

COMPARING NEKTON ASSEMBLAGES OF SUBTIDAL HABITATS IN PIPELINE CANALS TRAVERSING BRACKISH AND SALINE MARSHES IN COASTAL LOUISIANA

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Abstract: Subtidal habitats of pipeline canals in Louisiana brackish and saline marshes were sampled seasonally (fall, spring, and summer) between October 1991 and March 1993 with a 2-m² throw trap to identify dominant natant species and test hypotheses relating habitat selection to water depth. Densities of nekton were compared among canals and between shallow (<1 m) and deep (≥1m) areas within canals to test two null hypotheses: H₁: Densities of nekton in pipeline canals are not related to maximum canal depth and H₂: Densities of nekton in shallow and deep subtidal areas of canals are equal. Daggerblade grass shrimp *Palaemonetes pugio*, bay anchovy *Anchoa mitchilli*, blue crab *Callinectes sapidus*, brown shrimp *Penaeus aztecus*, and gulf menhaden *Brevoortia patronus* numerically dominated nekton assemblages in both brackish and saline canals. Naked goby *Gobiosoma bosc*, rainwater killifish *Lucania parva*, and gulf pipefish *Syngnathus scovelli* were dominant only in brackish canals, whereas white shrimp *Penaeus setiferus* and Atlantic croaker *Micropogonias undulatus* were abundant in saline canals only. Although variation in the abundance of most numerically dominant species could not be related to maximum canal depth, the distribution of several species within pipeline canals was influenced by habitat depth and other interrelated factors. The degree of habitat segregation with depth was largely influenced by submerged aquatic vegetation (SAV) and salinity as well as water depth. Habitat segregation with depth was most pronounced in brackish canals during late spring (May) when SAV was present. Naked goby, rainwater killifish, blue crabs, and daggerblade grass shrimp were significantly more abundant in shallow water (<1 m) at this time. In saline canals, most blue crabs and daggerblade grass shrimp occupied shallow habitats in March when small juveniles of these species reached peak abundance. Bay anchovy exhibited a pattern opposite that of other species. In March, bay anchovy abundance was positively related to maximum canal depth in brackish canals, and densities were greater in deep than shallow areas of saline canals in June. Salinity may have affected the distribution of freshwater species (e.g., centrarchids) and limited their occurrence in saline canals. Increasing shallow subtidal habitat by backfilling canals may enhance the nursery habitat for some species, especially in brackish canals where the area of subtidal habitat capable of supporting SAV would be expanded.

Key Words: pipeline canals, fishery impact, Louisiana, subtidal habitat, submerged aquatic vegetation, hurricane impact, backfilling

INTRODUCTION

In undisturbed marsh systems, shallow subtidal areas along the marsh-water interface provide essential nursery habitat for fishery species (Baltz et al. 1993, Ruiz et al. 1993). Such areas are critical for those aquatic organisms that use the marsh surface and retreat to

nearby subtidal habitat when the marsh drains at low tide (Zimmerman et al. 1984, Peterson and Turner 1994). In addition, light penetrates to the bottom of these shallow waters, permitting the growth of submerged aquatic vegetation (SAV) that may enhance habitat value by providing food and protection (Rozas and Odum 1988, Lubbers et al. 1990).

Pipeline canals constructed in coastal wetlands differ from natural subtidal areas in several important characteristics. Canals are usually straight, deep, and steep-sided, and their average depth (1.8–3.6 m) is substantially greater than nearby natural tidal channels or ponds (Tabberer et al. 1985, Abernethy and Gosselink 1988, Wicker et al. 1989, Rozas 1992). Most of the subtidal area in canals is too deep for SAV development, even where turbidity and salinity are favorable for its establishment.

Deep canals may provide a refuge for large predators that would otherwise be constrained by the shallow water in natural marsh systems. These deep corridors may allow predators easy access to what little shallow subtidal habitat there is along canal shorelines. Consequently, the presence of large predators in canals may reduce densities of early life stages of nekton (fishes and decapod crustaceans), either by increasing mortalities or because potential prey avoid canals with high predator densities. Therefore, we hypothesized that densities of major species of small nekton would be inversely related to canal depth (Hypothesis 1).

Among the mitigation options available for pipeline canals in coastal Louisiana is backfilling, by removing the dredged material levee and returning the material to the canal (Neill and Turner 1987a). Backfilling has been used for mitigation on a number of oil and gas access canals in Louisiana but, until recently, rarely applied to longer pipeline canals. Although backfilling can return the entire levee to the canal, oxidation of the dredged material through time results in an insufficient amount of material to fully restore the marsh habitat that was originally destroyed. Rather, shallow water bodies typically <1 m deep are produced (Neill and Turner 1987a, Abernethy and Gosselink 1988).

In a recent survey of pipeline canals in coastal southeast Louisiana, we measured canal bathymetry and calculated the volume of dredged material contained in levees and available for backfilling (Reed and Rozas 1994). From these data, we estimated that backfilling the canals in our study area would decrease the average depth of most canals to <1 m. Similar results were reported in studies of backfilled canals in coastal Louisiana (Neill and Turner 1987a, Abernethy and Gosselink 1988).

Backfilling may enhance the nursery value of pipeline canals by expanding the area of shallow subtidal habitat and reducing the density of large predators (McIvor and Odum 1988, Baltz et al. 1993, Ruiz et al. 1993). Ideally, one could test this hypothesis by comparing nekton densities in pipeline canals before and after backfilling. However, when we began this study, backfilling pipeline canals was rarely practiced in Louisiana, and the opportunity for collecting pre- and post-backfilling data did not exist. Therefore, we compared

nekton use of shallow (<1 m) and deep (≥ 1 m) subtidal areas in canals as a means of predicting the effect of backfilling on the nursery value of pipeline canals. We hypothesized that densities of nekton, and hence habitat use, would be greater in shallow than deep areas of canals (Hypothesis 2).

The major goals of our study were to determine whether the abundance of nekton in subtidal habitat is influenced by maximum canal depth (Hypothesis 1) and if subtidal habitat selection within pipeline canals is influenced by habitat water depth (Hypothesis 2). In addition, our sampling protocol allowed us to identify the major species of nekton using subtidal nursery habitats of pipeline canals within brackish and saline marshes of the Mississippi River deltaic plain.

MATERIALS AND METHODS

Study Area

We studied pipeline canals in the Terrebonne-Timbalier Basin of southeastern Louisiana (Figure 1). In a previous study, we divided each OCS (Outer Continental Shelf) canal in the study area into 1 km sections using quad maps (Reed and Rozas 1994). We separated each canal section into two types (saline and brackish) according to the marsh type in which they occurred (Chabreck and Linscombe 1978). Saline marshes were dominated by *Spartina alterniflora* Loisel, but *Juncus roemerianus* Scheele, *Distichlis spicata* (L.), and *S. patens* (Aiton) Muhl. were also present. Brackish marshes were dominated by *S. patens*. Although SAV was absent in saline canals, Eurasian watermilfoil *Myriophyllum spicatum* L. and widgeon grass *Ruppia maritima* L. occurred in subtidal areas of brackish canals. The predominant bottom type in all canals was soft mud. The system is microtidal. Tides are predominantly diurnal and have a mean range of approximately 0.4 m near the Gulf of Mexico, but tides are greatly diminished landward of the major bays, especially within brackish marshes (Shirzad et al. 1989).

Environmental Parameters

Immediately after a sample was enclosed (and before SAV or animals were removed), water temperature and salinity were measured at the site using a Beckman RS5-3 salinometer. If present in the sample area, SAV was removed before organisms were collected. Vegetation was placed into sample bags and transported to the laboratory in a cooler. Samples were washed in running water, dried to constant weight at 105 °C (48 h), and weighed (± 0.1 g). Because roots broke off during sampling, they were not included in the biomass measurements.

