DISTRIBUTION AND ABUNDANCE OF JUVENILE FISHES ALONG A SALINITY GRADIENT IN THE ANCLOTE RIVER ESTUARY, TARPON SPRINGS, FLORIDA

by

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An Abstract

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ABSTRACT

The relative importance of ocean spawned migrants in the juvenile fish population of the Anclote River Estuary, Tarpon Springs, Florida was determined by quantitative sampling of fish fauna along a salinity gradient. Three stations were established: station 1, an "estuarine" area (30 ppt); station 2, a "tidal salt marsh" (17 ppt); and station 3, a "river" area (7 ppt). Eight seine hauls were made bimonthly at each station with a fine mesh seine (1.5 mm) from March to October, 1980 for a total of 16 visits per station.

Station 1 was highest in total abundance, 4502 individuals/400 m^2 and number of species, 37. Station 2, had one-fifth the abundance of station 1, 857/400 m^2 and 23 species; station 3 had one-half the abundance of station 1, 2495/400 m^2 and 32 species. Stations were dominated by a few common species with most species low in abundance. Menidia beryllina (tidewater silverside), Anchoa mitchilli (bay anchovy), and Lagodon rhomboides (pinfish) made up 94% of station 1's total catch. Anchoa mitchilli, M. beryllina, and Leiostomus xanthurus (spot) made up 84% of station 2 and 90% of station 3 in total catch. Dominance, measured by the community dominance index (Krebs 1978), was positively related to species richness; as dominance increased richness increased. A succession pattern was observed, through length frequency analysis, for five fish species: L. xanthurus, L. rhomboides, A. mitchilli, *Eucinostomus gula* (silver jenny), and *Fundulus grandis* (Gulf killifish). The youngest members were found in low salinity waters, and moved to higher salinities as they grew. These ocean spawned migrants made up less than 23% of the total individuals of the Anclote River Estuary.

The estuary and river stations are apparently discrete community habitats, while the tidal salt marsh is a transitional zone as indicated by presence-absence, abundance, and size frequency data of the fish fauna. An increase in physical diversity of the habitat, mainly due to the presence of seagrass beds, is suggested as the principal factor affecting the distribution and abundance of fish fauna between sampling stations. The Anclote River Estuary serves as a nursery area for a few species of ocean spawned migrants but was dominated by resident species.

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INTRODUCTION

The nursery role of estuaries and rivers for larval and juvenile marine fishes has been studied in many areas north of the Florida peninsula (Bearden 1964; Thomas and Loesch 1970; Parker 1971; Herke 1971; Subrahmanyan and Drake 1975; Purvis 1976; Chao and Musick 1977; Weinstein 1980a). A successional pattern has emerged in these studies in which the youngest members of several ocean spawned species initially take up residence in upper tidal creeks; then gradually move into higher salinities as they grow, leaving behind slow growing individuals and new recruits (Herke 1971; Dunham 1972; Purvis 1976). The relative importance of inshore migration by ocean spawned fishes, in the ecology of the estuary, is not clear from the literature. In North Inlet Estuary, South Carolina (Shenker and Dean 1979) and Cape Fear River, North Carolina (Weinstein 1980a), fish communities were numerically dominated by ocean spawned migrants. However, studies as the Shocum River, Massachusetts (Hoff 1977) and Patuxent Estuary, Maryland (McErlean et al. 1973) showed that resident fish species were numerically dominant.

Few studies of this nature have been conducted on the west coast of Florida (Subrahmanyan et al. 1975; Weinstein et al. 1977), and the relative importance of transient versus resident fish in the estuary is still unresolved. Consideration of this problem was addressed in the present study by sampling the juvenile fish fauna of the Anclote River Estuary, Tarpon Springs, Florida. The study site was chosen because of its relatively abrupt salinity change (marine to low salinity water in a distance of 9 km) and the fact that no studies have sampled the juvenile fishes along its salinity gradient.

The purpose of the present work was 1), determine the relative importance of marine spawned fishes inhabiting the low salinity areas 2), evaluate a successional pattern if it exists 3), investigate the fish community found along the salinity gradient of the Anclote River Estuary, quantitatively.

