NOAA Technical Memorandum NMFS - SEFC - 236

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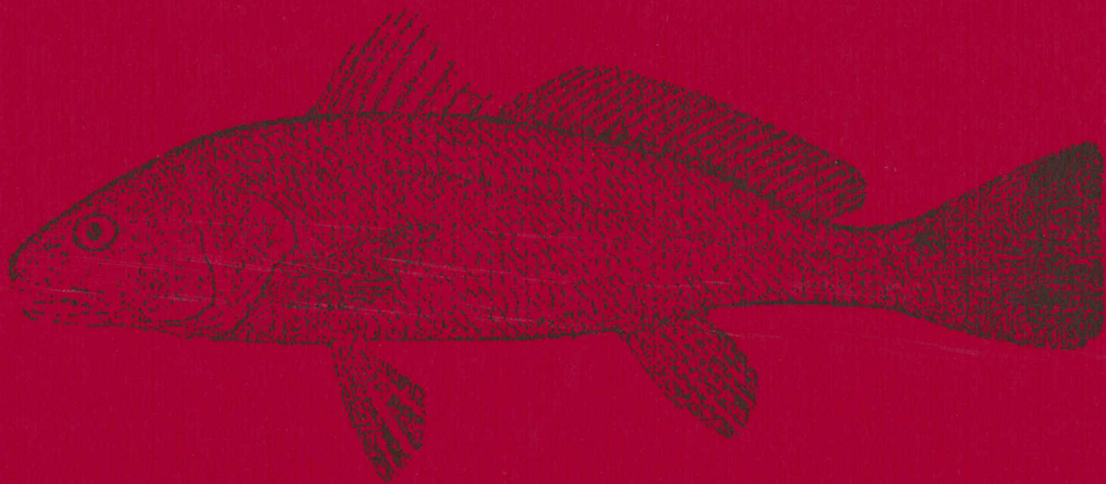

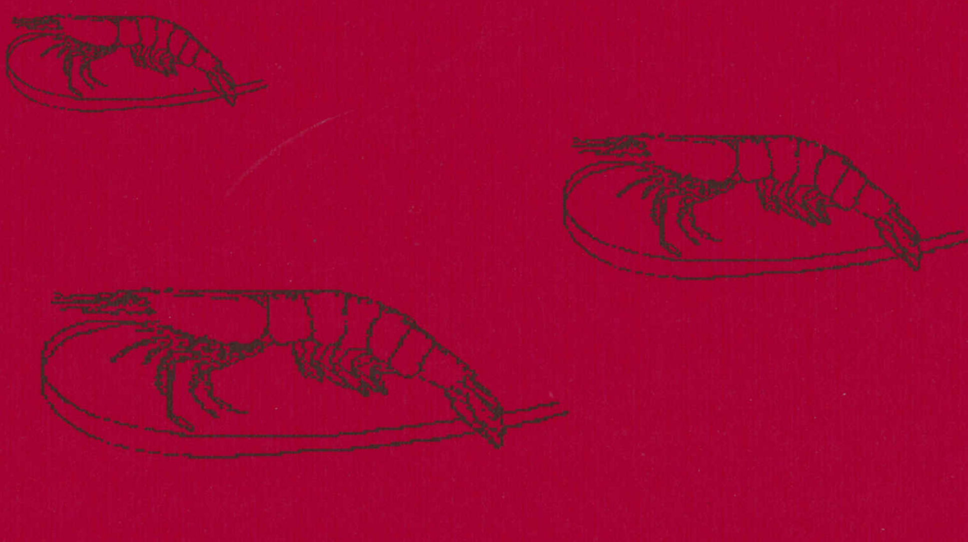

AUGUST 1989

GALVESTON LABORATORY

SOUTHEAST FISHERIES CENTER

NATIONAL MARINE FISHERIES SERVICE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

DEPARTMENT OF COMMERCE

NOAA TECHNICAL MEMORANDUM
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Habitat-Related Differences in Diets of Small Fishes in Lavaca Bay, Texas, 1985-1986

BY

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AUGUST 1989

ACKNOWLEDGEMENTS

This project is the result of cooperative research between NOAA's National Marine Fisheries Service Galveston Laboratory in the Southeast Fisheries Center and the Texas Water Development Board and The Texas Parks and Wildlife Department. Both state agencies have been mandated to study the effects and needs of freshwater inflow to the State's estuaries by House Bill 2 (1985) and Senate Bill 683 (1987) enacted by the Texas Legislature. As part of this program, a portion of this research was funded through the Texas Water Development Board's Water Research and Planning Fund, authorized under Texas Water Code Sections 15.402 and 16.058 (e), and administered by the Texas Parks and Wildlife Department under interagency cooperative contract No. IAC(86-87)1590. Additional acknowledgements are due E. Martinez, J. Kostera, R. Barry, J. Thomas, D. Smith, P. Barrick, D. Prior for their assistance in the collection and analysis of samples.

This report should be cited as follows:

Minello, T.J., R.J. Zimmerman and T.E. Czapla. 1989. Habitat-related differences in diets of small fishes in Lavaca Bay, Texas, 1985-1986. NOAA Technical Memorandum NMFS-SEFC-236, 16 p.

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ABSTRACT

The stomach contents of fishes collected in drop samples and trawls were examined to determine whether dietary patterns varied in relation to habitats in Lavaca Bay. The diets of fishes collected in delta areas, near the mouth of the Lavaca River, were compared with those collected in coastal areas during October 1985, May 1986, and August 1986. A qualitative analysis of feeding patterns of individual fish species did not reveal any habitat-related differences. In part, this may have been due to small sample sizes for many species. A consistent pattern in the data combined for all fish species examined, however, suggested that the quantity of food eaten at coastal sites was larger than at delta sites. Dominant fish predators on penaeid shrimp included the southern flounder, inshore lizardfish, spotted seatrout, and sand seatrout. Most of the shrimp were eaten at coastal sites even though fish predators and shrimp were abundant at both delta and coastal sites. These data suggest that habitat characteristics at delta sites may offer shrimp more protection from predation.