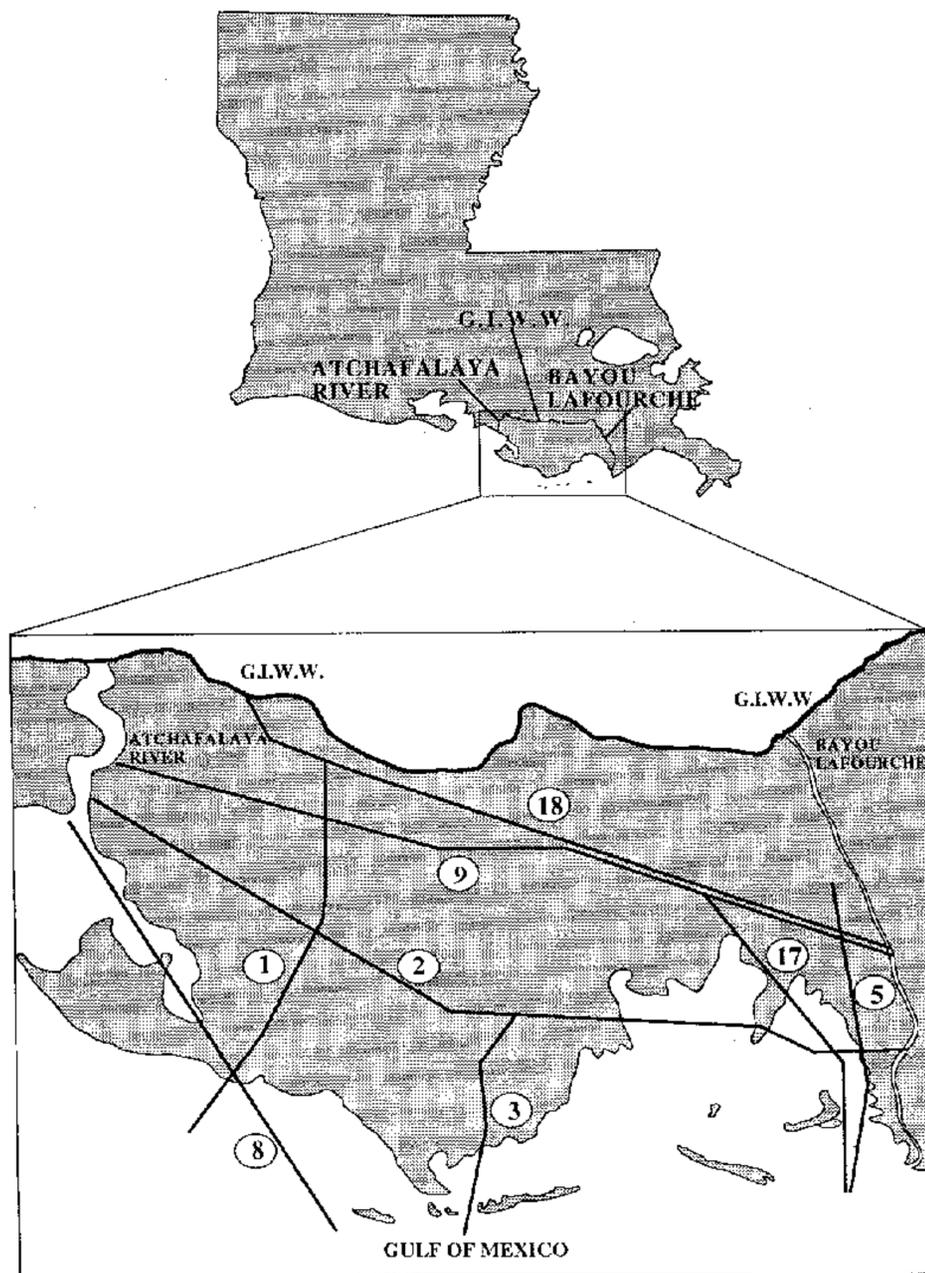


Figure 1. Map of the study area and the locations of OCS (Outer Continental Shelf) pipeline canals in coastal Louisiana. See text for a description of pipeline canals (referred to by number) that were sampled in the study. G.I.W.W. = Gulf Intracoastal Waterway.

Nekton Sampling

Eighteen sampling trips were scheduled to coincide with equatorial tides, predicted periods of low water levels when nekton would be restricted to subtidal habitats and not dispersed over intertidal areas. Although strong southerly winds occasionally raised water levels above those predicted by tide tables and inundated marshes, we collected most samples when nekton was restricted to subtidal areas. Low water caused by the passage of a cold front precluded sampling one saline canal in March 1992.

We collected nekton samples using a 2-m² throw trap in subtidal habitats <2 m deep, which represented on average >80% of total canal area. The throw trap had 1.4 × 1.4 × 2.0 m high walls constructed of 3-mm-mesh nylon netting. Four 1.3-cm-diameter steel reinforcing rods were welded together to form a square and attached to the bottom of the net to make it sink rapidly in water. A chain inserted into sleeves sewn to the

bottom of the net provided a 15-cm skirt that sealed the net bottom and prevented organisms from escaping beneath the net walls. A floating collar made of 3.8-cm-diameter plastic pipe and attached to the top of the net kept the throw trap vertical in the water column after it was deployed. When the net was deployed in water <2 m deep, the floating collar prevented most organisms from escaping over the net walls. However, on one occasion we observed two large striped mullet (*Mugil cephalus*) escape by jumping over the collar.

We slowly approached each site in a small boat (with the motor turned off), allowing the wind to push the boat near the sample area. When approximately 3 m away, two persons standing near the bow of the boat tossed the throw trap over the sample site. Every effort was made to sample subtidal sites at least 1.3 m from shore to eliminate the influence of the marsh edge on catch. Baltz et al. (1993) found that fish densities in open water were greater than expected when the sample site was ≤ 1.25 m from the marsh edge. Furthermore, most shallow habitat created by backfilling canals would be away from the marsh edge. We collected most throw trap samples (98%) ≥ 1.3 m from shore, but occasionally in order to sample depths <1 m, we had to sample nearer the marsh edge.

Animals were removed from the throw trap using a large clearing net. The clearing net was a 2.0-m-deep bag (with a 1.8 × 2.3 m opening) made of 3-mm mesh nylon netting. A frame constructed with 1.9-cm-diameter galvanized steel pipe was attached to the opening of the net for support. The throw trap was cleared by two persons placing the opening of the net against one side of the throw trap, then carefully pulling the net frame under and around the throw trap. Once the throw trap was engulfed, the clearing net and throw trap were lifted out of the water. The throw trap was then removed from the clearing net, and the contents of the clearing net were carefully washed to remove mud inadvertently collected along with the sample.

Samples were preserved in 20% formalin for at least 72 h, washed in running water for 24 h, and placed into 70% ethanol for storage. Organisms were separated from detritus, identified, and counted. All individuals of each species were weighed together to the nearest 0.1 g.

Testing Primary Hypotheses

We collected data to test the hypothesis that densities of nekton are not related to maximum canal depth (Hypothesis 1) from seven brackish and seven saline canal sections having a range of maximum depths (0.6–3.6 m) representative of those found in our initial survey (Reed and Rozas 1994). Sample locations included two sections of Canals 2 and 18 and one section of

Canals 1, 9, and 17 in brackish marsh and two sections of Canals 2 and 17 and one section of Canals 1, 3, and 8 in saline marsh (Figure 1). We sampled each canal section on two occasions, once between October 17 and 31, 1991 and again between March 2 and 19, 1992. On each occasion, we collected throw trap samples from three shallow subtidal sites (usually ≤ 1 m deep) selected haphazardly within each canal section. Five sampling trips (days) were required to collect samples each month.

