Allen. 2002. Nekton use of subtidal oyster shell habitat in a southeastern U.S. estuary. Estuaries 25: 1015–1024.

Lenihan, H. S., C. H. Peterson, J. E. Byers, J. H. Grabowski, G. W. Thayer, and D. R. Colby. 2001. Cascading of habitat degradation: oyster reefs invaded by refugee fishes escaping stress. Ecol. Appl. 11: 764–782.

Meyer, D. L. and E. C. Townsend. 2000. Faunal utilization of created intertidal eastern oyster (*Crassostrea virginica*) reefs in the southeastern United States. Estuaries 23: 34–45.

Minello, T. J. 1999. Nekton densities in shallow estuarine habitats of Texas and Louisiana and the identification of essential fish habitat. Am. Fish. Soc. Symp. 22: 43–75.

Muncy, R. J. and W. M. Wingo. 1983. Species profiles: life histories and environmental requirements of coastal fish and invertebrates (Gulf of Mexico) – seacatfish and gafftopsail. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.5. U.S. Army Corps of Engineers, TR EL-82-4. 17 p

Perry, H. M., K. M. Larsen, J. S. Warren, and C. B Trigg. 2001. Seasonal colonization of low profile artificial reefs in Mississippi coastal waters: invertebrates. Proc. Gulf Carib. Fish. Inst. 52: 498–511.

Posey, M. H., T. D. Alphin, C. M. Powell, and E. Townsend. 1999. Oyster reefs as habitat for fish and decapods. Pages 229–238 *in* M.W. Luckenbach, R. Mann, and J.A. Wesson (eds.). Oyster reef habitat restoration: a synopsis and synthesis of approaches. Virginia Institute of Marine Science Press, Gloucester Point.

Prchalova, M., V. Drastik, J. Kubecka, B. Sricharoendham, F. Schiemr and J. Vijverberg. 2003. Acoustic study of fish and invertebrate behavior in a tropical reservoir. Aquat. Living Resour. 16: 325–331.

Rountree, R. A. and K. W. Able. 1997. Nocturnal fish use of New Jersey marsh creek and adjacent bay shoal habitats. Estuar. Coast. Shelf Sci. 44: 703–711.

Runyan, S. 1962. Early development of the clingfish, *Gobiesox strumosus* Cope, Chesapeake Sci. 2: 113–141.

Wilson, C. A., J. M. Dean, and R. Radtke. 1982. Age, growth rate and feeding habits of the oyster toadfish, *Opsanus tau* (Linnaeus) in South Carolina. J. Exp. Mar. Biol. Ecol. 62: 251–259.

Zimmerman, R., T. J. Minello, T. Baumer, and M. Castiglione. 1989. Oyster reef as habitat for estuarine macrofauna. NOAA Tech. Memo. NMFS-SEFC-249. 16 p.

Date Submitted: 18 March, 2004. Date Accepted: 5 November, 2004.

Addresses: *US Geological Survey Louisiana Fish and Wildlife Cooperative Unit, School of Renewable Natural Resources, Louisiana State University Agricultural Center, Baton Rouge, Louisiana 70803.* Corresponding Author: (M.K.LaP.) *E-mail: <mlapey@lsu.edu>.*