INTRODUCTION

An examination of the diet of estuarine fishes in conjunction with estimates of prey abundance and distribution can be useful in determining the nutritional capacity of habitats for these fish and the protective nature of habitats for particular prey species. The availability of vegetative structure (Stoner 1979, Coen et. al. 1981, Heck and Thoman 1981), appropriate substrata for burrowing (Stein and Magnuson 1976), and the turbidity of the water (Moore and Moore 1976, Gardner 1981) have all been shown to alter predator-prey interactions. These factors have also been shown to alter feeding rates of estuarine fishes on juvenile penaeid shrimp (Minello and Zimmerman 1983, 1984, Zimmerman and Minello 1984, Minello et. al. 1987). Freshwater inflow and the associated sediment load affects these habitat characteristics, and the proximity of particular locations in an estuary to the source of freshwater can control the vegetation type, sediment characteristics, and perhaps the turbidity.

A major objective of our research program on the effects of freshwater inflow in estuaries is to compare habitats located near sources of freshwater with more marine habitats. In Lavaca Bay, Texas, the abundance of crustaceans and small fishes in nearshore and marsh habitats located near the Lavaca River delta were compared with similar habitats in areas of higher salinity, closer to Matagorda Bay and the Gulf of Mexico. As a part of this project, the stomach contents of small estuarine fishes collected in these upper bay and lower bay areas were examined for possible habitat-related dietary patterns.

METHODS AND MATERIALS

Fishes for dietary analyses were obtained from drop samples collected both in vegetated and nonvegetated shallow shoreline areas. A small trawl was also used to collect additional fish from the shallow waters along these shorelines. The samples were collected at three delta sites near the mouth of the Lavaca River and at three coastal sites in the lower bay nearer the Gulf (Figure 1). Four vegetated and four nonvegetated drop samples (2.6 m^2 each) were collected at each site along with one or more trawl samples. Trawl samples were taken to obtain an adequate number of fish for stomach analyses, and therefore trawl durations were adjusted in relation to the number of fish collected. Because of this variable sampling effort and the relatively poor catch efficiency of trawls, comparisons of the number of fish collected at the sites were made only from drop-sample data. A complete set of samples was collected in October 1985 and May 1986. During August 1986, low water levels prevented the collection of samples at vegetated delta sites, and therefore only nonvegetated samples from both coastal and delta sites were analyzed for this sampling period. The fish selected for analysis were chosen on the basis of their abundance and on their potential impact on fishery species i.e. they were known or suspected predators on important commercial or recreational species of prey, mainly juvenile shrimp, crabs and fishes. All fish collected and the species targeted for stomach analyses are listed in Table 1. Fishes were preserved in the field with a 10% Formalin solution. In the laboratory, fish were identified and total length was measured to the nearest 1 mm. Stomach contents were examined from all specimens in a targeted fish species, with the exception of individuals which were mutilated in the collection process. Stomachs were dissected and the contents were identified, counted, and separated into taxa for drying. Annelids were weighed but not counted due to fragmentation in guts. Both prey and predators were dried at 100° C for 24 hours or until a constant dry weight was obtained. Within samples, food items from fish of similar sizes were combined to obtain an overall estimate of dry weight of prey for that particular size group of predator. The data were examined for trends in feeding patterns, but statistical analyses were restricted to some of the summary data due to the large number of missing data points, the small number of fish collected, and the non-normal and heteroscedastic nature of the data. A log transformation of the data was used to reduce the positive relationship between the variance and the mean.

Figure 1. Sampling sites in Lavaca Bay, Texas

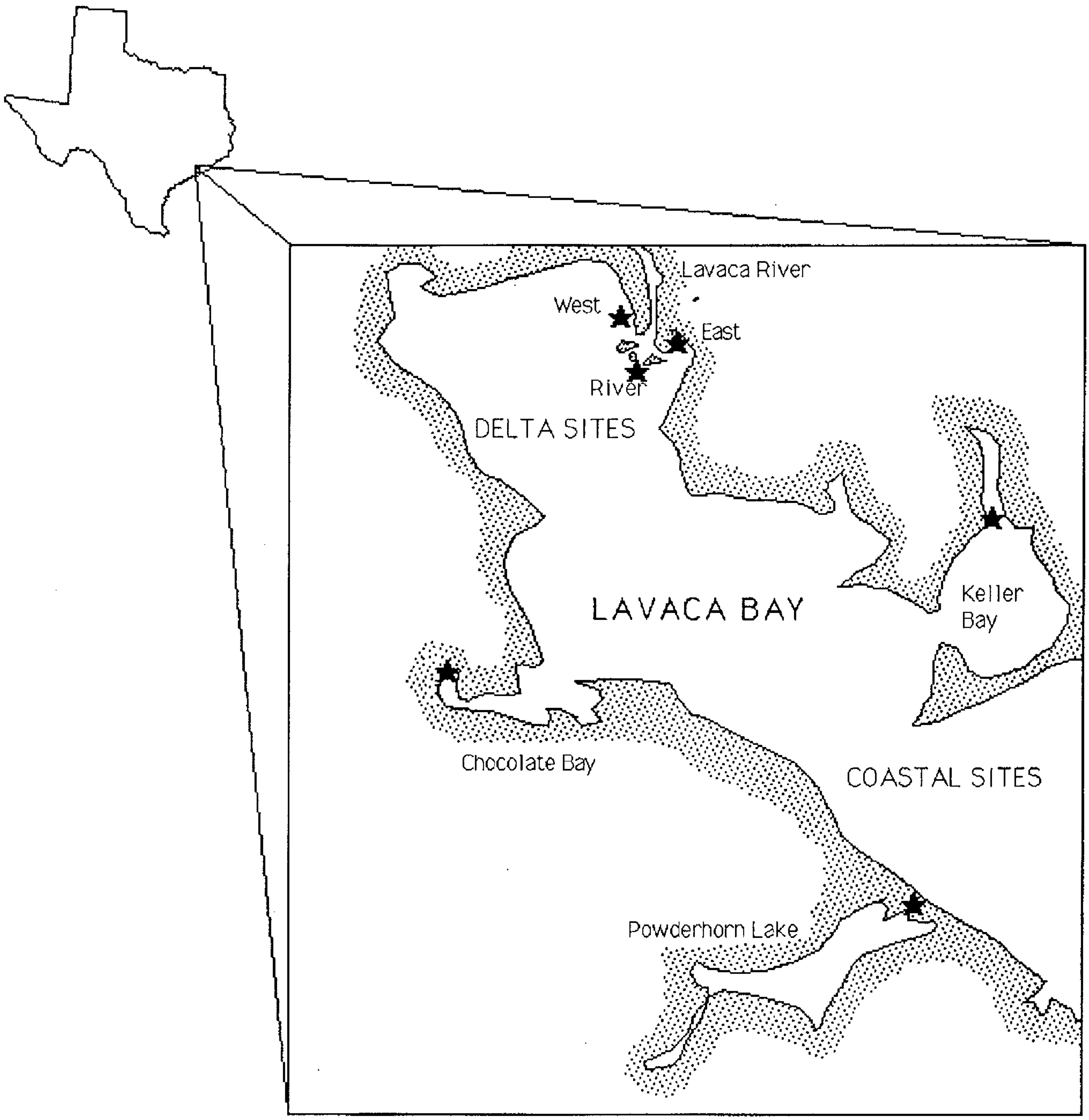

Table 1. Fish collected using the drop sampler and a trawl in Lavaca Bay during 1985-1986. Total number caught is given for Delta and Coastal sites during each sampling period. Fish are ranked according to the total number collected. Asterisks (*) indicate fish predators examined for stomach contents.