We collected data for testing the hypothesis that densities of nekton in shallow and deep subtidal habitats of canals are equal (Hypothesis 2) from a subset of the canals used to test Hypothesis 1. We selected three brackish and three saline canal sections, and in each section, we collected a throw trap sample within each of four depth zones (1= <0.5 m, 2= ≥ 0.5 m and <1.0 m, 3= ≥ 1.0 m and <1.5 m, 4= ≥ 1.5 m). Sample locations included one section in Canals 9, 17, and 18 in brackish marsh and one section of Canal 2 and two sections of Canal 3 in saline marsh (Figure 1). To capture seasonal variations in the peak abundance of nekton resulting from species differences in periods of recruitment to estuarine habitats, we sampled canals during four months (May, June, and October 1992, March 1993). Two sampling trips were required to collect samples each month.

Sampling Efficacy and Efficiency

To determine if our gear was effective within the range of water depths we would encounter in our study, we conducted two experiments. We estimated throw trap efficacy (i.e., net avoidance) at various water depths in September 1991 using gulf killifish *Fundulus grandis* collected in minnow traps from a marsh near the LUMCON Marine Center. We stocked a large panel tank (diameter=6.1 m; height=1.8 m) with 342 killifish (S.L.: range=33–75 mm, mean=42 mm) and sampled the tank filled to various water depths over a 2-day period. The experiment was begun on day 1 by filling the tank with ambient estuarine water (salinity=11.1‰) to a depth of 0.6 m and adding the fish. The fish were sampled by two persons throwing the trap into the tank from 8 different positions around its perimeter. Fish were removed from the trap using the clearing net, counted, and immediately returned to the tank. After sampling was completed at one depth, ambient water was added to raise the level to the next desired depth and sampling was resumed. The following sequence of water depths was sampled: Day 1=0.6 and 0.9 m; Day 2=1.2, 1.5 and 1.8 m.

To estimate the efficiency of removing organisms from the throw trap using the clearing net, we used marked gulf killifish (S.L.: range=35–60 mm, mean=50

mm) and daggerblade grass shrimp *Palaemonetes pugio* (T.L.: range=23–38 mm, mean=28 mm). Organisms were marked by clipping the anal fin of fish or uropods of shrimp. On May 11, 1992 while sampling the saline canals, ten individuals of each species were added to the throw trap immediately after it was deployed at nine sample sites having three ranges of water depth (≥ 0.5 m and <1.0 m, ≥ 1.0 m and <1.5 m, and ≥ 1.5 m). We calculated the percentage of those marked individuals retrieved with each sample.

Statistical Analyses

We used 1-way ANOVAs to test for differences in catch efficacy with water depth by comparing the means of fish collected at each depth and for examining differences in clearing efficiency by comparing the average number of organisms retrieved at each depth. We tested the null hypotheses that average water temperature and salinity in saline and brackish canals were equal during each sampling period using t-tests. We used a significance level of $p \leq 0.05$ for these analyses.

We tested Hypothesis 1 by regressing the mean number of animals collected in each canal during October 1991 and March 1992 with the maximum depth measured in each canal. We chose a significance level of $p \leq 0.05$ for testing Hypothesis 1.

To test Hypothesis 2 that densities of numerically dominant fishes and decapod crustaceans were equal among depth zones, we analyzed data collected May 1992 through March 1993 for each numerically dominant species, total fishes, and total decapods separately by canal type (brackish and saline) and sampling period using 1-way ANOVAs. Numerically dominant species were defined as (1) estuarine residents collected at densities > 1 individual/ 2 m^2 and representing $\geq 3\%$ of the total catch in more than one sampling period, and (2) estuarine transient species that met these criteria for density and relative abundance in at least one sampling period. Resident and transient species were classified according to Thompson and Forman (1987). If we found a significant effect of depth on mean animal density, we used *a priori* Contrasts to compare mean densities between shallow (<1 m) and deep (≥ 1 m) habitats. To increase the power of the analysis, we used a significance level of $p \leq 0.10$. We adjusted p values using the method described by Rice (1989) to correct for the error introduced by doing multiple analyses (i.e., testing a hypothesis for several species).

Mean densities of fishes and crustaceans were positively related to the standard deviation; therefore, we performed a $\ln(x+1)$ transformation of the original values prior to analyses (Green 1979). Other variables were not transformed. All tabular and graphical data presented in this paper are untransformed means. We

Table 1. A comparison of salinity, water temperature, and submerged aquatic vegetation (SAV) biomass measured in pipeline canals within brackish (B) and saline (S) marshes. n = number of canal sections sampled. Means (\pm one standard error of the mean) were calculated by first averaging data from 3 or 4 samples collected within each canal and then averaging canal means.

Sample Date	Marsh Type	n	Salinity (‰)	Water Temperature (°C)	SAV Biomass (g dry weight)
October 1991	B	7	9.6 \pm 1.1	25.2 \pm 0.6	24.6 \pm 16.0
	S	7	19.8 \pm 0.9	24.2 \pm 0.5	0
March 1992	B	7	2.3 \pm 0.6	16.0 \pm 1.8	23.3 \pm 7.1
	S	6	6.7 \pm 1.3	21.6 \pm 0.9	0
May 1992	B	3	10.6 \pm 0.5	24.9 \pm 0.4	66.1 \pm 24.9
	S	3	10.7 \pm 2.3	25.0 \pm 1.3	0
June 1992	B	3	11.2 \pm 0.7	31.7 \pm 0.9	77.6 \pm 31.0
	S	3	14.3 \pm 3.1	30.3 \pm 0.6	0
October 1992	B	3	7.9 \pm 0.5	24.1 \pm 0.7	0.1 \pm 0.0
	S	3	14.7 \pm 0.8	23.1 \pm 0.9	0
March 1993	B	3	5.6 \pm 0.6	20.7 \pm 0.8	7.5 \pm 7.4
	S	3	6.5 \pm 1.4	20.3 \pm 1.0	0

used SPSS software to run t-tests and regression analyses (Norusis 1990) and SuperANOVA software for all ANOVAs and *a priori* Contrasts (Abacus Concepts 1989).

RESULTS

Environmental Parameters

In general, brackish and saline canals had similar average water temperatures but differed in salinity and the presence of SAV. Mean water temperatures in our study canals ranged from 16.0 to 31.7 °C; temperatures were highest in June and lowest in March (Table 1). Water temperatures in brackish and saline canals differed little in a given month except in March 1992, when the passage of a cold front caused a statistically significant difference between the two canal types. Five brackish and five saline canals were sampled in the first week of March 1992, but water temperatures were substantially lower when the brackish canals were sampled on March 5 following the passage of a cold front. Mean salinities varied from 2.3 to 19.8‰ (Table 1). Salinities in brackish and saline canals were significantly different in half the months we sampled (October 1991, March and October 1992). Differences between brackish and saline canals were most pronounced in fall (October), which is the period of highest salinities in the Terrebonne-Timbalier Basin (Orlando et al. 1993). Submerged vegetation, mostly Eurasian watermilfoil and widgeon grass, was observed only in brackish canals. In May and June, SAV occurred at all shallow (<1 m) sample sites (Table 1), and although SAV biomass was much less at sites \geq 1 m but <1.5

m deep, 50% of these sites contained at least some vegetation. Submerged vegetation was absent from sites \geq 1.5 m deep. Peak biomass of SAV in canals occurred in June 1992. Little SAV remained in canals after Hurricane Andrew swept across coastal Louisiana in August 1992.

