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opinion that the tag would be retained in successive molts.

In summary, the method described above of tagging crabs by internally anchoring an external spaghetti tag seems promising based on laboratory trials. The only drawback observed in the laboratory is that the tag somewhat hinders molting and may therefore increase the susceptibility to predation of the crab during this vulnerable time. It is possible that this drawback could be avoided by hand insertion of a conventional dart tag which has no leader and would offer less resistance to molting. However, this type of tag would also be more difficult to insert and require punching a larger hole in the membrane. The gun produces a small hole only about one mm in diameter and minimizes trauma to the crab.

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FOOD HABITS OF THE BAY ANCHOVY, *Anchoa mitchilli*, IN APALACHICOLA BAY, FLORIDA

Ontogenetic, spatial and temporal aspects of the food habits of the bay anchovy, *Anchoa mitchilli*, were examined in fish collected from Apalachicola Bay, Florida. Calanoid copepods were the major constituent of the anchovy diet, but their importance declined with fish growth as larger zooplankters such as mysids were consumed. Specialization upon copepods led to moderate diet similarity among sites in the estuary, except in areas near the mouth of the Apalachicola River where mysids, insect larvae, and cladocerans were major food items. Copepods were the dominant prey in all months but were markedly less abundant prey in October, December, and February when other crustaceans and insect larvae became relatively more abundant.

INTRODUCTION

The bay anchovy, *Anchoa mitchilli*, is one of the most abundant fishes in South Atlantic and Gulf coast estuaries, ranking first in numerical abundance in many areas (Gunter, 1945; Perret, 1971; Swingle, 1971; Gallaway and Strawn, 1974; Subrahmanyam and Drake, 1975; Cain and Dean, 1976). An extended spawning season has been indicated (Gunter, 1938; Springer and Woodburn, 1960; Hoese, 1973), and one study (Dunham, 1972) found planktonic eggs and larvae throughout most of the year. This accounts for the collection of juveniles less than 30 mm in length during many months in southern estuaries. Major abundance peaks are generally observed in late summer through early winter, and the aforementioned studies indicate that anchovies are able to exploit all habitats from marshes to open waters. In the Apalachicola estuary of northwest Florida, anchovies are the numerical dominant, comprising 33% of the total catch of trawl-susceptible fishes over five years of study (Livingston *et al.*, 1976, and unpublished data). Peak abundances are noted in October and November, with occasional spring and summer peaks of lesser intensity.

Apalachicola Bay is a relatively unpolluted, shallow, barrier island estuary dominated by the Apalachicola River. Much of the information concerning the Apalachicola drainage basin has been reviewed by Livingston *et al.* (1974) and in Livingston and Joyce (1977). This paper is concerned with refining previous observations on anchovy feeding by examining ontogenetic, spatial and temporal differences in feeding habits.

MATERIALS AND METHODS

Anchovies were collected monthly by trawling with a 16' (5 m) otter trawl at ten sites in the Apalachicola Bay - East Bay complex (Figure 1). Details of field methods and area descriptions are given in Livingston *et al.* (1976). After field preservation in 10% Formalin, anchovies were rinsed and stored in 40% isopropanol until analysis. At such time, fish were sorted into 10 mm (SL) size classes by station and date of collection. Stomachs of up to 25 individuals (as collections permitted) from each size class were resected and their contents pooled. Stomach contents were then analyzed as percent dry weight com-