		OCTOBER			MAY			AUGUST			
Common Name	Scientific Name	Delta	Coastal	Sum	Delta	Coastal	Sum	Delta	Coastal	Sum	Year
Naked goby	*Gobiosoma bosci*	400	120	520	51	52	103	54	3	57	680
Bay anchovy	*Anchoa mitchilli*	267	161	428	66	77	143	0	0	0	571
Gulf menhaden	*Brevoortia patronus*	0	14	14	263	197	460	0	0	0	474
* Spot	*Leiostomus xanthurus*	3	49	52	106	182	288	19	46	65	405
* Pinfish	*Lagodon rhomboides*	0	6	6	57	121	178	16	21	37	221
* Atlantic croaker	*Micropogonias undulatus*	5	4	9	49	80	129	31	2	33	171
Darter goby	*Gobionellus boleosoma*	8	94	102	2	12	14	0	17	17	133
Chain pipefish	*Syngnathus louisianae*	0	6	6	1	1	2	91	5	96	104
* Silver perch	*Bairdiella chrysoura*	1	2	3	5	59	64	1	2	3	70
* Gulf killifish	*Fundulus grandis*	37	2	39	8	18	26	0	0	0	65
Inland silverside	*Menidia beryllina*	0	3	3	17	15	32	23	2	25	60
Blackcheek tonguefish	*Symphurus plagiusa*	26	17	43	0	2	2	2	6	8	53
Striped mullet	*Mugil cephalus*	0	5	5	0	2	2	0	30	30	37
Least puffer	*Sphoeroides parvus*	3	22	25	9	2	11	0	0	0	36
Clown goby	*Microgobius gulosus*	23	12	35	0	0	0	0	0	0	35
* Southern flounder	*Paralichthys lethostigma*	0	0	0	13	8	21	4	2	6	27
* Sand seatrout	*Cynoscion arenarius*	0	0	0	0	1	1	7	16	23	24
* Spotted seatrout	*Cynoscion nebulosus*	9	10	19	0	1	0	0	3	3	23
Diamond killifish	*Adinia xenica*	19	0	19	0	1	1	0	0	0	20
Hardhead catfish	*Arius felis*	3	0	3	9	5	14	0	0	0	17
Gulf toadfish	*Opsanus beta*	0	0	0	12	1	13	0	0	0	13
Spotfin mojarra	*Eucinostomus argenteus*	4	8	12	0	0	0	1	0	1	13
* Pigfish	*Orthopristis chrysoptera*	0	0	0	1	6	7	0	2	2	9
* Inshore lizardfish	*Synodus foetens*	1	7	8	0	1	1	0	0	0	9
Gulf pipefish	*Syngnathus scovelli*	0	3	3	0	6	6	0	0	0	9
Speckled Worm eel	*Myrophis punctatus*	4	0	4	1	0	1	3	0	3	8
Bay whiff	*Citharichthys spilopterus*	1	1	2	2	3	5	0	0	0	7
Atlantic threadfin	*Polydactylus octonemus*	0	0	0	1	6	7	0	0	0	7
Sheepshead minnow	*Cyprinodon variegatus*	1	0	1	2	3	5	0	0	0	6
Lined sole	*Achirus lineatus*	0	2	2	0	0	0	0	4	4	6
Skilletfish	*Gobiesox strumosus*	2	0	2	0	3	3	0	0	0	5
* Longnose killifish	*Fundulus similis*	4	0	4	0	0	0	0	0	0	4
Bayou killifish	*Fundulus pulvereus*	4	0	4	0	0	0	0	0	0	4
Sheepshead	*Archosargus probatocephalus*	0	1	1	0	2	2	0	0	0	3
* Red drum	*Sciaenops ocellatus*	0	0	0	1	1	2	0	1	1	3
Frillfin goby	*Bathygobius soporator*	0	2	2	0	0	0	0	0	0	2
Threadfin shad	*Dorosoma petenense*	0	1	1	0	0	0	0	0	0	1
Atlantic spadefish	*Chaetodipterus faber*	0	0	0	0	1	1	0	0	0	1
Smooth puffer	*Lagocephalus laevigatus*	0	1	1	0	0	0	0	0	0	1
* Silver seatrout	*Cynoscion nothus*	0	0	0	0	0	0	0	1	1	1
Dusky pipefish	*Syngnathus floridae*	0	1	1	0	0	0	0	0	0	1
Crevalle	*Caranx hippos*	0	0	0	0	1	1	0	0	0	1
Code goby	*Gobiosoma robustum*	0	0	0	1	0	1	0	0	0	1
Bluntnose jack	*Hemicaranx amblyrhynchus*	1	0	1	0	0	0	0	0	0	1
Totals		826	554	1380	677	869	1546	252	163	415	3342

RESULTS

Diet of Individual Species

Spot

Most spot were collected during May, and approximately 97% of these fish were caught in the trawl. A total of 317 spot were examined and the predominate food items that could be identified were copepods and annelid worms (Table 2). Spot collected during August had been feeding almost exclusively on copepods. Only three relatively large specimens were collected on the delta in October, and these fish had been feeding on mysids. Juvenile spot have been found to feed on postlarval penaeid shrimp in Galveston Bay (Minello et. al., in press), but no penaeids were found in the fish examined from Lavaca Bay.

Pinfish

Most pinfish were also collected in May. A large portion of their stomach contents consisted of plant material, but these fish also fed upon a variety of invertebrates including relatively large numbers of copepods and amphipods (Table 2). Small numbers of penaeid shrimp and crabs were also found in the stomachs of some fish. There did not appear to be any major differences in the feeding patterns of fish collected at the delta in comparison with fish collected at coastal sites.