LITERATURE REVIEW

Estuarine and adjacent low salinity areas have been identified as nursery areas for ocean spawned larval and juvenile fishes (Purvis 1976). In particular, Bearden (1964) showed that *Micropogon undulatus*, the Atlantic croaker, spawned several miles offshore. After hatching, larvae spent their first days at sea; subsequently, the main body of young croakers moved up tidal creeks into areas of reduced salinity, and as growth proceeded they gradually moved seaward again. Other fish species have shown a similar life cycle: *Urophycis regius*, the spotted hake; *Cynoscion regalis*, the weakfish; *Bairdiella chrysura*, the silver perch; *Leiostomus xanthurus*, the spot; and *Lagodon rhomboides*, the pinfish (Hansen 1969; Parker 1971; Markle 1976; Weinstein 1979a).

While the nursery role of estuaries and low salinity areas is apparent, the relative importance of ocean spawned migrants in the low salinity area is somewhat vague. In North Inlet Estuary, South Carolina, 70% of the total number of fishes were transients: *Leiostomus xanthurus*; *Mugil* sp.; *Myrophis punctatus*, the speckled worm eel; *Lagodon rhomboides*; *Paralichthys* sp.; and *Micropogon undulatus*, while about 25% were permanent residents: *Menidia menidia*, the Atlantic silverside; *Anchoa mitchilli*, the bay anchovy; *Fundulus* sp., as well as several gobies (Shenker and Dean 1979).

Weinstein (1980a) found a similar fish community in the Cape Fear River, North Carolina. Transient species were dominant and included: Leiostomus xanthurus; Mugil cephalus, the striped mullet; and Brevoortia tyrannus, the Atlantic menhaden. The permanent residents, although common, were second in abundance compared to transients and included: Anchoa mitchilli; Fundulus sp.; Mendia menidia; and Eucinostomus argenteus, the silver jenny.

Other investigators of fish communities in estuaries report that resident fish species were the numerical dominants. Hoff (1977) showed that Buzzards Bay, Mass. was dominated by the resident fishes: Fundulus heteroclitus, the mummichog, and Menidia menidia. McErlean et al. (1973) sampled the Patuxent Estuary, Maryland and also observed that Fundulus sp. and Menidia sp. were the shore dominants. Merriner et al. (1976) sampled the Piakatank River, Virginia and there again: Anchoa mitchilli; Trinectes maculatus, the hogchoker; and Bairdiella chrysura, all resident fishes, dominated the catches.

On the west coast of Florida it is still unknown to what extent fishes use the estuaries as nursery grounds. Subrahmanyan et al. (1975) found that tidal creeks off Apalachee Bay, Fla. were dominated by transients, Leiostomus xanthurus and Lagodon rhomboides, while the adjacent Fenholloway River and Apalachicola Bay systems were dominated by resident species (Livingston 1975, 1976).

The Anclote River Estuary, also on the west coast of Florida, was repeatedly dominated by transient species (Baird et al. 1971; Fable 1973; Rolfes 1974; Mayer and Maynard 1975; Thorhaug et al. 1977). However, these studies of the Anclote concerned the fish fauna in the high salinity areas ($\approx$ 30 ppt) and no studies have extended upriver into the low salinity waters.

The present study details the composition of the nekton community in several low salinity areas. Quantitative distribution analyses of individual species and communities were compared through size frequencies and cluster analysis. Consideration is given to the role of these habitats as primary nurseries, and the relative importance of transients in the low salinity fish community.

STUDY AREA

The Anclote River Estuary is a shallow, semi-enclosed, coastal embayment, located on the west-central Gulf coast of Florida between latitudes 28°09' - 28°13'N and latitudes 82°47' - 82°51'W (Fig. 1). Three station areas were established in the Anclote River and its estuary (Fig. 1). Station 1, an "estuarine" area, salinity ≈30 ppt, was located at the mouth of the Anclote River and covered approximately 25 ha. The benthos at station 1 consisted of fine to medium quartz sand with scattered sandy clay deposits (Mohler 1963), and patches of seagrasses: *Thalassia testudium*, turtle grass; *Syringodium filiforme*, manatee grass; *Diplanthera wrightii*, shoal grass; *Halophila engelmannii*; and *Ruppia maritima*, widgeon grass (Humm et al. 1971). *Thalassia*, the most abundant species of seagrass at station 1, grows below mean low water. Therefore, it was only sampled at low tides. *Diplanthera*, the second most abundant seagrass in the Anclote estuary station, grows in the lower intertidal zone and was sampled on every station visit. The estuary station also contained oyster bars, mangrove stands, and channels.