Nekton Assemblages

Nekton assemblages using pipeline canals in our study area included 42 species of fishes and 6 species of decapod crustaceans (Table 2). We collected a total of 13,040 organisms having a wet weight of approximately 4.89 kg. Perhaps due to the presence of SAV in brackish canals, we collected >60% of the total number and biomass of organisms in this canal type, and more species were taken in brackish than saline canals (41 vs 35 species). Daggerblade grass shrimp was the most abundant estuarine resident species in both brackish and saline canals. Naked goby *Gobiosoma bosc* dominated brackish canals during most sampling periods, and rainwater killifish *Lucania parva* and gulf pipefish *Syngnathus scovelli* were very abundant in brackish canals during late spring and summer. Two additional resident species, clown goby *Microgobius gulosus* and sailfin molly *Poecilia latipinna*, were only abundant seasonally (summer) in brackish canals. Bay anchovy *Anchoa mitchilli*, blue crab *Callinectes sapidus*, brown shrimp *Penaeus aztecus*, and gulf menhaden *Brevoortia patronus* were numerically dominant transient species in both saline and brackish canals. White shrimp *Penaeus setiferus* and Atlantic croaker *Micropogonias undulatus* were dominant transient species in saline canals only.

Table 2. List of fishes and decapod crustaceans collected with 2-m² throw trap in subtidal habitats of pipeline canals within brackish (B) and saline (S) marshes. Total numbers and (biomass, g wet weight) are given for each species collected during each sampling period. n = number of canal sections sampled during each period. For March 1992, n equals 7 and 6 for brackish and saline canals, respectively.

Species		Oct 1991 n = 7	Mar 1992 n = 7/6	May 1992 n = 3	Jun 1992 n = 3	Oct 1992 n = 3	Mar 1993 n = 3
<i>Palaemonetes pugio</i> Holthuis	B	285 (25.9)	1,069 (162.4)	125 (32.0)	158 (33.6)	25 (3.0)	529 (113.9)
Daggerblade Grass Shrimp	S	28 (3.5)	828 (161.1)	1 (0.4)	2 (0.3)	55 (5.7)	1,006 (219.7)
<i>Brevoortia patronus</i> Goode	B	0	1,048 (182.2)	6 (0.9)	0	2 (26.3)	10 (0.6)
Gulf Menhaden	S	0	662 (138.7)	1 (7.8)	0	0	486 (53.3)
<i>Anchoa mitchilli</i> (Valenciennes)	B	110 (20.3)	163 (18.9)	29 (4.5)	72 (12.6)	399 (42.6)	66 (17.0)
Bay Anchovy	S	71 (12.3)	55 (19.9)	190 (45.1)	298 (27.7)	151 (26.3)	41 (4.5)
<i>Callinectes sapidus</i> Rathbun	B	388 (27.8)	454 (418.5)	82 (52.0)	35 (316.1)	122 (15.1)	86 (26.1)
Blue Crab	S	93 (35.2)	207 (266.7)	9 (3.3)	13 (1.1)	41 (1.9)	90 (33.7)
<i>Lucania parva</i> (Baird & Girard)	B	240 (30.4)	250 (82.9)	90 (18.9)	440 (58.3)	6 (1.5)	2 (0.5)
Rainwater Killifish	S	0	0	0	0	0	0
<i>Gobiosoma bosc</i> (Lacepede)	B	44 (3.8)	256 (75.4)	29 (11.1)	137 (13.8)	74 (8.7)	75 (20.0)
Naked Goby	S	7 (1.1)	23 (10.3)	0	5 (0.5)	6 (0.3)	14 (3.6)
<i>Microgobius gulosus</i> (Girard)	B	176 (21.5)	44 (33.8)	10 (6.7)	62 (14.9)	7 (2.4)	0
Clown Goby	S	6 (0.2)	1 (0.4)	0	0	0	0
<i>Poecilia latipinna</i> (Lesueur)	B	1 (0.2)	16 (7.7)	0	200 (42.4)	0	0
Sailfin Molly	S	1 (2.1)	0	0	0	0	0
<i>Penaeus aztecus</i> Ives	B	25 (19.6)	14 (4.2)	52 (54.2)	21 (69.8)	5 (24.9)	4 (0.5)
Brown Shrimp	S	11 (11.6)	23 (5.1)	37 (37.2)	6 (3.3)	9 (5.0)	9 (2.7)
<i>Syngnathus scovelli</i> (Evermann & Kendall)	B	2 (0.6)	63 (18.1)	60 (10.6)	58 (13.0)	5 (0.5)	4 (1.9)
Gulf Pipefish	S	0	0	0	1 (0.2)	0	0
<i>Micropogonias undulatus</i> (Linnaeus)	B	1 (0.0)	29 (43.5)	4 (7.8)	0	0	21 (24.2)
Atlantic Croaker	S	0	95 (122.4)	0	0	0	27 (49.2)
<i>Penaeus setiferus</i> (Linnaeus)	B	6 (3.6)	0	0	0	5 (10.7)	0
White Shrimp	S	60 (46.9)	0	0	0	52 (73.6)	0
<i>Menidia beryllina</i> (Cope)	B	15 (5.0)	3 (2.4)	23 (2.9)	10 (5.0)	6 (3.7)	0
Inland Silverside	S	6 (8.7)	12 (21.9)	0	0	0	0
<i>Lepomis microlophus</i> (Gunther)	B	50 (68.7)	10 (24.7)	0	3 (3.6)	0	0
Redear Sunfish	S	0	0	0	0	0	0
<i>Leiostomus xanthurus</i> Lacepede	B	0	6 (6.3)	0	0	2 (238.0)	0
Spot	S	0	25 (37.8)	9 (69.3)	0	0	8 (11.6)
<i>Gobionellus boleosoma</i> (Jordan & Gilbert)	B	3 (0.2)	6 (6.2)	0	0	0	2 (0.5)
Darter Goby	S	16 (3.3)	9 (4.0)	0	0	2 (0.2)	12 (6.2)
<i>Microgobius thalassinus</i> (Jordan & Gilbert)	B	17 (1.3)	1 (0.5)	1 (0.4)	1 (0.5)	3 (0.9)	4 (1.9)
Green Goby	S	7 (1.1)	1 (0.4)	0	0	3 (0.4)	1 (0.6)
<i>Lagodon rhomboides</i> (Linnaeus)	B	0	3 (2.1)	0	1 (12.4)	0	3 (0.3)
Pinfish	S	0	6 (2.3)	2 (8.1)	1 (6.1)	0	24 (4.7)

Table 2. Continued.