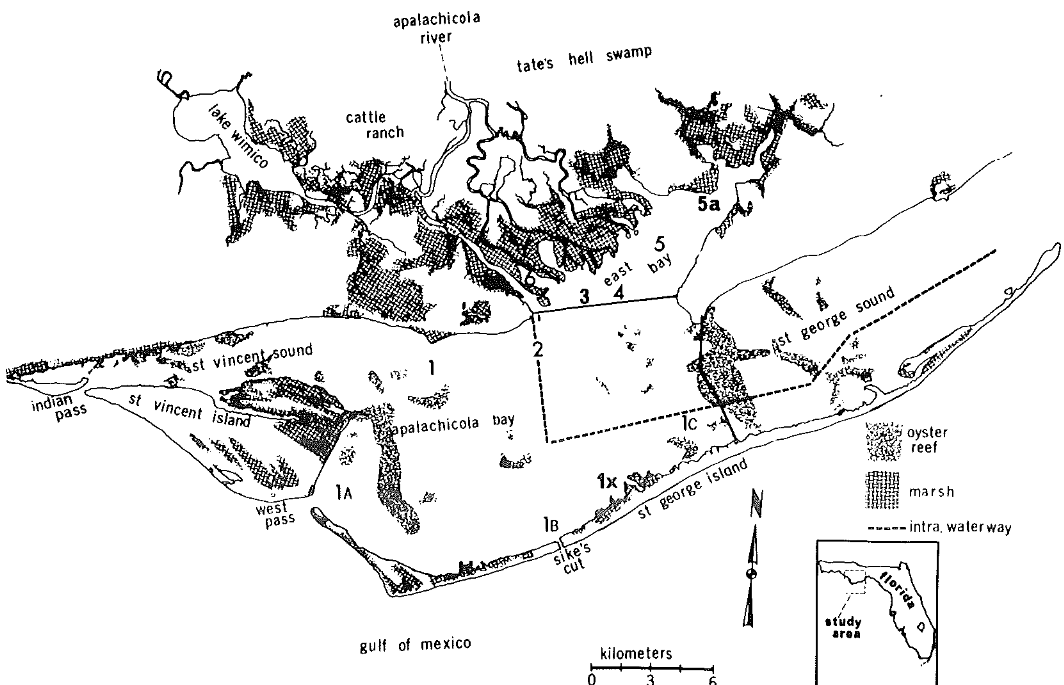

Figure 1. Map of the Apalachicola estuary showing permanent sampling locations.

Table 1. Stomach contents (% of total dry weight) of *Anchoa mitchilli* relative to standard length groups.

	Size (mm)						
Material recovered	10-19	20-29	30-39	40-49	50-59	60-69	Avg. 10-69
Sand grains			<.1	<.1	0.1	0.1	<.1
Detritus		2.2		2.5	2.3	2.4	1.6
Diatoms		0.7	1.0	0.8	0.4	0.2	0.5
Plant remains		<.1	0.7	0.2	1.0	0.5	0.4
Scyphozoans				<.1		<.1	<.1
Polychaete larvae	1.1	0.3	0.2	0.3	0.3	0.3	0.4
Polychaetes		0.2		0.2	2.2	0.3	0.5
Gastropod veligers		<.1		0.4	0.2	0.2	0.1
Gastropods		<.1	0.4	1.2	1.0	1.6	0.7
Bivalve veligers		0.3	0.5	0.8	0.6	0.8	0.5
Bivalves		1.3	<.1	0.3	0.4	0.2	0.4
Unassigned mollusc larvae					<.1	0.1	<.1
Hydracarinids			<.1		<.1	<.1	
Cladocerans		2.8	3.9	1.5	0.8	3.1	2.0
Ostracods		0.4	1.0	0.9	1.8	2.6	1.1
Calanoid copepods	97.8	82.3	72.7	60.6	52.7	49.3	69.2
Barnacle nauplii		0.2	4.8	4.2	1.2	0.4	1.8
Cumaceans		<.1	<.1	0.2	0.1	0.2	<.1
Isopods			<.1		<.1		<.1
Amphipods		<.1	0.5	1.3	1.0	0.7	0.6
Mysids	1.1	1.7	3.1	17.0	16.5	15.3	9.1
Shrimp zoeae			0.2	0.5	0.4	0.4	0.2
Shrimp postlarvae		2.1	1.6	0.4	0.2		0.7
Shrimp			0.2	0.3	2.3	0.7	0.6
Crab zoeae		0.2	0.4	0.9	0.5		0.3
Crab megalopae				<.1	2.1		0.4
Unassigned decapod larvae		0.4	0.6	0.5	0.4	0.3	0.4
Insect larvae		4.5	2.6	2.2	4.3	12.0	4.3
Insects		0.4	<.1	<.1		<.1	<.1
Chaetognaths					0.6		0.1
Invertebrate eggs		2.0	3.2	2.1	1.5	0.6	1.6
Fish eggs			0.1	0.4	1.0	0.6	0.4
Fish larvae					1.0		<.1
Fishes				0.2	2.6	6.7	1.6
Number of individuals	28	851	1055	839	525	101	3399
Number of samples (after pooling)	1	44	69	62	56	18	250
Number of dates (maximum=31)	1	26	28	28	25	10	31
Number of stations (maximum=10)	1	8	9	9	10	8	10

position by a gravimetric method described by Carr and Adams (1972,1973).