Station 2, salinity ≈17 ppt, was a "tidal salt marsh". It was located 6.5 km from the mouth of the Anclote River and covered approximately 15 ha. Station 2 was characterized by sediments

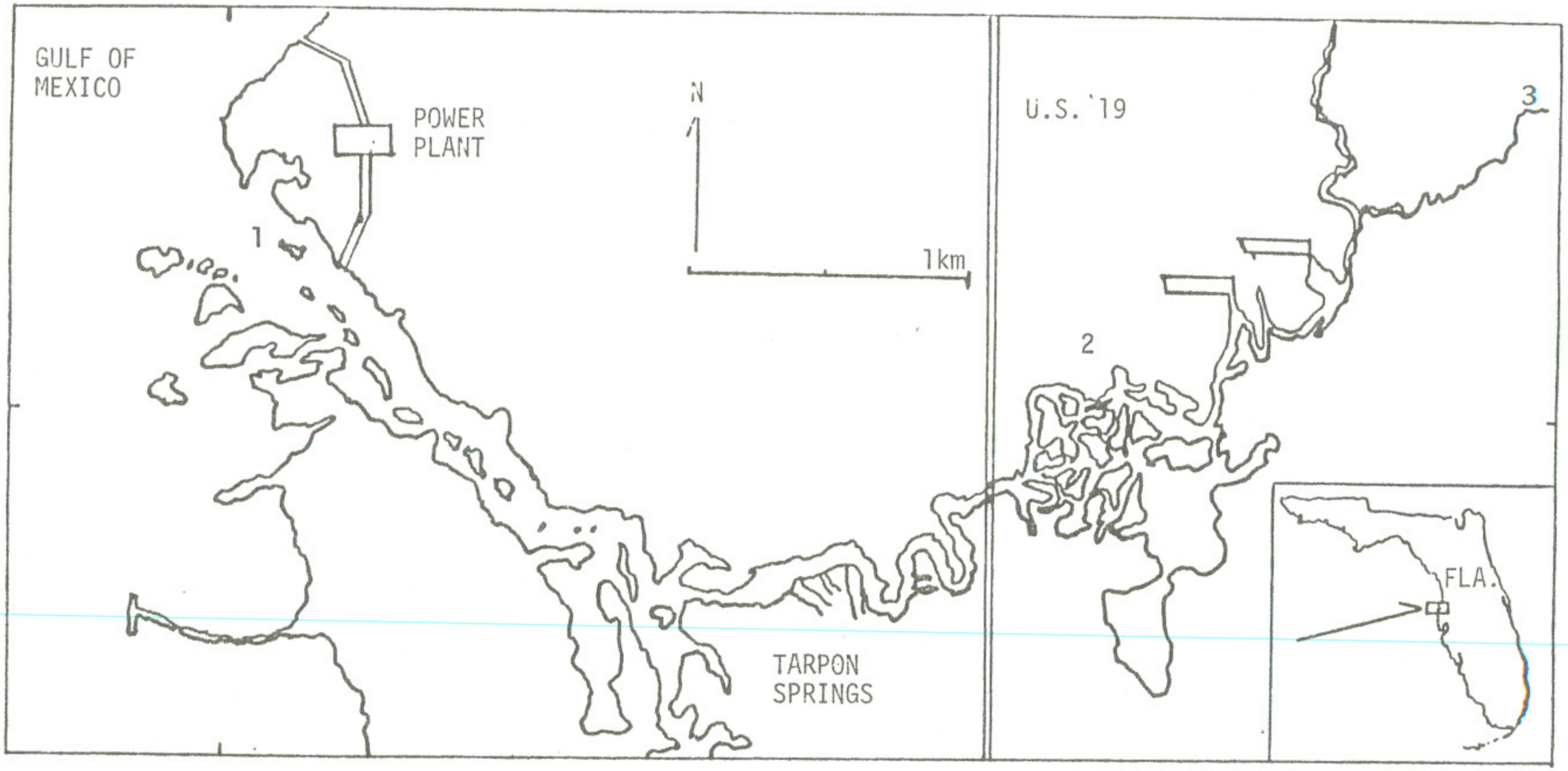


Figure 1. Anclote River Estuary, Tarpon Springs, Fla. Station 1 was an estuarine area, station 2 was a tidal salt marsh area, and station 3 was a river area.

grading from fine sand to clay mud deposits and was free of benthic vegetation. Shoreline vegetation of station 2 consisted of stands of _Juncas roemerianus_, the black rush.

Station 3, salinity ≈7 ppt, a "riverine area" was located 9.6 km from the river mouth and covered approximately 10 ha. The bottom at the river station was mud to soft organic ooze without submerged benthic plants. Shoreline vegetation of the river area was characteristic of fresh waters and included _Typha_ sp., cattails and _Taxodium_ sp., cypress trees.

MATERIALS AND METHODS

Field

Salinity determinations were made with a refractometer and surface temperature with a hand-held mercury bulb thermometer. Specimens were collected with a 1.5mm mesh 6.3 x 1.8m seine net with extra weights to improve its efficiency. A method of eight seine sweeps per station was adapted as a compromise between oversampling and undersampling species richness. This method was adequate for stations 2 and 3 but insuffecient for station 1 (Fig's. 2, 3, 4).

Seine sweeps were made bi-monthly from March to October, 1980 for a total of sixteen visits per station. On one occasion a station was missed: station 2, 9/18/80 due to weather. Sweep locations were chosen to maximize variation in physical characteristics (benthos type) and were random with respect to tidal conditions. In the estuary area, three sweeps were made in the thick intertidal seagrass beds, three in a sheltered area of sand shell hash sediment with intermittent seagrass beds, and two in a Red mangrove-oyster bar area. At station 2, three sweeps were made in a narrow tidal creek, three on the leeward side of a sandbar, and two near a drop off. At station 3, one sweep was made next to a log jam, four along the sides of the river, and