Species		Oct 1991 n = 7	Mar 1992 n = 7/6	May 1992 n = 3	Jun 1992 n = 3	Oct 1992 n = 3	Mar 1993 n = 3
<i>Lepomis macrochirus</i> Rafinesque	B	22 (25.4)	7 (104.0)	0	0	0	0
Bluegill	S	0	0	0	0	0	0
<i>Myrophis punctatus</i> Lutken	B	8 (4.5)	7 (6.6)	1 (1.0)	0	1 (0.8)	1 (0.9)
Speckled Worm Eel	S	1 (0.1)	3 (2.4)	1 (0.1)	0	0	1 (1.3)
<i>Gobionellus shufeldti</i> (Jordan & Eigenmann)	B	0	5 (10.9)	0	0	0	0
Freshwater Goby	S	0	15 (5.4)	0	0	0	0
<i>Symphurus plagiusa</i> (Linnaeus)	B	0	1 (0.3)	0	1 (0.0)	1 (0.6)	2 (0.7)
Blackcheek Tonguefish	S	8 (7.6)	1 (0.1)	0	1 (0.2)	4 (4.6)	0
<i>Paralichthys lethostigma</i> Jordan & Gilbert	B	0	1 (7.4)	0	0	0	0
Southern Flounder	S	0	8 (4.2)	5 (6.4)	0	0	3 (3.0)
<i>Sphoeroides parvus</i> Shipp & Yerger	B	0	0	1 (0.1)	0	0	0
Least Puffer	S	2 (10.8)	0	2 (0.7)	5 (7.7)	1 (2.7)	0
<i>Palaemonetes vulgaris</i> (Say)	B	0	5 (0.8)	0	0	0	1 (0.7)
Marsh Grass Shrimp	S	1 (0.1)	0	0	0	3 (0.3)	0
<i>Cynoscion nebulosus</i> (Cuvier)	B	1 (4.1)	0	0	1 (7.8)	1 (5.3)	0
Spotted Seatrout	S	2 (11.3)	1 (25.1)	0	0	3 (3.6)	0
<i>Fundulus jenkinsi</i> (Evermann)	B	0	8 (7.9)	0	0	0	0
Saltmarsh Topminnow	S	0	1 (0.6)	0	0	0	0
<i>Eucinostomus argenteus</i> Baird & Girard	B	4 (2.0)	0	0	0	0	0
Spotfin Mojarra	S	4 (0.2)	0	0	0	0	0
<i>Gobionellus oceanicus</i> (Pallas)	B	0	0	0	0	0	6 (5.2)
Highfin Goby	S	0	0	0	0	0	0
<i>Fundulus grandis</i> Baird & Girard	B	0	1 (3.9)	0	0	0	1 (7.7)
Gulf Killifish	S	0	2 (5.2)	0	0	0	0
<i>Cyprinodon variegatus</i> Lacepede	B	0	4 (7.0)	0	0	0	0
Sheepshead Minnow	S	0	0	0	0	0	0
<i>Micropterus salmoides</i> (Lacepede)	B	0	1 (105.9)	2 (3.4)	0	0	0
Largemouth Bass	S	0	0	0	0	0	0
<i>Fundulus pulvereus</i> (Evermann)	B	1 (0.0)	2 (3.2)	0	0	0	0
Bayou Killifish	S	0	0	0	0	0	0
<i>Trinectes maculatus</i> (Bloch & Schneider)	B	0	0	0	0	1 (0.1)	2 (0.2)
Hogchoker	S	0	0	0	0	0	0

Table 2. Continued.

Species		Oct 1991 n = 7	Mar 1992 n = 7/6	May 1992 n = 3	Jun 1992 n = 3	Oct 1992 n = 3	Mar 1993 n = 3
<i>Porichthys plectrodon</i> Jordan & Gilbert	B	0	0	0	0	0	0
Atlantic Midshipman	S	0	0	3 (0.4)	0	0	0
<i>Adinia xenica</i> (Jordan & Gilbert)	B	0	0	0	0	0	0
Diamond Killifish	S	1 (0.3)	1 (0.8)	0	0	0	0
<i>Bairdiella chrysoura</i> (Lacepede)	B	0	0	0	2 (4.4)	0	0
Silver Perch	S	0	0	0	0	1 (1.6)	0
<i>Achirus lineatus</i> (Linnaeus)	B	0	0	0	0	2 (0.2)	0
Lined Sole	S	0	0	0	0	0	0
<i>Arius felis</i> (Linnaeus)	B	0	0	0	0	0	0
Hardhead Catfish	S	0	0	0	0	2 (12.9)	0
<i>Menticirrhus americanus</i> (Linnaeus)	B	0	0	0	0	2 (0.6)	0
Southern Kingfish	S	0	0	0	0	0	0
<i>Ameiurus natalis</i> (Lesueur)	B	1 (66.5)	0	0	0	0	0
Yellow Bullhead	S	0	0	0	0	0	0
<i>Mugil cephalus</i> Linnaeus	B	0	0	0	0	0	0
Striped Mullet	S	0	1 (21.6)	0	0	0	0
<i>Fundulus similis</i> (Baird & Girard)	B	0	0	0	0	1 (0.9)	0
Longnose Killifish	S	0	0	0	0	0	0
<i>Sciaenops ocellatus</i> (Linnaeus)	B	0	0	0	0	0	0
Red Drum	S	0	0	1 (8.2)	0	0	0
<i>Syngnathus louisianae</i> Gunther	B	0	0	0	0	1 (0.8)	0
Chain Pipefish	S	0	0	0	0	0	0
<i>Elops saurus</i> Linnaeus	B	0	0	0	0	0	0
Ladyfish	S	0	0	1 (0.1)	0	0	0
<i>Cynoscion arenarius</i> Ginsburg	B	1 (1.2)	0	0	0	0	0
Sand Seatrout	S	0	0	0	0	0	0
<i>Palaemonetes intermedius</i> Holthuis	B	0	0	0	0	0	0
Brackish Grass Shrimp	S	0	0	0	0	1 (0.1)	0
Totals	B	1,401 (332.6)	3,477 (1,347.8)	515 (206.5)	1,202 (608.2)	671 (387.6)	819 (222.8)
	S	325 (156.5)	1,980 (856.0)	262 (187.1)	332 (47.1)	334 (139.2)	1,722 (394.1)

Table 3. Results of regression analyses in which abundance of each dominant species was regressed with maximum canal depth. Spring and fall data were analyzed separately. $n = 6$ for Saline Canal in March 1992 and $n = 7$ for all others. Data are not given for months when species were not numerically dominant.

Species	October 1991		March 1992	
	R ²	<i>p</i>	R ²	<i>p</i>
Brackish Canals				
Bay anchovy	0.000	0.99	0.567	0.05
Daggerblade grass shrimp	0.009	0.84	0.099	0.49
Blue crab	0.055	0.61	0.014	0.80
Rainwater killifish	0.103	0.48	0.233	0.27
Gulf menhaden	—	—	0.014	0.80
Saline Canals				
Bay anchovy	0.507	0.11		
Daggerblade grass shrimp	0.056	0.65	0.016	0.81
Blue crab	0.000	0.99	0.000	0.97
White shrimp	0.041	0.70	—	—
Gulf menhaden	—	—	0.475	0.13
Atlantic croaker	—	—	0.199	0.38

Primary Hypotheses

Variation in the abundance of numerically dominant species could not be related to maximum canal depth except for one species (Hypothesis 1; Table 3). All of the regression models with high R² values depicted a relationship of increasing animal abundance with canal depth. None of these data support an inverse relationship between nekton abundance and maximum canal depth as we had hypothesized. Bay anchovy abundance increased with canal depth in March but only in brackish canals. Relatively high R² values were also obtained in saline canals for bay anchovy in October and gulf menhaden in March, but these models were not statistically significant (Table 3, $p > 0.10$).

Within the same canal, however, the distribution of several species was influenced by habitat depth (Tables 4–6), and the degree of habitat segregation with depth was largely an interaction among salinity, depth, and SAV. The degree of habitat segregation with depth was most pronounced in brackish canals during late spring and summer when SAV was present (Tables 4 and 6). Prior to hurricane passage in August 1992, densities of most dominant species (naked goby, rainwater killifish, gulf pipefish, blue crab, and daggerblade grass shrimp) were greater where SAV was present, usually in shallow water (<1 m). Although average densities of naked goby and rainwater killifish in shallow and deep habitats were not significantly different in June, this result was due to the distribution of SAV at the time. Densities of these two species at depths >1 m were very low ($\leq 1/m^2$) in all but one of the canals we sampled. Unlike the other two canals, this one had SAV present in water >1 m deep, and where SAV

occurred in the deep habitat, densities of naked goby and rainwater killifish were 27 and 29/m², respectively. After most SAV was removed by the hurricane, only one species (naked goby) showed a preference for the shallow habitat (Table 6). The removal of SAV by the hurricane caused naked goby to retreat from the deep areas it had occupied during the summer (Figure 2). Other species that have a great affinity for SAV (e.g., rainwater killifish and gulf pipefish) completely disappeared along with the vegetation. In saline canals, juvenile blue crabs and daggerblade grass shrimp selected shallow habitats in March (Tables 5 and 6), an indication that these species truly prefer shallow water habitats even when SAV is not present. Bay anchovy was the only abundant fish species in saline canals for which a relationship between water depth and density could be shown, and the relationship was one of greater abundance in deep water in June (Table 6).