RESULTS

A total of 3,399 anchovy stomachs were examined in the present study, spanning the dates December, 1973, through October, 1976. When pooled as described above, 250 discrete station-date-size combinations were formed. Calanoid copepods (*Acartia* spp.) were the major food item of all size classes of *A. mitchilli* (Table 1), although predation upon copepods decreased steadily with growth of anchovies. Although only one sample of 10-19 mm anchovies was obtained (due to mesh size of the trawl), the apparent specialization upon copepods is thought to be real since laboratory studies of larval anchovies (Detwyler and Houde, 1970) indicated selection of copepods over other zooplankters. Foods which increased in importance with growth of anchovies included mysids (predominantly *Mysidopsis bahia,* occasionally *M. bigelowi, M. almyra,* and *Taphromysis bowmani*), insect larvae (*Dicrontendipes* sp.), and larval/juvenile fishes.

Spatial comparison of anchovy feeding indicated specialization on calanoid copepods in most areas of the estuary (Table 2). Anchovies collected near the

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mouth of the Apalachicola River (stations 2 and 6) fed more heavily upon mysids, insect larvae and cladocerans than in other areas. In fact, mysids were more abundant in anchovy stomachs from station 6 (44%) than copepods (32%). Mysids were usually the second or third most abundant dietary item on each station. At more saline sites, chaetognaths (station 1B) or barnacle nauplii (station 1C) were often eaten, while anchovies from low salinity areas (stations 2, 3, 5, 5A, 6) consumed insect larvae and cladocerans as secondary diet components.

Temporal diet comparison also indicated that copepods were the major food item of anchovies on a month to month basis (Table 3). However, certain months (October, December, February) were characterized by low copepod consumption and relatively high utilization of other foods, particularly mysids. Mysids were important secondary food items from February through June and from September through December. Other relatively abundant foods included cladocerans in January and February, insect larvae in February and March, and crab zoeae (*Rhithropanopeus harrisii*) in August and September (particularly on upper East Bay stations 5 and 5A).

DISCUSSION

A number of studies have examined the food habits of bay anchovies. Qualitative studies by Reid (1954) and Springer and Woodburn (1960) and quantitative studies by Darnell (1958), Odum and Heald (1972), and Carr and

Table 2. Stomach contents (% of total dry weight) of *Anchoa mitchilli* relative to collection site (see map).