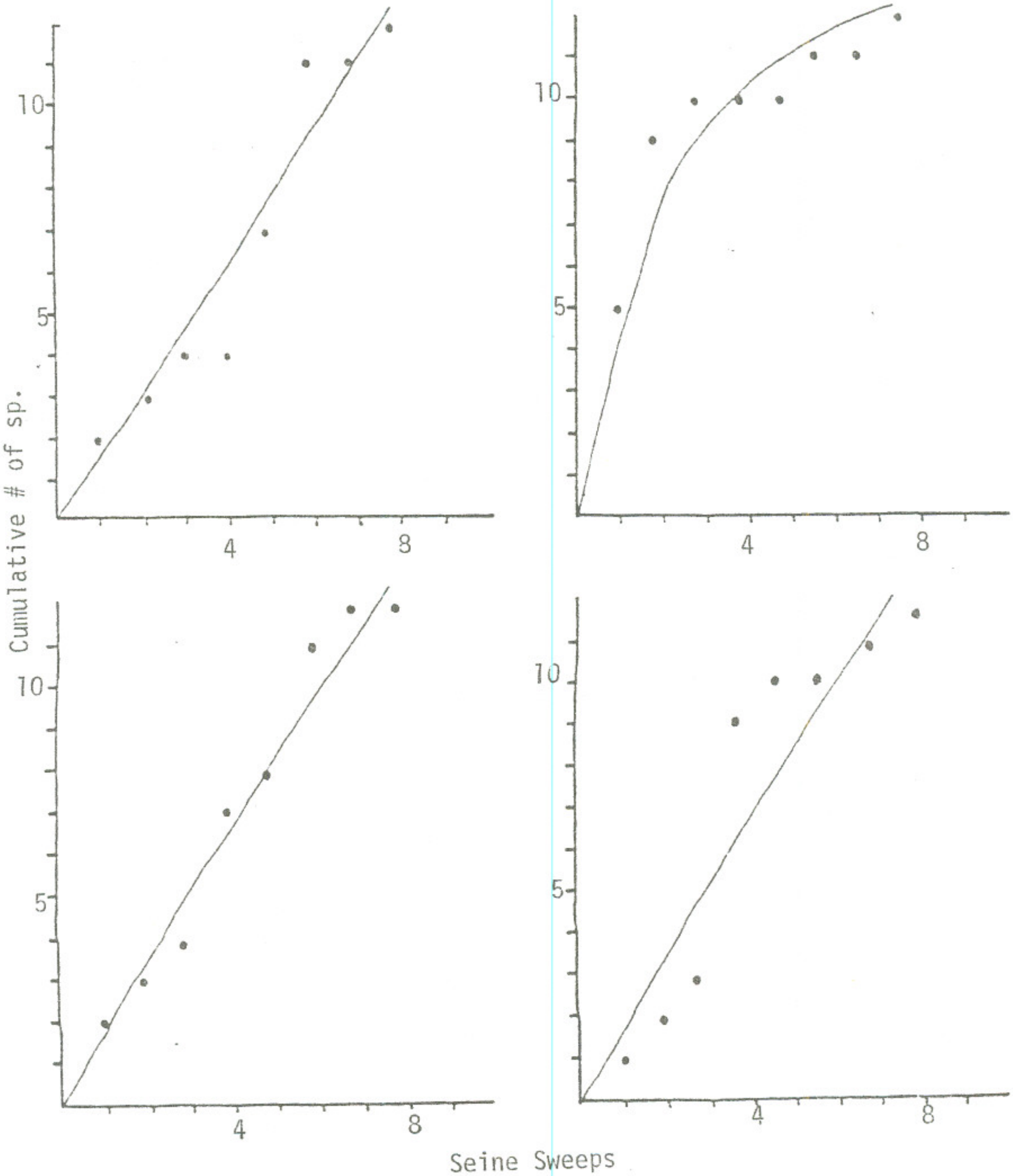


Figure 2. Species number vs. seine sweep, from station 1. Seine sweeps were arranged in random order and graph lines were drawn by sight.