Sampling Efficacy and Efficiency

The efficacy of the throw trap was not reduced in deep water. In fact, highest catches were obtained when sampling at a depth of 1.5 m (Figure 3; ANOVA: 4,35 d.f.; $F=3.884$; $p=0.01$). The mean catch at 1.5 m exceeded the actual density of killifish (11.7 fish/m²) in the experimental tank by 10%, whereas mean catches at other depths ranged from 59–74% of the actual density.

The efficiency of clearing the throw trap in the field was high for both species tested, although the recovery rate for daggerblade grass shrimp was less than that for killifish (Figure 4). Clearing efficiency was not in-

Table 4. Numerically dominant species of nekton collected in subtidal habitats of pipeline canals within brackish marshes. Means (\pm one standard error of the mean) are given for each species, total fishes, and total decapods for each depth range sampled in each sampling period. Sample size was 2 m² and means were calculated from 3 observations. Data are not given for months when species were not numerically dominant.

Taxon	<0.5 m	<1.0 m	<1.5 m	≥ 1.5 m	<0.5 m	<1.0 m	<1.5 m	≥ 1.5 m
	May 1992				June 1992			
Bay anchovy	0	2.3 \pm 2.3	1.0 \pm 1.0	6.3 \pm 4.9	0.3 \pm 0.3	0.7 \pm 0.7	12.0 \pm 6.7	11.0 \pm 10.0
Daggerblade grass shrimp	38.3 \pm 13.9	3.0 \pm 1.0	0	0.3 \pm 0.3	46.0 \pm 21.6	3.7 \pm 3.2	3.0 \pm 1.7	0
Naked goby	5.3 \pm 3.4	3.7 \pm 0.3	0.7 \pm 0.7	0	9.7 \pm 4.1	17.3 \pm 4.5	18.3 \pm 17.8	0.3 \pm 0.3
Blue crab	11.0 \pm 4.4	14.0 \pm 3.6	1.7 \pm 1.2	0.7 \pm 0.7				
Rainwater killifish	17.0 \pm 9.6	12.0 \pm 7.6	1.0 \pm 1.0	0	66.7 \pm 28.8	59.7 \pm 30.4	19.7 \pm 19.2	0.7 \pm 0.7
Gulf pipefish	10.7 \pm 7.2	8.0 \pm 7.5	1.3 \pm 1.3	0	7.7 \pm 2.6	11.0 \pm 4.7	0.7 \pm 0.7	0
Brown shrimp	8.0 \pm 0.6	6.3 \pm 4.9	2.3 \pm 1.3	0.7 \pm 0.3				
Total fish	34.0 \pm 16.3	36.7 \pm 20.8	7.3 \pm 5.0	7.3 \pm 5.0	155.3 \pm 76.7	98.7 \pm 37.2	62.7 \pm 55.3	12.7 \pm 10.7
Total decapods	57.3 \pm 18.5	23.3 \pm 4.8	4.0 \pm 2.5	1.7 \pm 0.3	55.7 \pm 23.2	7.3 \pm 3.4	7.7 \pm 4.3	0.7 \pm 0.3
	October 1992				March 1993			
Bay anchovy	24.7 \pm 11.5	19.7 \pm 16.7	21.3 \pm 20.3	67.3 \pm 54.4	3.7 \pm 3.7	2.3 \pm 0.9	12.3 \pm 7.0	3.7 \pm 2.0
Daggerblade grass shrimp	8.3 \pm 8.3	0	0	0	175.0 \pm 173.5	0.3 \pm 0.3	0.3 \pm 0.3	0.7 \pm 0.3
Naked goby	12.3 \pm 2.8	9.7 \pm 0.9	1.0 \pm 1.0	1.7 \pm 1.2	16.7 \pm 9.7	4.3 \pm 0.9	1.7 \pm 1.7	2.3 \pm 2.3
Blue crab	11.0 \pm 4.4	14.0 \pm 3.6	1.7 \pm 1.2	0.7 \pm 0.7	15.0 \pm 11.1	4.7 \pm 1.8	5.7 \pm 2.6	3.3 \pm 0.9
Total fish	44.3 \pm 13.2	32.0 \pm 15.0	23.7 \pm 20.2	71.3 \pm 52.5	25.7 \pm 9.3	11.3 \pm 2.4	19.7 \pm 5.2	9.7 \pm 5.0
Total decapods	31.7 \pm 11.4	9.7 \pm 5.0	5.7 \pm 3.0	8.0 \pm 5.0	190.0 \pm 184.5	5.0 \pm 2.1	7.0 \pm 3.2	4.7 \pm 1.5

Table 5. Numerically dominant species of nekton collected in subtidal habitats of pipeline canals within saline marshes. Means (\pm one standard error of the mean) are given for each species, total fishes, and total decapods for each depth range sampled in each sampling period. Sample size was 2 m² and means were calculated from 3 observations. Data are not given for months when species were not numerically dominant.

Taxon	<0.5 m	<1.0 m	<1.5 m	≥ 1.5 m	<0.5 m	<1.0 m	<1.5 m	≥ 1.5 m
	May 1992				June 1992			
Bay anchovy	0	25.7 \pm 7.3	14.3 \pm 4.7	23.3 \pm 11.6	0.3 \pm 0.3	0	13.3 \pm 10.9	85.7 \pm 45.3
Blue crab					1.3 \pm 0.7	2.0 \pm 0.0	0	1.0 \pm 1.0
Brown shrimp	2.0 \pm 1.2	1.7 \pm 1.2	3.7 \pm 1.8	5.0 \pm 2.6				
Total fish	0.3 \pm 0.3	30.0 \pm 8.5	16.0 \pm 5.9	25.3 \pm 12.0	2.6 \pm 1.2	1.0 \pm 0.6	14.0 \pm 10.6	86.0 \pm 45.0
Total decapods	4.3 \pm 1.2	2.3 \pm 0.9	3.7 \pm 1.8	5.3 \pm 2.6	3.0 \pm 2.1	2.3 \pm 0.3	0.3 \pm 0.3	1.3 \pm 1.3
	October 1992				March 1993			
Bay anchovy	4.7 \pm 2.4	11.3 \pm 7.5	4.0 \pm 2.0	30.3 \pm 12.7				
Blue crab	3.0 \pm 1.5	4.3 \pm 3.0	3.0 \pm 2.0	3.3 \pm 4.9	18.3 \pm 6.5	6.7 \pm 5.2	1.3 \pm 0.3	3.7 \pm 0.3
Daggerblade grass shrimp	2.0 \pm 1.2	0	0	16.3 \pm 16.3	256.0 \pm 117.8	66.0 \pm 53.3	7.7 \pm 2.8	5.7 \pm 2.8
Gulf menhaden					4.1 \pm 0.8	2.3 \pm 1.2	1.6 \pm 0.9	1.5 \pm 1.5
White shrimp	11.7 \pm 11.2	1.7 \pm 1.7	1.0 \pm 0.6	3.0 \pm 2.1				
Atlantic croaker					2.3 \pm 1.9	0.7 \pm 0.7	2.7 \pm 1.8	3.3 \pm 0.7
Total fish	6.7 \pm 3.3	12.7 \pm 6.9	5.3 \pm 1.7	33.0 \pm 11.5	112.0 \pm 63.5	43.3 \pm 22.2	16.3 \pm 4.9	34.0 \pm 24.6
Total decapods	18.3 \pm 10.0	7.0 \pm 2.1	4.7 \pm 2.0	25.0 \pm 21.5	5.3 \pm 0.6	3.5 \pm 1.0	2.2 \pm 0.4	2.2 \pm 0.3

Table 6. Results of the ANOVA *a priori* Contrasts of differences in mean densities between shallow (<1 m) and deep (≥ 1 m) subtidal habitats of pipeline canals within brackish and saline marshes. The F- and *p*-values are given for each variable tested and for each sampling period. Degrees of freedom = 1,8. NS = Main Effect (Depth) not significant. Underscored values = significant difference (adjusted *p* < 0.10). Data are not given for months when species were not numerically dominant.