	Station									
Material recovered	1A	1B	1C	1	2	3	4	5	5A	6
Sand grains	0.3		0.1	<.1	<.1			<.1	0.1	<.1
Detritus	2.6	1.4	0.4	7.9			0.6	0.4		0.2
Diatoms	0.3	0.2		0.7	0.2	2.2	1.7	0.6	0.7	0.2
Plant remains	0.4		<.01	1.6	0.4	0.1	<.1	0.1	2.5	0.2
Scyphozoans	0.1			<.1						
Polychaete larvae	0.5		0.3	0.5	0.2	0.1	0.3	<.1	<.1	0.1
Polychaetes		0.2	3.9	0.5	0.6	0.4	0.1		0.5	<.1
Gastropod veligers		0.4		<.1	0.7			0.1	1.5	0.2
Gastropods	0.2		0.1	0.1	2.7			0.4	0.5	2.9
Bivalve veligers	1.1	0.3	0.2	1.0	0.1	0.6	0.7	<.1	1.7	0.8
Bivalves	0.1	<.1	0.1	0.4	0.2	1.2	0.1		2.7	0.1
Unassigned mollusc larvae	<.1	<.1								
Hydracarinids	0.2		<.1		<.1		0.1	0.1		
Cladocerans		0.3	<.1	0.1	6.7	3.2	3.5	0.3	4.8	4.5
Ostracods	0.2	2.4	1.3	1.4	1.2	0.2	3.2	0.4	0.8	1.3
Calanoid copepods	68.7	80.7	65.3	68.0	48.3	75.0	66.4	80.7	68.4	32.1
Barnacle nauplii	0.1	0.3	18.5	1.4	<.1	0.1	0.3			
Cumaceans	1.1			0.2	0.2	0.1	0.1			
Isopods		0.1	0.2	<.1						
Amphipods	0.6	0.4		<.1	1.9	3.5	1.9		0.7	1.8
Mysids	19.7	8.2	5.3	8.8	3.7	3.4	6.5	4.6	1.1	44.1
Shrimp zoeae	2.4	0.2	<.1	0.2	0.8		0.1	0.2		0.3
Shrimp postlarvae				<.1	0.6	4.2		0.8	8.5	0.2
Shrimp			1.0	0.1	5.5	0.4				
Crab zoeae		0.2		0.2	0.3	0.8		1.6	2.5	0.4
Crab megalopae				<.1	4.6					
Unassigned decapod larvae	0.6	0.2	<.1	0.3	0.1	<.1	2.0	0.1	0.2	1.0
Insect larvae	0.4			1.9	13.8	1.3	2.5	4.5	0.8	7.4
Insects				<.1			0.1		0.8	0.2
Chaetognaths		4.0								
Invertebrate eggs	0.4		1.3	2.6	2.0	3.0	4.1	1.2	1.1	2.2
Fish eggs	0.3	0.5	1.9	0.7	0.1		0.2	<.1		
Fish larvae				0.9			5.5	2.3		
Fishes					4.7			1.6		
Number of individuals	78	75	332	640	384	318	371	434	322	445
Number of samples (after pooling)	10	7	24	58	26	24	21	26	22	32
Number of dates (maximum=31)	4	6	9	23	10	12	10	12	14	13
Size classes examined (mm)	30-69	50-69	20-69	20-69	20-69	10-59	20-69	20-69	20-59	20-69

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Table 3. Stomach contents (% of total dry weight) of *Anchoa mitchilli* relative to the month of collection.

	Month											
Material recovered	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Sand grains				0.1		0.3	<.1	<.1		<.1		
Detritus			2.9			1.1	0.2		0.3	0.3	3.6	14.9
Diatoms	1.3	0.3	0.5	<.1	0.3	0.3	0.8	1.8	2.1	0.9	0.2	0.4
Plant remains		0.2	0.9	<.1	0.1	3.3	0.2	2.1	<.1	0.1	0.1	0.2
Scyphozoans			<.1	<.1								
Polychaete larvae	0.5		0.2	0.4	0.4	0.2	0.8	0.1	<.1	0.1	<.1	<.1
Polychaetes		3.5	0.3	0.9		0.2	<.1			1.4		
Gastropod veligers						0.5	<.1	0.9	1.2			
Gastropods	<.1	2.9	0.3	1.4		<.1	3.5		0.1			<.1
Bivalve veligers	1.8		<.1	<.1	1.1	0.7	2.6	2.8	0.6	0.2		
Bivalves	8.6	<.1	<.1	0.1	1.0	0.2	0.3	0.2	0.2			<.1
Unassigned mollusc larvae						<.1	<.1					
Hydracarinids			<.1	<.1		<.1						
Cladocerans	5.4	10.1	0.6	3.7	0.2	1.8				<.1	0.3	0.1
Ostracods	<.1	0.4	4.6	0.6	<.1	<.1	0.9	0.4	0.6	0.2	0.1	2.8
Calanoid copepods	69.6	27.4	67.5	75.7	70.9	65.6	70.8	80.2	72.8	58.4	81.0	39.1
Barnacle nauplii		18.3	0.2	0.7			2.0	<.1				
Cumaceans	<.1	0.4		0.3	<.1				<.1	0.3		
Isopods			<.1	0.2							<.1	<.1
Amphipods		1.8	0.7	0.4			0.6	1.8	1.5			2.0
Mysids	1.4	10.6	5.9	8.4	18.2	18.2	3.5	1.4	8.6	10.8	13.0	38.4
Shrimp zoeae				0.4	0.7	1.9	0.1	0.7	0.3			
Shrimp postlarvae				2.4	2.1		1.5	0.5	1.8		1.7	
Shrimp		0.7	0.6			0.2	2.8	0.2		7.3		
Crab zoeae								4.3	2.5			
Crab megalopae							<.1	<.1		9.9		
Unassigned decapod larvae			0.1	0.4	0.4	2.4	0.2	1.6	<.1			
Insect larvae		18.0	8.2	0.8		1.2				<.1		1.3
Insects		0.1		0.3	<.1				0.4			
Chaetognaths				1.4								
Invertebrate eggs	10.8	5.1	0.3	0.6	1.4	4.8	3.4	2.7	0.6	<.1	<.1	0.6
Fish eggs			1.3	0.7			2.4					
Fish larvae			4.5		3.0							
Fishes									4.2	9.8		
Number of individuals	107	239	443	214	203	173	325	534	313	389	180	279
Number of samples (after pooling)	8	16	39	24	19	16	22	27	22	27	11	19
Number of dates (maximum = 3)	2	2	3	3	3	2	3	3	3	3	2	2
Number of stations (maximum = 10)	4	6	7	8	5	6	7	7	8	7	4	7