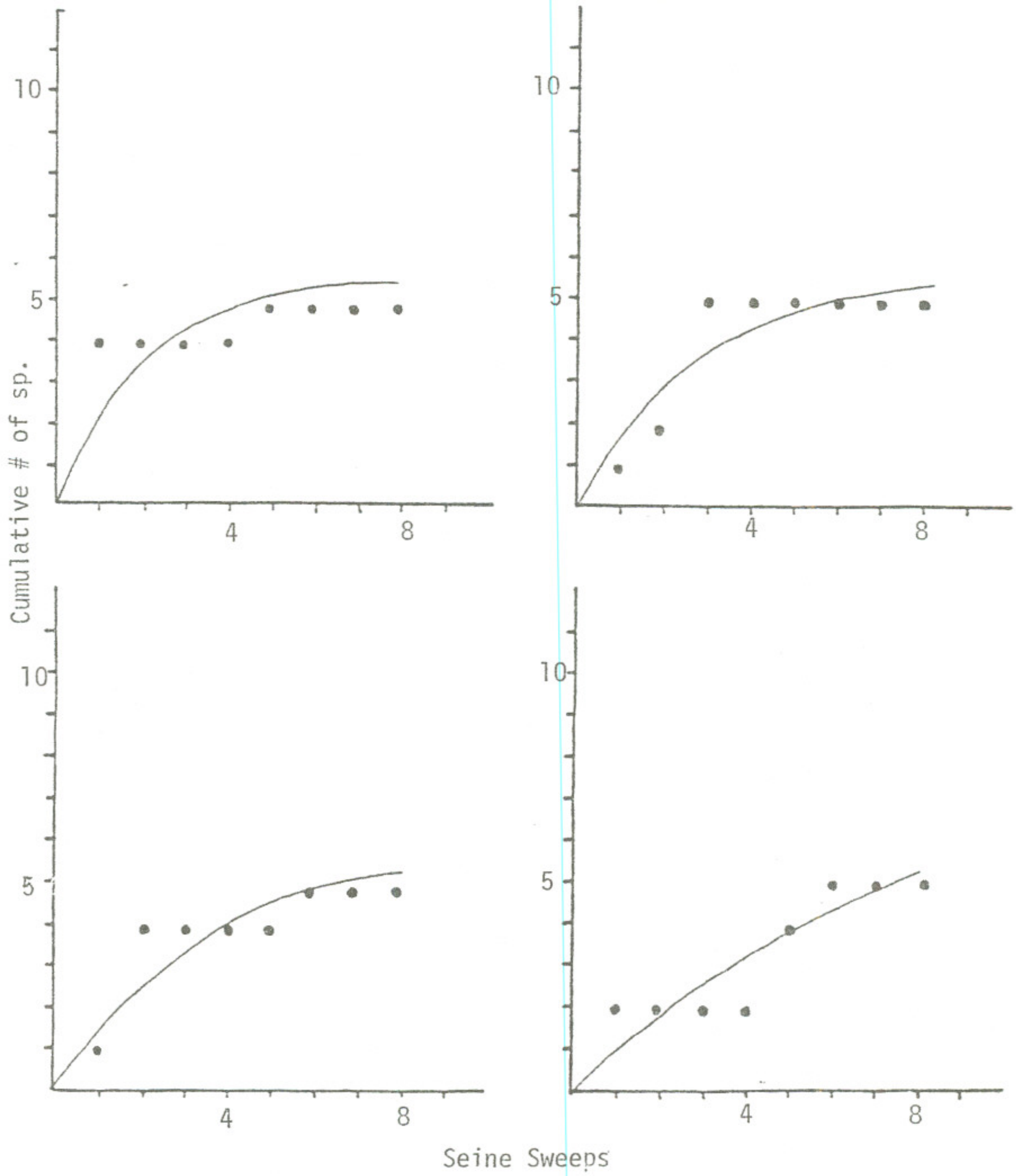


Figure 3. Species number vs. seine sweep, from station 2. Seine sweeps were arranged in random order and graph lines were drawn by sight.