Atlantic Croaker

As with the spot and pinfish, most Atlantic croaker were collected in the May samples. A large percentage of the stomach contents of these fishes consisted of unidentifiable animal material (no chloroplasts). The dominant identifiable prey items were annelids, but fish and copepods were also present (Table 2).

Silver Perch

The majority of silver perch (84%) were collected during May in the coastal area with 67% occurring at one site (Keller Bay). Almost all of these fish were early juveniles, and they had been feeding upon a relatively wide variety of crustaceans including amphipods, tanaids, mysids, and copepods (Table 2).

Gulf Killifish

Fundulus grandis showed a strong affinity for vegetated habitats, and all specimens were collected in vegetated drop samples. Killifish are year-round residents of the marsh, and apparently many individuals do not migrate from the marsh surface at low tide but find refuge in small pools and in the burrows of other animals (Kneib 1986). This behavior may explain the lack of any specimens in our August samples, which were collected on nonvegetated bottom at low water levels. Overall, amphipods appeared to be the dominant prey item of this species (Table 2). During May, the fish collected at coastal sites were feeding mainly on amphipods, but over 90% of the food eaten by fish at delta sites consisted of insects.

Southern Flounder

A total of 27 southern flounder were collected, and most of these were juveniles (less than 120 mm, total length) caught during May. Penaeid shrimp were the dominant food of these fish, making up 76% and 92% of the weight of food eaten at delta and coastal sites, respectively (Table 2).

Spotted Seatrout

Most of the 23 spotted seatrout examined were collected in October. At coastal sites, penaeid shrimp were the dominant food item (Table 2), and at delta sites the fish had been feeding on mysids, caridean shrimp, and fish.

Sand Seatrout

Sand seatrout occurred mainly in the August samples, and all but one of the 23 fish examined was caught during this sampling period. These fish had been feeding mostly on mysids although fish prey made up a relatively large percentage of the weight of stomach contents at delta sites (Table 2). The one specimen caught during May had eaten four penaeid shrimp.

Inshore Lizardfish

The nine specimens of lizardfish were all collected with the trawl, and eight of the nine were caught in October. Although the density of these fish appeared low, they may be dominant predators of penaeid shrimp. The stomach contents of the fish examined consisted almost exclusively of penaeid shrimp and fish (Table 2).

Other species

Stomach contents of red drum, silver seatrout, and pigfish were also examined, but the small number of specimens collected made it difficult to characterize dietary patterns for these fish. A large number of small gobies (mostly under 25 mm, TL) was also collected (Table 1) in the drop samples, and although we did not target these fish for a detailed analysis, we examined stomach contents of 56 specimens from 3 species (naked goby, darter goby, clown goby). These fish had all been feeding on small infaunal and epifaunal organisms including amphipods, tanaids, mysids, copepods, and polychaetes.

Habitat-Related Patterns in the Amount of Food Eaten

Data on the weight of food eaten by individual fish species were highly variable, and this along with the lack of specimens at many sites made it difficult to detect differences between coastal and delta areas (Table 3). There was some indication from the May data that spot caught at coastal sites had been eating more than spot caught at delta sites. There was a consistent difference in the weight of food eaten per gram of fish between these two areas, although the t-test between means was not significant at the 5% level (Table 3). Combining the data for all the fish species examined reduced some of the problems related to unequal sample size (Table 4). In October the weight of food eaten per fish was significantly greater in the coastal area (31.6 g) compared with the delta area (21.7 g) of the bay. A large portion of this difference, however, appeared to be related to a difference (not significant) in the size of fish collected in the two areas. When the weight of food eaten was corrected for the weight of the fish, mean values were still larger in the coastal area, but the difference was not significant. In May, the mean weight of fish was much lower than at other times of the year indicating the abundance of new recruits during the spring. The weight of food eaten per weight of fish was consistently larger at coastal sites and the t-test approached significance (P=0.07). No significant differences were evident in August, but the trend of more food being eaten at coastal sites continued. Overall, the mean weight eaten per weight of fish at the coastal sites was similar for the three sampling periods, ranging from 10.06 mg/g in August to 11.14 mg/g in May, and these coastal values were consistently larger than the values from the delta.

Predation on Penaeid Shrimp

A special effort was made to identify predators of juvenile penaeid shrimp. A total of 47 penaeids (mostly *Penaeus aztecus*) were eaten by the fish examined, and 39 of these (83%) were eaten at coastal sites. Near the delta, the southern flounder was the dominant predator, eating 97% of the shrimp by weight (Table 5). At coastal sites 3 species of fish combined to eat approximately 98% of the shrimp by weight including the inshore lizardfish (65.8%), the spotted seatrout (19.6%), and the southern flounder (12.4%). The combined data from both areas and all sampling times showed that overall, 78% of

Table 2. Comparison of the diet of fishes between delta and coastal sites in Lavaca Bay. The size range (mm, TL) and mean dry weight (g) are given for all fish examined. The total number of each prey item found in the fish stomachs is listed along with the percentage of the total dry weight (mg) of food.

Spot

	OCTOBER				MAY				AUGUST			
Location	DELTA		COASTAL		DELTA		COASTAL		DELTA		COASTAL	
No. examined		3		49		80		123		19		43
No. with food		3		44		68		122		19		43
Size Range		114-122		12-130		44-73		47-126		65-105		60-150
Mean Weight (g)		4.6		2.9		0.5		0.8		1.3		3.0
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Amphipods		0.0	11	3.5		0.0	14	1.1		0.0	2	0.2
Mysids	207	79.3		0.0		0.0		0.0	4	0.0		0.0
Copepods		0.0	198	5.5	860	19.7	5202	13.3	1783	67.1	3466	72.7
Cumaceans		0.0		0.0		0.0		0.0	5	2.4		0.0
Annelids		0.0		24.5		11.6		2.5		0.0		0.3
Plant Material		0.0		0.0		0.0		0.3		0.0		0.4
Unid. foods		20.7		66.5		68.7		82.7		30.5		26.4
Total weight (mg)		9.2		335.2		85.3		1096		71.4		338.7

