SUMMER FOODS OF TEXAS COASTAL FISHES RELATIVE TO AGE AND HABITAT

Age and habitat are often ignored as factors which simultaneously influence the diets of demersal fishes. Studies of fish foods by age (size) or habitat (depth of capture, substrate) either summarize foods over all sizes and depths (Henwood et al. 1978), construct several size or depth groupings to equalize sampling effort (Overstreet and Heard 1978; Mericas 1981), or establish arbitrary size or capture depth ranges for ontogenetic or depth-related analyses (Rogers 1977; Divita et al. 1983). In this paper, we analyze the stomach contents of seven species of Texas coastal fishes with respect to both age and habitat.

Materials and Methods

Fishes examined in our study were taken from trawl catches by the NOAA RV *Oregon II* and the Texas Parks and Wildlife Department RV *Western Gulf* between sunset and sunrise in waters 7-73 m deep along the entire Texas coast. Each vessel towed a 12.2 m semiballoon trawl with tickler chain at 5-6 km/h. The species collected from the family Sciaenidae are sand seatrout, *Cynoscion arenarius*; silver seatrout, *C. nothus*; spot, *Leiostomus xanthurus*; and Atlantic croaker, *Micropogonias undulatus*; from the family Sparidae, longspine porgy, *Stenotomus caprinus*; and from the family Trichiuridae, Atlantic cutlassfish, *Trichiurus lepturus*. Fishes were collected by depth ranges (7-17, 18-44, or 45-73 m) and preserved in 3.7% formaldehyde-seawater. These depth ranges correspond to distinctive habitats (substrates) as reported by Grady (1971), Flint and Rabalais (1980), and Gallaway and Reitsema (1981): sand or muddy-sand (7-17 m), sand-silt-clay (18-44 m), and silty-sand or silty-clay (45-73 m).

In the laboratory, fishes from each depth range were measured (standard length, SL, or total length, TL, where applicable) and further separated into either age-0 or age-I classes, based upon data summarized by the Gulf of Mexico Fishery Management Council (1980) or upon unpublished personal data on gonadal maturation. Fishes were presumed to have reached age I at the following lengths: longspine porgy, 75 mm SL; spot, 100 mm SL; Atlantic croaker, 125 mm SL; sand and silver seatrouts, 150 mm SL; hardhead catfish, 200 mm SL; and Atlantic cutlassfish, 400 mm TL. No age II individuals were collected. For each species, the stomach contents of all individuals in a given age/depth category were combined and washed through sieves to separate similar-sized food items (Carr and Adams 1972), which were identified and enumerated microscopically and then dried at 80°-90°C for 24 h. The dry weights of the various food items were calculated from their numerical proportions and converted to percentages of total food dry weight. Stomach contents were identified to broad but exclusive categories such as sand, diatoms, shrimps, or fishes. Fish bones and scales without associated flesh were often found in hardhead catfish stomachs and were thus given a category. Animal fragments not distinctly referable to any taxon were also categorized. Fine organic matter not referable to any other category was termed detritus. Prey fishes, shrimps, and crabs were identified to family or genus when possible. Within each species, diet similarities among age/depth categories were compared by the Spearman rank correlation coefficient, r_s (Fritz 1974).

Results

The stomach contents of the four sciaenid fishes are summarized in Table 1, and those of the other three species in Table 2. Intraspecific diet similarities are given in Table 3. The effect of depth of capture on diets of spot and Atlantic cutlassfish could not be evaluated, since the majority of individuals were collected from a single depth range (7-17 m and 18-44 m, respectively). Correlations between diets of age-0 and age-I spot ($r_s = 0.069$) and between diets of age-0 and age-I Atlantic cutlassfish ($r_s = 0.399$) were not significant. Age-0 spot consumed more infaunal organisms, such as polychaetes and nematodes, and nearly twice as much detritus as age-I spot, which captured proportionately more epifaunal prey such as fishes, amphipods, and shrimps. While both age classes of Atlantic cutlassfish preyed primarily upon fish, age-I individuals also exploited squids. Small sample size (three stomachs) for the age-0 Atlantic cutlassfish is probably responsible for the lack of diet correlation.

Sand and silver seatrouts fed both in the water column and near the bottom. Diets of three of the four age/depth categories of sand seatrout were significantly correlated, primarily because fishes and shrimps were the favored prey. The exception was the diet of age-0 sand seatrout in 18-44 m waters in which squids were the primary prey. The most frequently identified sand seatrout prey taxa were anchovies, *Anchoa*, and roughback shrimp, *Trachypenaeus* sp. Silver seatrout also preyed upon fishes and shrimps, but only the age-0 diets in the two inhabited depth ranges were correlated. The data on

TABLE 1.—Stomach contents of sand seatrout, silver seatrout, spot, and Atlantic croaker collected from Texas coastal waters between 4 June and 3 July 1981, expressed as percentages of total food dry weight by age and depth of capture. A "+" indicates presence in the diet but <0.1%. Fish lengths are mm SL, depth ranges in meters.