Variable	May 1992		June 1992		October 1992		March 1993	
	F	<i>p</i>	F	<i>p</i>	F	<i>p</i>	F	<i>p</i>
Brackish Canals								
Total fish		NS		NS		NS		NS
Bay anchovy		NS		NS		NS		NS
Naked goby	16.834	<u>0.003</u>		NS	28.332	<u>0.001</u>	7.642	<u>0.025</u>
Rainwater killifish	14.99	<u>0.005</u>		NS	—	—	—	—
Gulf pipefish		NS	37.509	<u>0.000</u>	—	—	—	—
Total decapods	55.978	<u>0.000</u>	13.118	<u>0.007</u>		NS		NS
Daggerblade grass shrimp	91.099	<u>0.000</u>	12.414	<u>0.008</u>		NS		NS
Blue crab	26.225	<u>0.001</u>	—	—		NS		NS
Brown shrimp		NS	—	—	—	—	—	—
Saline Canals								
Total fish	4.672	0.063	14.036	<u>0.006</u>		NS		NS
Bay anchovy	5.268	0.051	19.759	<u>0.002</u>		NS	—	—
Gulf menhaden	—	—	—	—	—	—		NS
Atlantic croaker	—	—	—	—	—	—		NS
Total decapods		NS		NS		NS	12.058	<u>0.008</u>
Blue crab	—	—		NS		NS	5.973	<u>0.040</u>
Daggerblade grass shrimp	—	—	—	—		NS	8.719	<u>0.018</u>
Brown shrimp		NS	—	—	—	—	—	—
White shrimp	—	—	—	—		NS	—	—

fluenced by water depth for either species (Figure 4; ANOVA—killifish: 2,6 d.f.; $F=1.000$; $p=0.42$; grass shrimp: 2,6 d.f.; $F=0.174$; $p=0.84$).

DISCUSSION

Our results and previous studies (Loesch 1965, Mock 1966, Baltz et al. 1993, Ruiz et al. 1993) document the selection of shallow subtidal habitats by some estuarine species. Although several species in our study preferred shallow habitats in brackish canals due to their association with SAV, shallow water (<1 m) devoid of SAV was selected by daggerblade grass shrimp and blue crabs in saline canals and naked goby in brackish canals. Likewise, Ruiz et al. (1993) reported significantly higher densities of several small species including daggerblade grass shrimp and naked goby on non-vegetated sediments in water depths <70 cm. Although they found large blue crabs preferred water >70 cm deep, the proportion of small juvenile blue crabs decreased with water depth in their study as well. Small fishes and crustaceans vulnerable to predation may concentrate in shallow water to avoid large aquatic predators (Schlosser 1987, McIvor and Odum 1988, Baltz et al. 1993). Ruiz et al. (1993) reported that aquatic predators of small fishes and crustaceans were often more abundant in deep water, and the mortality of

tethered daggerblade grass shrimp and small blue crabs increased significantly with depth.

In our study canals, water depth was confounded not only with SAV, but also with distance to the marsh edge, and all of these factors may effect the distribution of nekton. Baltz et al. (1993) found greatest densities of early life stages of fishes in shallow water near the marsh-edge interface. The proximity of the marsh vegetation was an important influence on habitat selection in their study. We attempted to remove the influence of the marsh edge by avoiding sample areas near the marsh because backfilling canals will create broad, shallow water bodies in which most subtidal habitat will be remote from the surrounding marsh. Had our shallow sample sites been adjacent to the marsh edge, we may have found more species showing a preference for shallow subtidal habitats.

In brackish canals, where (prior to the hurricane) the shallow subtidal always contained submerged vegetation, five species (naked goby, rainwater killifish, gulf pipefish, daggerblade grass shrimp, and blue crab) showed a preference for shallow water. Predator encounter rates can be very high in unvegetated areas of pipeline canals, even in water < 1 m deep (Rozas 1992). Small organisms vulnerable to predation may be attracted to submerged vegetation because it affords added protection from predators as well as a food-rich

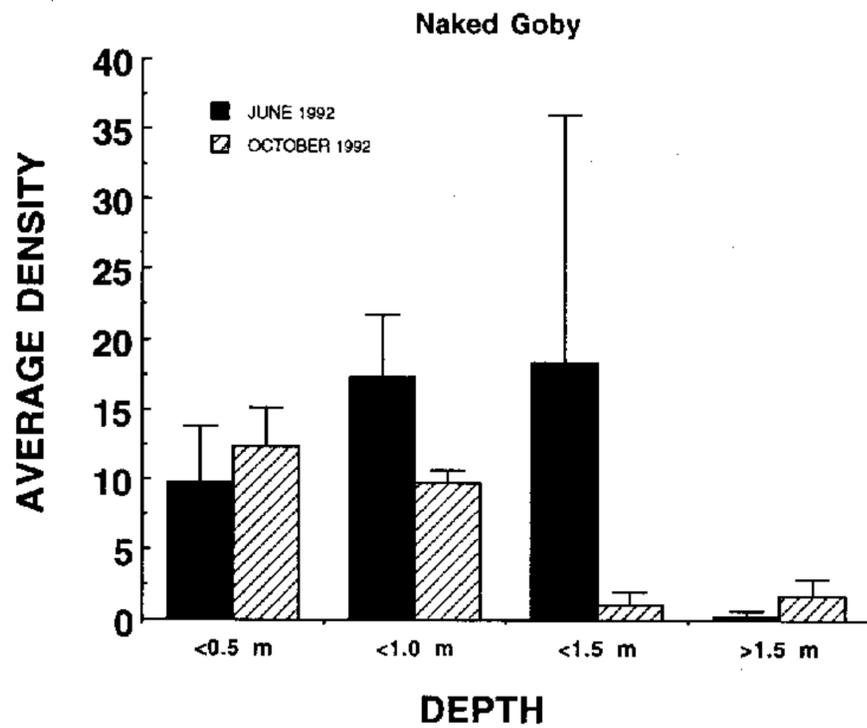


Figure 2. Average densities of naked goby (fish/2 m²) found in shallow and deep habitats of brackish canals before (June) and after (October) the passage of Hurricane Andrew removed SAV from the area.

environment (Rozas and Odum 1988, Lubbers et al. 1990, Fredette et al. 1991). Both water depth and the presence of SAV could have influenced the distribution of animals in brackish canals. However, the patterns we observed before and after the passage of Hurricane Andrew suggest that SAV may have a stronger influence on the distribution of animals than water depth. After the SAV was removed from brackish canals, only one of the five species (naked goby) showed a preference for shallow water, and two species (rainwater killifish and gulf pipefish) completely disappeared. In the aftermath of a hurricane that struck coastal Louisiana

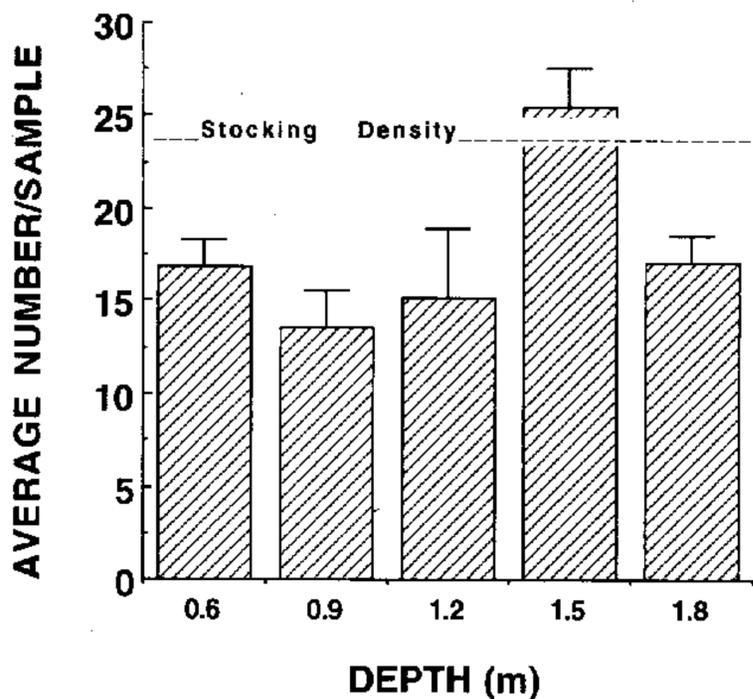


Figure 3. Results of the estimation of 2-m² throw trap efficacy showing the average number of gulf killifish captured with the throw trap at a range of water depths. Fish were sampled eight times at each depth. The stocking density was 23.4 fish/2 m². Error bars equal one standard error (1 S. E.).