Pinfish

	OCTOBER				MAY				AUGUST			
Location	DELTA		COASTAL		DELTA		COASTAL		DELTA		COASTAL	
No. examined		0		6		57		97		16		21
No. with food				6		56		97		16		21
Size Range				96-138		42-88		36-88		71-120		65-118
Mean Weight (g)				7.4		1.0		1.0		2.9		2.8
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penaeus aztecus				0.0		0.0	1	2.2		0.0		0.0
Penaeus spp.			2	0.1		0.0		0.0		0.0		0.0
Amphipods			2	0.0	36	2.5	66	5.3	9	0.3	2	0.1
Tanaids				0.0	2	0.0	1	0.0	7	0.4		0.0
Mysids			4	0.0		0.0	2	0.0		0.0		0.0
Copepods				0.0	376	4.6	428	1.0	6	0.2	116	0.6
Crabs			1	0.3		0.0		0.0		0.0		0.0
Unid. Crustacea				0.0		3.3	20	2.2	2	0.2	3	3.4
Annelids				0.0		4.6		21.6		0.0	1	0.3
Fish				0.0	1	1.8		0.0		0.0		0.0
Plant Material				99.6		44.7		28.7		89.9		92.9
Unid. foods				0.0		38.6		39.0		9.1		2.7
Total weight (mg)				454.6		594.5		910.8		371.5		533.7

Atlantic croaker

	OCTOBER				MAY				AUGUST			
Location	DELTA		COASTAL		DELTA		COASTAL		DELTA		COASTAL	
No. examined		5		4		49		62		31		2
No. with food		5		3		47		60		30		2
Size Range		115-150		14-119		57-107		54-114		98-151		152-155
Mean Weight (g)		6.1		1.2		1.2		1.3		3.6		9.7
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penaeus spp.		0.0		0.0		0.0	1	0.9		0.0		0.0
Amphipods		0.0	1	5.6		0.0	7	0.5		0.0		0.0
Mysids	5	4.3	1	11.1	1	0.0		0.0	32	2.5		0.0
Copepods		0.0		0.0	36	0.1	354	1.1	10	0.4		0.0
Carideans		0.0		0.0		0.0		0.0		0.0	1	8.8
Unid. Crustacea		0.0		0.0	3	0.6		0.0		0.0		0.0
Annelids		58.4		0.0		34.6		13.7		0.0		64.0
Fish		29.2		0.0	4	23.0		0.0		0.0		0.0
Plant Material		0.0		38.9		3.8		0.0		41.6		0.0
Unid. foods		8.1		44.4		37.9		83.7		55.5		27.2
Total weight (mg)		147.7		1.8		357.5		894.7		185.7		40.8

Table 2. Continued.

Silver Perch

Location	OCTOBER DELTA		OCTOBER COASTAL		MAY DELTA		MAY COASTAL		AUGUST DELTA		AUGUST COASTAL	
No. examined		1		2		5		58		1		2
No. with food		1		2		4		43		1		1
Size Range		130		72-110		8-30		9-32		74		68
Mean Weight (g)		6.2		2.0		0.0		0.0		0.9		9.6
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penaeus aztecus		0.0		0.0		0.0	1	1.8	1	14.7		0.0
Penaeus spp.		0.0	1	16.6		0.0		0.0		0.0		0.0
Amphipods		0.0		0.0	9.0	43.2	46.0	34.0		0.0		0.0
Isopods		0.0		0.0		0.0	1.0	0.0		0.0		0.0
Tanaids		0.0	24	66.2	5	27.3	24	9.0		0.0		0.0
Mysids		0.0	52	9.9		0.0	2	1.8		0.0		0.0
Copepods		0.0		0.0		0.0	189	35.6	4	17.3		0.0
Unid. Crustacea		0.0		0.0	3	29.5	12	17.5		0.0	8	100.0
Annelids		0.0		0.0		0.0		0.0		0.0		0.0
Unid. foods		100.0		7.3		0.0		0.3		68.0		0.0
Total weight (mg)		8.6		15.1		4.4		38.8		7.5		4.1

Gulf killifish

Location	OCTOBER DELTA		OCTOBER COASTAL		MAY DELTA		MAY COASTAL		AUGUST DELTA		AUGUST COASTAL	
No. examined		27		0		8		18		0		0
No. with food		22				7		15				
Size Range		26-43				32-69		20-82				
Mean Weight (g)		0.1				0.2		0.5				
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Amphipods	15	60.0			7	4.0	29	55.2				
Tanaids	4	6.2										
Copepods	24	6.9					1	2.5				
Carideans							1	7.4				
Insects					9	90.5	1	2.0				
Plant Material		19.3										
Unid. foods		7.6				5.5		33.0				
Total weight (mg)		14.5				34.6		20.4				

Southern flounder

Location	OCTOBER DELTA		OCTOBER COASTAL		MAY DELTA		MAY COASTAL		AUGUST DELTA		AUGUST COASTAL	
No. examined		0		0		13		8		4		2
No. with food						7		7		4		1
Size Range						50-119		60-117		77-95		169-355
Mean Weight (g)						0.8		2.8		1.4		
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penaeus aztecus					7	75.8	7	61.0		0.0		0.0
P. setiferus						0.0	2	31.0		0.0		0.0
Penaeus spp.						0.0	1	1.6		0.0		0.0
Amphipods					1	3.5	3	1.5		0.0		0.0
Mysids					5	15.3	1	0.5	60	100.0		0.0
Carideans						0.0	2	1.3		0.0		0.0
Unid. Crustacea						5.4	6	2.7		0.0		0.0
Fish						0.0		0.0		0.0	2	100.0
Plant Material						0.0		0.5		0.0		0.0
Total weight (mg)						48.3		199.7		24.1		1798

Table 2. Continued.

Spotted seatrout

	OCTOBER				MAY				AUGUST			
Location	DELTA		COASTAL		DELTA		COASTAL		DELTA		COASTAL	
No. examined		9		10		0		1		0		3
No. with food		9		9				0				2
Size Range		26-110		7-133				26				13-99
Mean Weight (g)		0.8		1.0				0.0				0.6
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penaeus aztecus		0.0	4	78.7								0.0
Amphipods	3	0.4		0.0								0.0
Mysids	111	23.6	24	4.6							2	3.1
Carideans	1	25.1	3	9.8							1	96.9
Fish	1	48.7		0.0								0.0
Plant Material		0.0		6.9								0.0
Unid. foods		2.2		0.0								0.0
Total weight (mg)		226.6		377.6								39.0

Sand seatrout

	OCTOBER				MAY				AUGUST			
Location	DELTA		COASTAL		DELTA		COASTAL		DELTA		COASTAL	
No. examined		0		0		0		1		7		15
No. with food								1		6		14
Size Range								41		62-93		46-83
Mean Weight (g)								0.1		0.6		0.3
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penaeus aztecus							2	7.0		0.0		0.0
Penaeus spp.							2	8.0		0.0	2	0.0
Mysids								0.0	62	24.1	86	93.9
Copepods								0.0		0.0	3	4.3
Unid. Crustacea								85.0		0.0		0.0
Fish								0.0	3	69.7		0.0
Unid. foods								0.0		6.2		1.8
Total weight (mg)								10.0		141.6		27.7