	Sand seatrout				Silver seatrout				Spot		Atlantic croaker			
Stomach Age:	O		I		O		I		O	I	O		I	
contents Depth:	7-17	18-44	7-17	18-44	7-17	18-44	7-17	18-44	7-44	7-44	7-17	18-44	7-17	18-44
Diatoms	—	—	—	—	—	—	—	—	0.6	0.9	—	—	—	—
Nematodes	+	—	—	—	—	—	—	—	3.8	0.4	0.1	—	—	—
Polychaetes	0.4	—	—	—	0.1	—	—	—	7.3	3.9	61.2	35.9	4.3	36.1
Bivalves	—	—	—	—	—	—	—	—	1.8	1.2	—	—	—	—
Squids	—	47.5	—	—	—	—	—	19.7	—	—	0.2	—	—	—
Copepods	+	—	—	—	—	—	—	—	5.2	0.6	+	+	+	—
Stomatopods	+	—	+	—	0.3	0.2	—	11.4	—	—	—	—	—	—
Mysids	0.5	—	+	—	3.0	0.1	0.6	—	1.4	—	0.7	—	—	0.6
Cumaceans	—	—	—	—	0.1	—	—	—	0.8	2.0	—	—	—	—
Isopods	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—
Amphipods	0.2	—	—	—	+	—	0.3	—	2.2	4.3	0.2	—	—	—
Crabs	0.9	—	7.2	4.4	4.3	—	1.2	+	—	—	5.9	0.3	76.5	—
Shrimps	2.0	24.7	59.5	40.3	6.7	16.8	88.9	12.9	4.8	6.6	8.6	35.6	9.0	16.3
Holothurians	—	—	—	—	—	—	—	—	—	—	—	9.4	6.7	—
Tunicates	—	—	—	—	—	—	—	—	—	—	—	—	—	30.0
Lancelets	—	—	—	—	—	—	—	—	—	3.0	—	—	—	—
Fishes	87.0	27.7	24.4	52.3	76.5	82.9	9.1	55.9	0.1	17.0	0.9	—	—	—
Animal fragments	3.2	—	8.0	1.5	8.9	—	—	—	8.2	9.9	10.4	9.4	0.9	8.4
Detritus	5.7	—	0.8	1.5	—	—	—	—	62.4	37.6	8.4	9.3	2.6	8.7
Sand	—	—	—	—	—	—	—	—	1.4	12.6	3.3	—	—	—
Number examined	126	11	9	31	35	38	5	25	103	17	136	47	12	12
Number empty	27	6	1	13	6	18	3	8	53	9	17	24	4	6
Mean weight/stomach (g)	0.051	0.035	0.664	0.353	0.036	0.149	0.058	0.450	0.007	0.012	0.017	0.021	0.058	0.024
Length range	51-139	33-74	152-225	163-250	92-145	92-149	153-173	150-172	75-99	100-159	83-121	95-124	126-152	125-159

age-I silver seatrout from 7-17 m waters, indicating shrimps as the primary food, were based on only two stomachs. Age-I silver seatrout from 18-44 m depths consumed relatively large proportions of squids and stomatopods, unlike any other age/depth category. The most often noted prey taxa in silver seatrout stomachs were *Anchoa* and unidentified caridean shrimps.

Atlantic croaker, hardhead catfish, and longspine porgy were benthic feeders. No significant correlations in diet were found among the four age/depth categories of Atlantic croaker. Although the

TABLE 2.—Stomach contents of hardhead catfish, longspine porgy, and Atlantic cutlassfish collected from Texas coastal waters between 4 June and 3 July 1981, expressed as percentages of total food dry weight by age and depth of capture. A "+" indicates presence in the diet but <0.1%. Fish lengths are mm SL, except Atlantic cutlassfish which are mm TL. Depth ranges are in meters.