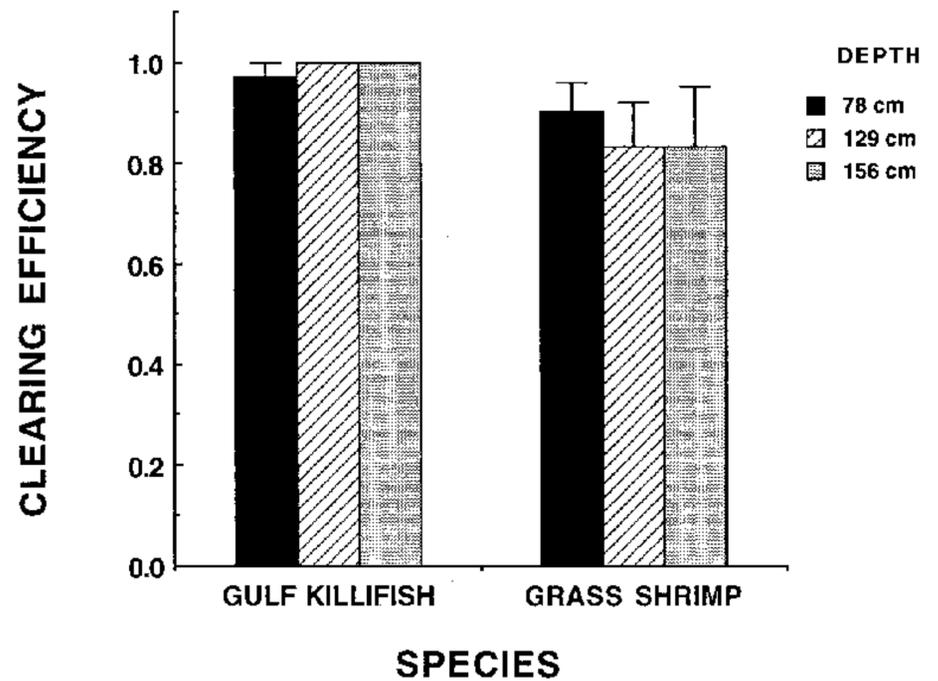


Figure 4. Estimation of the efficiency of removing animals from the throw trap with a clearing net. The proportions of gulf killifish and grass shrimp retrieved from the trap are plotted for three different average water depths in which experiments were conducted. Experiments were replicated three times at each depth for each species. Error bars equal 1 S. E.

in August 1969, Chabreck and Palmisano (1973) also observed a drastic decline in the relative abundance of SAV in marsh ponds and lakes. Our study documents the dramatic change such an event may have on the nekton assemblages of habitats containing SAV.

Species dominating the assemblages in pipeline canals are common in estuaries of the northern Gulf of Mexico (Adkins and Bowman 1976, Neill and Turner 1987b, Rozas 1992). Because our study was confined to open-water habitats, and we purposefully avoided sampling along the marsh edge, pelagic species (e.g., bay anchovy and gulf menhaden) dominated our samples, especially those of saline canals that lacked SAV. Many common estuarine taxa that dominate marsh-surface habitats, e.g., cyprinodonts (Hettler 1989, Kneib 1991, Rozas 1993, Rozas and Reed 1993, Peterson and Turner 1994), were uncommon in our study, with the exception of rainwater killifish. Interestingly, green gobies *Microgobius thalassinus* were common in pipeline canals, but this species is considered rare along the northern Gulf coast (Hoese and Moore 1977).

Brackish and saline canals differed both in terms of average salinity and the presence of SAV, which was dependent on the salinity regime of the canals. Both factors could affect the distribution of some species and may explain differences in species density between brackish and saline canals. High salinities undoubtedly excluded some freshwater species from saline canals. For example, bluegill *Lepomis macrochirus*, largemouth bass *Micropterus salmoides*, and yellow bullhead *Ameiurus natalis* were collected only in brackish canals. Redear sunfish *Lepomis microlophus*, although

present in saline canals, were much more abundant in brackish canals. Other studies of low salinity estuarine habitats have documented high densities of early life stages of centrarchids and ictalurids in SAV (Weaver and Holloway 1974, Rozas and Odum 1987). The apparent preference for brackish canals by gulf pipefish and rainwater killifish was likely due to the presence of SAV there and not to differences in salinity. Both species are euryhaline, and the salinities encountered in saline canals are well within their range of tolerance. In a study of brackish marsh ponds with similar salinities, Weaver and Holloway (1974) found much higher densities of gulf pipefish and rainwater killifish in vegetated than unvegetated ponds. Further evidence for their strong association with submerged vegetation was the dramatic decline of gulf pipefish and rainwater killifish in brackish canals when SAV disappeared following passage of Hurricane Andrew in August 1992.

Early life stages and small adults of fishes and decapod crustaceans residing in subtidal habitats <2 m deep were effectively sampled using the 2-m² throw trap. Increasing water depth to 1.8 m did not decrease sampling efficacy for small organisms, and the efficiency of removing organisms with the clearing net (83–100%) was comparable to other methods using bar seines or dip nets (Freeman et al. 1984, Zimmerman et al. 1984, Rozas and Odum 1987).

Management Implications

Given the large area of Louisiana coastal wetlands occupied by canals and associated dredged material levees (80,426 ha or approximately 8.6% of the wetland area in 1978, Baumann and Turner 1990), the potential for restoring nursery habitat through canal backfilling is enormous (Turner et al. 1994). Backfilling canals would decrease deep subtidal area and increase shallow habitat. The resulting mean depths of most canals in our study area would be less than 1 m (Reed and Rozas 1994). Similar results of backfilling were reported in other studies of canals in coastal Louisiana. Backfilling a 56-km long pipeline canal resulted in mean depths of 67 and 60 cm in brackish and saline sections, respectively (Abernethy and Gosselink 1988). In a study of oil and gas access canals, Neill and Turner (1987a) found that after backfilling, most canals (81%) had an average depth \leq 1 m. Our results suggest that increasing shallow subtidal habitat in canals at the expense of deep areas would enhance the value of nursery habitat for some species, especially in brackish canals where backfilling would expand the subtidal area capable of supporting SAV. Abernethy and Gosselink (1988) reported that four years after backfilling, SAV covered 23% of the bottom in the brackish section of a pipeline canal, but it was rarely observed in the saline section.

Increasing the abundance of SAV in backfilled canals would also enhance habitat quality for waterfowl, which use submerged vegetation as food (Chabreck 1971, Neill and Turner 1987a). Our study suggests that only bay anchovy might be negatively affected by a reduction in deep habitats, as they preferred deep water during some times of the year. However, our study did not evaluate the affect of backfilling on large aquatic predators (e.g., adult spotted seatrout *Cynoscion nebulosus*) which may also use the deep areas of pipeline canals.

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