Inshore lizardfish

	OCTOBER				MAY				AUGUST			
Location	DELTA		COASTAL		DELTA		COASTAL		DELTA		COASTAL	
No. examined		1		7		0		1		0		0
No. with food		0		7				1				
Size Range		104.0		123-203				174				
Mean Weight (g)		2.1		5.8				8.3				
PREY ITEMS	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Penaeus aztecus			7	73.2				0.0				
Penaeus spp.			6	2.9				0.0				
Fish			6	21.3			1	100.0				
Unid. foods				2.7				0.0				
Total weight (mg)				1309				340.8				

Table 3. Mean weight of food present in the stomachs of fishes collected at three delta sites and three coastal sites in Lavaca Bay. Probability (P) values are from a t-test comparing means between delta and coastal areas (log transformed data); nt = no test performed.

OCTOBER		Delta Sites				Coastal Sites				P value
		East	Channel	West	Mean	Keller	Chocolate	Powderhorn	Mean	
Spot	Number of Fish Examined		3			11	1	37		
	Size Range (mm,TL)		114-122			12-127	94	78-130		
	Mean Wt (g) of Fish		4.63		4.63	4.65	2.22	2.41	3.09	
	Wt (mg) Eaten/Fish		3.07		3.07	13.16	4.00	5.04	7.40	0.44
	Wt (mg) Eaten/ g Fish		0.66		0.66	2.83	1.80	2.09	2.24	0.07
Pinfish	Number of Fish Examined					2	1	3		
	Size Range (mm,TL)					132	138	96-120		
	Mean Wt (g) of Fish					9.37	10.63	4.91	8.30	
	Wt (mg) Eaten/Fish					125.30	70.80	44.40	80.17	nt
	Wt (mg) Eaten/ g Fish					13.38	6.66	9.04	9.69	nt
Atlantic Croaker	Number of Fish Examined	1	3	1		2	2			
	Size Range (mm,TL)	136	115-150	150		14-26	95-119			
	Mean Wt (g) of Fish	4.94	6.05	7.50	6.16	0.02	2.34		1.18	
	Wt (mg) Eaten/Fish	5.80	46.20	3.30	18.43	0.05	0.85		0.45	0.12
	Wt (mg) Eaten/ g Fish	1.17	7.63	0.44	3.08	3.33	0.36		1.85	0.81
Spotted Seatrout	Number of Fish Examined	4	3	2		1	4	4		
	Size Range (mm,TL)	26-110	88-100	48-77		65	50-108	73-133		
	Mean Wt (g) of Fish	0.66	1.24	0.45	0.78	0.44	0.09	1.74	0.76	
	Wt (mg) Eaten/Fish	31.98	6.17	40.10	26.08	11.80	9.20	82.25	34.42	0.97
	Wt (mg) Eaten/ g Fish	48.82	4.97	90.11	47.97	26.82	105.14	47.27	59.74	0.58
Lizardfish	Number of Fish Examined			1		1	4	2		
	Size Range (mm,TL)			104		139	123-150	189-203		
	Mean Wt (g) of Fish			2.07	2.07	3.16	3.58	11.45	6.06	
	Wt (mg) Eaten/Fish			0.00	0.00	162.30	64.78	443.85	223.64	nt
	Wt (mg) Eaten/ g Fish			0.00	0.00	51.36	18.08	38.76	36.07	nt
Silver Perch	Number of Fish Examined		1			1	1			
	Size Range (mm,TL)		130			110	72			
	Mean Wt (g) of Fish		6.22		6.22	2.96	0.90		1.93	
	Wt (mg) Eaten/Fish		8.60		8.60	1.10	14.00		7.55	nt
	Wt (mg) Eaten/ g Fish		1.38		1.38	0.37	15.56		7.96	nt

MAY		Delta Sites				Coastal Sites				P value
		East	Channel	West	Mean	Keller	Chocolate	Powderhorn	Mean	
Spot	Number of Fish Examined	32	10	38		47	40	38		
	Size Range (mm,TL)	44-68	47-70	53-73		51-126	47-92	52-85		
	Mean Wt (g) of Fish	0.43	0.50	0.50	0.48	0.75	0.73	0.86	0.78	
	Wt (mg) Eaten/Fish	0.79	1.26	1.25	1.10	3.18	2.56	22.21	9.32	0.12
	Wt (mg) Eaten/ g Fish	1.85	2.51	2.48	2.28	4.23	3.52	25.87	11.20	0.17
Pinfish	Number of Fish Examined	26	14	14		39	9	49		
	Size Range (mm,TL)	51-83	42-88	58-73		36-79	54-88	56-88		
	Mean Wt (g) of Fish	0.89	1.08	1.03	1.00	0.59	1.68	1.22	1.16	
	Wt (mg) Eaten/Fish	8.48	8.91	17.79	11.73	7.87	19.19	8.80	11.95	0.99
	Wt (mg) Eaten/ g Fish	9.50	8.28	17.32	11.70	13.36	11.42	7.23	10.67	0.82
Atlantic Croaker	Number of Fish Examined	18	6	25		14	40	8		
	Size Range (mm,TL)	57-107	74-98	71-101		75-114	54-99	87-101		
	Mean Wt (g) of Fish	1.06	1.05	1.23	1.11	1.83	1.05	1.98	1.62	
	Wt (mg) Eaten/Fish	8.38	8.20	6.30	7.63	9.03	18.32	4.44	10.60	0.67
	Wt (mg) Eaten/ g Fish	7.94	7.80	5.14	6.96	4.93	17.48	2.24	8.22	0.85

Southern Flounder	Number of Fish Examined	8	5			5	2	1		
	Size Range (mm,TL)	50-119	63-95			73-177	60-67	120		
	Mean Wt (g) of Fish	0.78	0.94		0.86	3.54	0.42	3.52	2.49	
	Wt (mg) Eaten/Fish	2.55	5.58		4.07	31.90	20.10	0.00	17.33	0.70
	Wt (mg) Eaten/ g Fish	3.29	5.92		4.61	9.00	47.86	0.00	18.95	0.82
Lizardfish	Number of Fish Examined							1		
	Size Range (mm,TL)							174		
	Mean Wt (g) of Fish							8.33	8.33	
	Wt (mg) Eaten/Fish							340.80	340.80	nt
	Wt (mg) Eaten/ g Fish							40.91	40.91	nt
Silver Perch	Number of Fish Examined	3		2		46	7	5		
	Size Range (mm,TL)	8-20		22-30		9-25	20-32	10-17		
	Mean Wt (g) of Fish	0.01		0.03	0.02	0.01	0.05	0.01	0.02	
	Wt (mg) Eaten/Fish	0.87		0.90	0.88	0.75	0.46	0.26	0.49	0.14
	Wt (mg) Eaten/ g Fish	86.67		36.00	61.33	71.46	8.65	43.33	41.15	0.53