	Hardhead catfish				Longspine porgy				Atlantic cutlassfish	
Age:	O		I		O		I		O	I
Stomach contents / Depth:	7-17	18-44	7-17	18-44	18-44	45-73	18-44	45-73	7-73	7-73
Nematodes	—	0.1	—	0.9	0.2	—	0.2	—	—	—
Polychaetes	4.5	+	—	—	33.0	60.9	47.0	45.6	0.6	—
Bivalves	0.7	—	—	—	0.1	—	—	—	—	—
Gastropods	—	—	—	—	—	6.4	—	—	—	—
Squids	—	—	—	—	—	—	—	—	—	28.8
Copepods	0.2	—	—	—	4.0	4.9	0.2	—	—	—
Stomatopods	0.1	40.1	38.0	85.7	0.6	—	1.3	—	—	0.1
Mysids	—	—	—	—	—	—	—	—	0.8	—
Cumaceans	0.1	—	—	—	—	—	—	—	—	—
Amphipods	—	—	—	—	0.7	—	1.0	3.2	+	+
Crabs	34.1	26.4	29.9	1.1	0.8	3.7	15.7	6.8	0.6	—
Shrimps	37.8	11.2	0.9	12.2	6.7	3.2	4.9	12.7	1.6	0.8
Holothurians	10.0	3.5	11.8	—	—	—	—	—	—	—
Tunicates	—	2.8	—	—	—	—	—	—	—	—
Fishes	1.6	—	9.0	—	1.0	—	2.3	—	81.3	66.6
Fish bones/scales	1.2	9.3	0.5	—	—	—	—	—	—	—
Animal fragments	7.6	2.5	—	—	25.6	7.8	11.0	15.7	10.5	1.3
Detritus	1.9	4.0	9.9	—	25.9	13.2	12.7	16.1	3.4	2.3
Sand	0.5	—	—	—	1.5	—	3.6	—	1.1	—
Number examined	24	13	7	3	127	8	13	42	5	33
Number empty	1	0	1	0	67	0	7	28	2	13
Mean weight/stomach (g)	0.157	0.323	0.967	0.785	0.007	0.005	0.018	0.003	0.070	0.399
Length range	137-192	169-192	202-255	222-255	25-74	40-51	84-94	78-127	229-399	400-595

TABLE 3.—Spearman rank correlation coefficient matrices comparing *age and depth-specific diets within species of Texas coastal fishes* collected between 4 June and 3 July 1981. Significant correlations indicated by * at 0.05 or ** at 0.01 levels. Depth ranges in meters.

Species	Age	Depth	O 7-17	O 18-44	I 7-17	I 18-44
Sand seatrout	O	7-17	—	0.215	0.831**	0.847**
		18-44		—	0.484	0.516
	I	7-17			—	0.940**
Silver seatrout	O	7-17	—	0.687*	0.605	0.371
		18-44		—	0.746	0.732
	I	7-17			—	0.555
Hardhead catfish	O	7-17	—	0.186	0.232	0.131
		18-44		—	0.689*	0.697*
	I	57-17			—	0.545
Atlantic croaker	O	7-17	—	0.460	0.346	0.389
		18-44		—	0.569	0.482
	I	7-17			—	0.135

Species	Age	Depth	O 18-44	O 45-73	I 18-44	I 45-73
Longspine porgy	O	18-44	—	0.590*	0.762**	0.758**
		45-73		—	0.469	0.741*
	I	18-44			—	0.655*

favored prey in three of four categories, polychaetes comprised more than half the diet only in age-0 Atlantic croaker in shallow waters. Age-I Atlantic croaker in shallow waters preferred crabs (mainly *Albunea*). Alpheid and other caridean shrimps formed one-third of the age-0 Atlantic croaker diet in 18-44 m waters, while age-I individuals at these depths consumed large amounts of tunicates. The prey of hardhead catfish was mainly stomatopods, crabs, and shrimps. The diets of age-I hardhead catfish in both inhabited depth ranges were correlated with the age-0 diet in 18-44 m, where the primary food was stomatopods. Age-0 hardhead catfish in shallow waters did not consume stomatopods but concentrated on crabs and shrimps. Crabs comprised at least 25% of the diets of all age/depth categories except the age-I hardhead catfish from 18-44 m depths, probably due to the small number of stomachs (3) analyzed. Identifiable prey taxa were mainly brown shrimp, *Penaeus aztecus*; rock shrimp, *Sicyonia* sp.; and the crabs *Albunea* and *Pinnixa*. All comparisons of longspine porgy diets were significantly correlated, except between age-0 in 45-73 m waters and age-I in 18-44 m waters. Polychaetes were the primary food in all age/depth categories, and animal fragments and detritus were also abundant. The main differences between age classes were that age-0 longspine porgy consumed more copepods but less crabs than age-I individuals.

Discussion

The major foods identified in this study are generally similar to the foods of these seven species described by other investigations in the Gulf of Mexico. Gunter (1945), Knapp (1949), and Darnell (1958) reported that hardhead catfish consumed crabs, shrimps, and detritus in estuaries, but provided neither age nor habitat-related analyses of their data. Divita et al. (1983), using samples collected at the same time as ours but analyzing diets by percent frequency of occurrence, reported differences between age-0 and age-I hardhead catfish diets in 9-17 m waters. They found that, in comparison with age-0 individuals, age-I fish consumed holothurians, fishes, bivalves, shrimps, and detritus more frequently and crabs, stomatopods, and polychaetes less frequently. Our results (based on percent dry weight) contrast in that, for the age-I catfish diet, shrimps were less important and stomatopods were more important than in the age-0 diet in 7-17 m waters.