Adams (1973) reported that calanoid copepods were the favored food of anchovies and that, with growth, copepod consumption declined in favor of larger zooplankters (amphipods, isopods, mysids, insect larvae, shrimp, and fishes). Unfortunately, none of these studies reported on seasonal or spatial components of the anchovy diet, as was done in the present report. This quantitative study is in general agreement with previous reports in that calanoid copepods are the predominant food of anchovies and that there is an ontogenetic change in the anchovy diet. Predation upon benthic organisms as necessitated by scarcity of zooplankton (reported by Odum and Heald, 1972) was not observed in the Apalachicola estuary, nor was heavy predation upon oyster veligers (reported by Carr and Adams, 1973). The Apalachicola estuary appears most similar to the Lake Ponchartrain, Louisiana, area (Darnell, 1958) with respect to anchovy food habits.

The bay anchovy is the numerically

dominant fish in the Apalachicola estuary. Anchovies are present throughout the year and are the only planktivores of consequence in the system. Menhaden (*Brevoortia patronus*) are the next most abundant planktivore but comprise only 1-3% of the fish community and are abundant only in the early spring (Livingston *et al.*, 1976, and unpublished data). *Menidia beryllina* and *Membras martinica* often feed heavily upon zooplankton, especially as juveniles (Reid, 1954; Darnell, 1958); however, these species were rarely collected in the estuarine areas examined here. Many other fishes exhibit a planktivorous stage, but only in their early life histories (Sheridan, 1978). It is of interest to note the relationship of the anchovy population distribution to the zooplankton community and to the predators of anchovies. The zooplankton community, dominated by the calanoid copepod *Acartia tonsa*, reaches maximum abundance in early summer, although numbers and biomass are relatively high from March to October (H. L. Edmiston, Dept. of Oceanography, Florida State Univ., pers. comm.). The anchovy population is actually least abundant during the zooplankton peak and only reaches maximum abundance in the late fall as the zooplankton community declines. The reason for this lack of exploitation by anchovies centers upon the sand seatrout, *Cynoscion arenarius*. Seatrout begin entering the estuary in April and juveniles are quite abundant throughout the summer. More importantly, seatrout are voracious piscivores and are major predators of anchovies (Sheridan, 1978), effectively checking the potential utilization of the summer zooplankton peak by anchovies.

In summary, *Anchoa mitchilli* feeds primarily upon calanoid copepods but consumes a wide variety of items found in the water column of the Apalachicola estuary. With growth, copepod consumption declines and predation upon larger zooplankters increases. Copepods are the dominant food item in most areas of the estuary and in all months of the year. The anchovy population does not appear to exploit the seasonal peak in zooplankton abundance, being regulated by the piscivore *Cynoscion arenarius* during these months.

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