AUGUST		Delta Sites				Coastal Sites				P value
		East	Channel	West	Mean	Keller	Chocolate	Powderhorn	Mean	
Spot	Number of Fish Examined	5	10	4		9		34		
	Size Range (mm,TL)	65-85	67-105	76-96		11-115		60-110		
	Mean Wt (g) of Fish	0.95	1.53	1.35	1.28	7.76		1.72	4.74	
	Wt (mg) Eaten/Fish	2.08	4.67	3.58	3.44	27.13		2.78	14.96	0.35
	Wt (mg) Eaten/ g Fish	2.20	3.05	2.65	2.63	3.50		1.62	2.56	0.83
Pinfish	Number of Fish Examined	5		11		5		16		
	Size Range (mm,TL)	82-96		71-120		65-100		70-118		
	Mean Wt (g) of Fish	2.74		2.94	2.84	2.14		3.06	2.60	
	Wt (mg) Eaten/Fish	20.84		24.30	22.57	13.88		29.02	21.45	0.79
	Wt (mg) Eaten/ g Fish	7.59		8.28	7.94	6.47		9.48	7.98	0.96
Atlantic Croaker	Number of Fish Examined	19	6	6		2				
	Size Range (mm,TL)	98-151	118-145	100-126		152-155				
	Mean Wt (g) of Fish	3.61	4.67	3.38	3.89	9.65			9.65	
	Wt (mg) Eaten/Fish	5.14	5.87	8.80	6.60	20.40			20.40	0.06
	Wt (mg) Eaten/ g Fish	1.42	1.26	2.61	1.76	2.12			2.12	0.67
Sand Seatrout	Number of Fish Examined	6	1				15			
	Size Range (mm,TL)	62-93	74				46-83			
	Mean Wt (g) of Fish	0.64	0.69		0.67		0.35		0.35	
	Wt (mg) Eaten/Fish	22.05	9.30		15.68		1.85		1.85	nt
	Wt (mg) Eaten/ g Fish	34.36	13.48		23.92		5.33		5.33	nt
Spotted Seatrout	Number of Fish Examined							3		
	Size Range (mm,TL)							13-99		
	Mean Wt (g) of Fish							0.57	0.57	
	Wt (mg) Eaten/Fish							13.00	13.00	nt
	Wt (mg) Eaten/ g Fish							22.81	22.81	nt
Southern Flounder	Number of Fish Examined	2	2			1		1		
	Size Range (mm,TL)	77-80	93-95			169		355		
	Mean Wt (g) of Fish	1.01	1.70		1.35	11.34		--		
	Wt (mg) Eaten/Fish	6.20	5.85		6.03	0.00		1798.60	899.33	nt
	Wt (mg) Eaten/ g Fish	6.17	3.44		4.81	0.00		--	--	nt
Silver Perch	Number of Fish Examined			1		1	1			
	Size Range (mm,TL)			74		175	68			
	Mean Wt (g) of Fish			0.94	0.94	18.48	0.62		9.55	
	Wt (mg) Eaten/Fish			7.50	7.50	0.00	4.10		2.05	nt
	Wt (mg) Eaten/ g Fish			7.98	7.98	0.00	6.61		3.31	nt

Table 4. Summary data on the weight of food present in the stomachs of selected species of fishes collected in Lavaca Bay. The fish species included in this analysis are listed in Table 3. Probability (P) values are from a t-test comparing means between delta and coastal sites. Both of the variables involving weight of food eaten were log transformed before statistical analysis.

	Delta Sites				Coastal Sites				
OCTOBER	Channel	West	East	Mean	Keller	Powderhorn	Chocolate	Mean	P Value
Number of Fish Examined	10	4	5	6.3	18	46	13	25.7	
Mean Wt (g) of Fish	4.20	2.62	1.51	2.78	4.25	2.90	2.55	3.23	0.65
Wt (mg) Eaten/ Fish	17.49	20.88	26.74	21.70	31.71	33.40	29.72	31.61	0.04
Wt (mg) Eaten/ g Fish	4.16	7.98	17.69	9.94	7.47	11.50	11.67	10.21	0.73
MAY									
Number of Fish Examined	35	79	87	67.0	151	102	98	117.0	
Mean Wt (g) of Fish	0.89	0.81	0.71	0.81	0.68	1.18	0.89	0.91	0.50
Wt (mg) Eaten/ Fish	6.13	5.77	4.83	5.57	5.14	16.20	10.73	10.69	0.18
Wt (mg) Eaten/ g Fish	6.89	7.10	6.76	6.92	7.60	13.77	12.04	11.14	0.07
AUGUST									
Number of Fish Examined	19	22	37	26.0	18	54	16	29.3	
Mean Wt (g) of Fish	2.50	2.68	2.51	2.56	7.20	2.02	0.36	3.20	0.78
Wt (mg) Eaten/ Fish	5.42	15.54	9.65	10.20	19.69	44.38	1.99	22.02	0.74
Wt (mg) Eaten/ g Fish	2.17	5.81	3.84	3.94	2.73	21.98	5.46	10.06	0.39

Table 5. Major fish predators on penaeid shrimp. Total dry weights are given for fish (g) and shrimp (mg).