Two studies have investigated the diet of longspine porgy, the results of which generally agree with ours. Henwood et al. (1978), summarizing data over a 130 m depth range and ages 0 and I, found polychaetes, shrimps, and crabs were the most abundant foods. Rogers (1977) analyzed longspine porgy diets in four arbitrary size classes (two each in ages 0 and I) and three arbitrary depth zones (3-18, 19-55, and 56-200 m), but not by age/depth combinations. He found that both ages preferred polychaetes and that age-0 porgy stomachs contained more animal fragments and detritus than did age-I porgy stomachs, as we report. In contrast, though, Rogers noted that age-I longspine porgy preyed extensively on fishes causing midshelf diets to differ from outer shelf diets. The differences between our reports are probably due to Rogers' year-round sampling over a wide area (Texas, Louisiana, and Mississippi shelf).

The diets of sand and silver seatrouts were also examined by Rogers (1977). His three size classes of sand seatrout were all age-0 fish (26-100 mm SL) which consumed fishes, shrimps, and squids, preyed mainly upon fishes in shallow waters and squids in moderate depths, thus agreeing with our data. His largest size class of silver seatrout (76-175 mm SL, ages 0 and I combined) was piscivorous and is comparable to our findings, but no age/depth data were given.

We found the Atlantic croaker diet was influenced by both age and depth of capture. This is the likely reason for the variety of primary foods previously reported for this species. Chen (1976) examined age-0 and age-I Atlantic croaker (data summed over 9-73 m depths) and reported similar diets of primarily organic and inorganic matter with lesser amounts of crabs, shrimps, and stomatopods. Although the influence of depth was not discussed, she proposed that diet variations were substrate-related. Rogers (1977) noted that polychaetes and stomatopods were the main foods of age-0 Atlantic croaker in shallow and moderate depths. Overstreet and Heard (1978) documented both size and depth of capture as factors independently affecting Atlantic croaker diets: small individuals (76-195 mm SL) consumed more polychaetes and fewer molluscs, crustaceans, and fishes than did large individuals (200-351 mm), and fish from shallow water (11-29 m) consumed more polychaetes and fishes and fewer crustaceans than fish from deep water (30-90 m). However, their comparisons apparently included two age classes in each size range, formed arbitrary depth zones, and did not examine age/depth as a combined influence. Divita et al. (1983) found detritus to be the most frequently observed item in both age-0 and age-I Atlantic croaker stomachs from both shallow- and midshelf, and observed no differences in diets among age/depth categories. The available data thus indicate that Atlantic croaker are highly opportunistic in their feeding strategy, which is readily influenced by age, depth, season, and, probably, site.

Our results agree with previous reports concerning offshore spot and Atlantic cutlassfish diets. Chen (1976) examined age-I spot from 9-27 m depths and found inorganic and organic matter, polychaetes, and shrimps were the primary foods. Mericas (1981) noted Atlantic cutlassfish were piscivorous from late age 0 into age III.

We conclude that the degree to which age and depth of capture simultaneously affect fish diets depends upon the species examined: Atlantic croaker are highly influenced and longspine porgy are only slightly influenced. This variation between species may have been due to the age/depth distributions of the fishes during the limited collecting period, and thus seasonal collections should be compared. It is also possible that fishes had fed in one depth zone and moved into the adjacent depth zone prior to capture.

We know of no data concerning swimming speeds of the species examined, but an individual moving completely across one depth zone would cover 6-35 km in southern and up to 20-90 km in northern Texas coastal waters.

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LIFE HISTORY OF SPLITTAIL (CYPRINIDAE: *POGONICHTHYS MACROLEPIDOTUS*) IN THE SACRAMENTO-SAN JOAQUIN ESTUARY[1]

The Sacramento-San Joaquin estuary is the largest on the west coast of North America. Because of its comparatively young geologic age, <8,000 yr (Atwater 1979), its fish fauna is a mixture of native freshwater and marine species, to which numerous exotic species have been added in the past 100 yr (Moyle 1976). The ranges of two extant species, the delta smelt, *Hypomesus transpacificus*, and the splittail, *Pogonichthys macrolepidotus*, are restricted to the estuary. Both species are abundant but their biology is nevertheless poorly known, since most fisheries research in the estuary has concentrated on species of major economic importance, especially the introduced striped bass, *Morone saxatilis* (Stevens 1980; Collins 1982).

The fish communities of the estuary are changing, however, as new species are introduced and as conditions change in response to upstream water projects, water diversions, such as increased use of the water for cooling power plants, and pollution. Given the restricted ranges and habitats of these two species (Moyle 1976), their abundance could decline rapidly if environmental conditions become unfavorable for them, possibly making them candidates for listing as threatened species. This paper is concerned with the life history of the splittail, a species of

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