DELTA

Species	Fish Examined No.	Fish Examined Wt.	Fish with Food No.	Fish with Food Wt.	Fish Eating Shrimp[1] No.	Fish Eating Shrimp[1] Wt.	Shrimp Eaten[2] No.	Shrimp Eaten[2] Wt.	% of All Shrimp Eaten by No.	% of All Shrimp Eaten by Wt.	% of Fish Eating Shrimp[3]
Pinfish	73	100.70	72	100.27	0	0.00	0	0.0	0.00	0.00	0.00
Atlantic croaker	85	203.48	82	197.58	0	0.00	0	0.0	0.00	0.00	0.00
Silver perch	7	7.24	6	7.22	1	0.94	1	1.1	12.50	2.92	14.29
Southern flounder	17	16.32	11	8.41	4	2.05	7	36.6	87.50	97.08	23.53
Sand seatrout	7	4.54	6	3.37	0	0.00	0	0.0	0.00	0.00	0.00
Spotted seatrout	9	7.23	9	7.23	0	0.00	0	0.0	0.00	0.00	0.00
Lizardfish	1	2.07	0	0.00	0	0.00	0	0.0	0.00	0.00	0.00
TOTALS	199	341.58	186	324.08	5	2.99	8	37.7			

COASTAL

Species	Fish Examined No.	Fish Examined Wt.	Fish with Food No.	Fish with Food Wt.	Fish Eating Shrimp No.	Fish Eating Shrimp Wt.	Shrimp Eaten No.	Shrimp Eaten Wt.	% of All Shrimp Eaten by No.	% of All Shrimp Eaten by Wt.	% of Fish Eating Shrimp
Pinfish	124	201.52	124	201.52	3	16.60	3	20.5	7.69	1.35	2.42
Atlantic croaker	68	107.40	65	103.34	1	0.73	1	8.4	2.56	0.55	1.47
Silver perch	62	23.84	46	5.11	2	0.90	2	3.2	5.13	0.21	3.23
Southern flounder	10	22.08	8	18.56	6	17.80	10	186.9	25.64	12.35	60.00
Sand seatrout	16	5.33	15	4.55	2	0.25	6	1.5	15.38	0.10	12.50
Spotted seatrout	14	11.33	11	11.29	3	6.30	4	297.0	10.26	19.62	21.43
Lizardfish	8	48.72	8	48.72	7	40.40	13	996.1	33.33	65.81	87.50
TOTALS	302	420.22	277	393.09	24	82.98	39	1513.6			

DELTA AND COASTAL SITES COMBINED

Species	Fish Examined No.	Fish Examined Wt.	Fish with Food No.	Fish with Food Wt.	Fish Eating Shrimp No.	Fish Eating Shrimp Wt.	Shrimp Eaten No.	Shrimp Eaten Wt.	% of All Shrimp Eaten by No.	% of All Shrimp Eaten by Wt.	% of Fish Eating Shrimp
Pinfish	197	302.22	196	301.79	3	16.60	3	20.5	6.38	1.32	1.52
Atl. croaker	153	310.88	147	300.92	1	0.73	1	8.4	2.13	0.54	0.65
Silver perch	69	31.08	52	12.33	3	1.84	3	4.3	6.38	0.28	4.35
S. flounder	27	38.40	19	26.97	10	19.85	17	223.5	36.17	14.41	37.04
Sand trout	23	9.87	21	7.92	2	0.25	6	1.5	12.77	0.10	8.70
Spotted trout	23	18.56	20	18.52	3	6.30	4	297.0	8.51	19.15	13.04
Lizardfish	9	50.79	8	48.72	7	40.40	13	996.1	27.66	64.21	77.78
TOTALS	501	761.80	463	717.17	29	85.97	47	1551.3			

[1] Fish having eaten at least one penaeid shrimp.

[2] Total shrimp eaten by each predator species.

[3] Percent of fish examined having eaten at least one penaeid shrimp.

the lizardfish examined contained penaeid shrimp compared with 37% for southern flounder and 13% for spotted seatrout. Only a small percentage of the juvenile pinfish and Atlantic croaker were feeding on penaeids, but these fish were relatively abundant and together their populations were responsible for over 8% of the number of penaeids in fish stomachs.

DISCUSSION

A qualitative comparison of diets for individual fish species did not reveal any large differences between coastal and delta habitats. The most abundant species examined, spot and pinfish, exhibited very little habitat-related variability in their diets. The small apparent differences between coastal and delta sites in diets of other species can probably be attributed to the small sample size and to natural variability in prey selection.

Variability in the amount of food eaten was also high for individual species, but for all fish species combined there appeared to be consistently more food in the stomachs of fish collected at coastal sites compared with fish collected at delta sites. Habitat-related differences in the weight of food eaten by estuarine fishes may indicate differences in the availability of food and the relative quality of these areas for foraging. However, data on the weight of food eaten at different sites should be analyzed carefully, because diel changes in feeding combined with variability in collection times could bias the results. Our samples were generally collected between 0930 and 1700 hrs, and there did not appear to be any relationship between the time of collection and the weight of food eaten or any consistent confounding between the time of collection and the sample sites.

Major predators on the young of commercially-important penaeid shrimp were also identified from the diets of small estuarine fishes. Previous studies, on mostly large fish, have shown that southern flounder, spotted seatrout, and red drum are frequent predators on shrimp in Texas estuaries (Pearson 1928, Gunter 1945, Miles 1949, Kemp 1950, Seagle 1969, Stokes 1977). Studies in salt marshes of Galveston Bay have shown that small juveniles of these fishes also prey upon penaeid shrimp (Zimmerman et. al. 1984; Minello et al. in press). In general the data collected in Lavaca Bay agree with previously reported results as to the importance of these fish as predators on shrimp. Only a few red drum were collected, however, and none of these had eaten any shrimp. In addition inshore lizardfish and sand seatrout ate a large percentage of the shrimp identified in stomachs. Most of these fish were collected at coastal sites, and all of the shrimp eaten by these two fish species were eaten at coastal sites. Divita et. al. (1983) and Sheridan and Trimm (1983) have reported these fish as predators on penaeid shrimp in nearshore and coastal waters.

There appeared to be a large difference in the overall number of shrimp eaten between areas in the bay, with 83% of the shrimp being eaten at coastal sites. This difference could be due to a number of factors including the presence of larger numbers of shrimp or fish predators in coastal areas. The difference may also be related, however, to differences in the protective nature of habitats related to their location in the bay. A comparison of crustacean densities between the coastal and delta sites revealed few obvious differences (Zimmerman and Minello 1987), and there were no significant differences in penaeid shrimp abundances between the areas. The four major predators on shrimp, southern flounder, inshore lizardfish, sand seatrout, and spotted seatrout were slightly more abundant at coastal sites, but the ratio of the number of shrimp eaten to the number of fish examined in this group was 0.7 at coastal sites in comparison with 0.2 at delta sites. These limited data, therefore, suggest that mortality rates for shrimp may be lower in the upper portion of the bay, and reduced mortality in this area may not strictly be due to fewer fish predators. Differences in vegetation, substrate, and water turbidity may all be involved in altering predation rates on shrimp, and could be responsible for habitat-related differences in shrimp mortality.

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