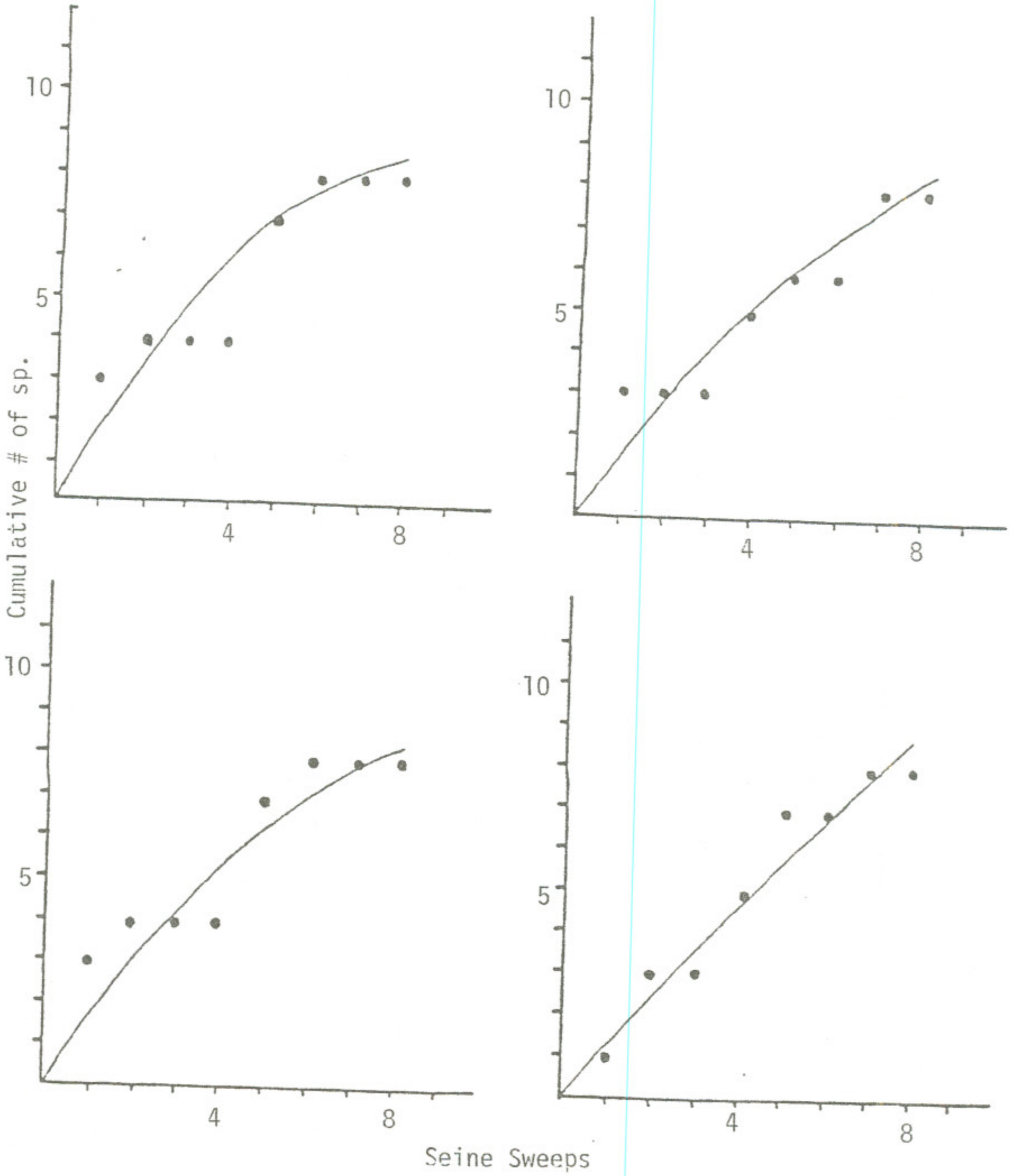


Figure 4. Species number vs. seine sweep, from station 3. Seine sweeps were arranged in random order and graph lines were drawn by sight.

three in a sheltered cove with soft organic substrate.

The actual length of the seine net was 6.3 m but since a bow forms when the seine is used the effective length was approximately 4.5 m. The distance from shore was constant, 9.0 m (a transect line was used), thus the approximate area sampled per seine haul was 40 m^2. On some occasions the depth of water was too great for seining at a distance of 9.0 m from shore, and in these cases adjustments were made for calculation of area sampled based on actual measured distance from shore.

Laboratory

Specimens were stored in 10% formalin and brought back to the lab for identification and measurement. Random samples for size estimations of abundant species were obtained from each seine haul. The catch was homogeneously distributed over a grid then all those individuals in the first square, second square, and so on were used for size measurement until a maximum of twenty-five fish were measured. Rarer species necessitated the use of all specimens collected in a single haul to obtain size frequency data.

RESULTS

Salinity and Temperature

Salinity ranges were 22 - 34 ppt at station 1, 6 - 25 ppt at station 2, and 2 - 15 ppt at station 3. From March to October, 1980, the salinity gradient between stations 1, 2, and 3 always exceeded 4 ppt. Synchronized fluctuations in salinity occurred at stations 2 and 3 (Fig. 5). The lowest salinities recorded for stations 2 (6 ppt) and 3 (2 ppt) were in March with a steady increase to 25 ppt at station 2 and 15 ppt at station 3 in June. Salinities then declined to 14 ppt at station 2 and 5 ppt at station 3 in October (Fig. 5). Station 1 did not rigorously follow the pattern of salinity fluctuation seen at the other two stations. Station 1's salinity fluctuated around 30 ppt from March to September, then dropped to 22 ppt with a quick return to 30 ppt in October (Fig. 5). In all three stations water temperature ranged from 23°C in early March to 35°C in July. There was little difference in temperature between stations in any one sampling period (Fig. 6).

Abundance and Composition

Station 1 showed the highest estimated abundance, 4502 individuals/400 m^2 and number of species, 37. Station 2 was lowest in abundance, 857/400 m^2 and number of species, 23. Station

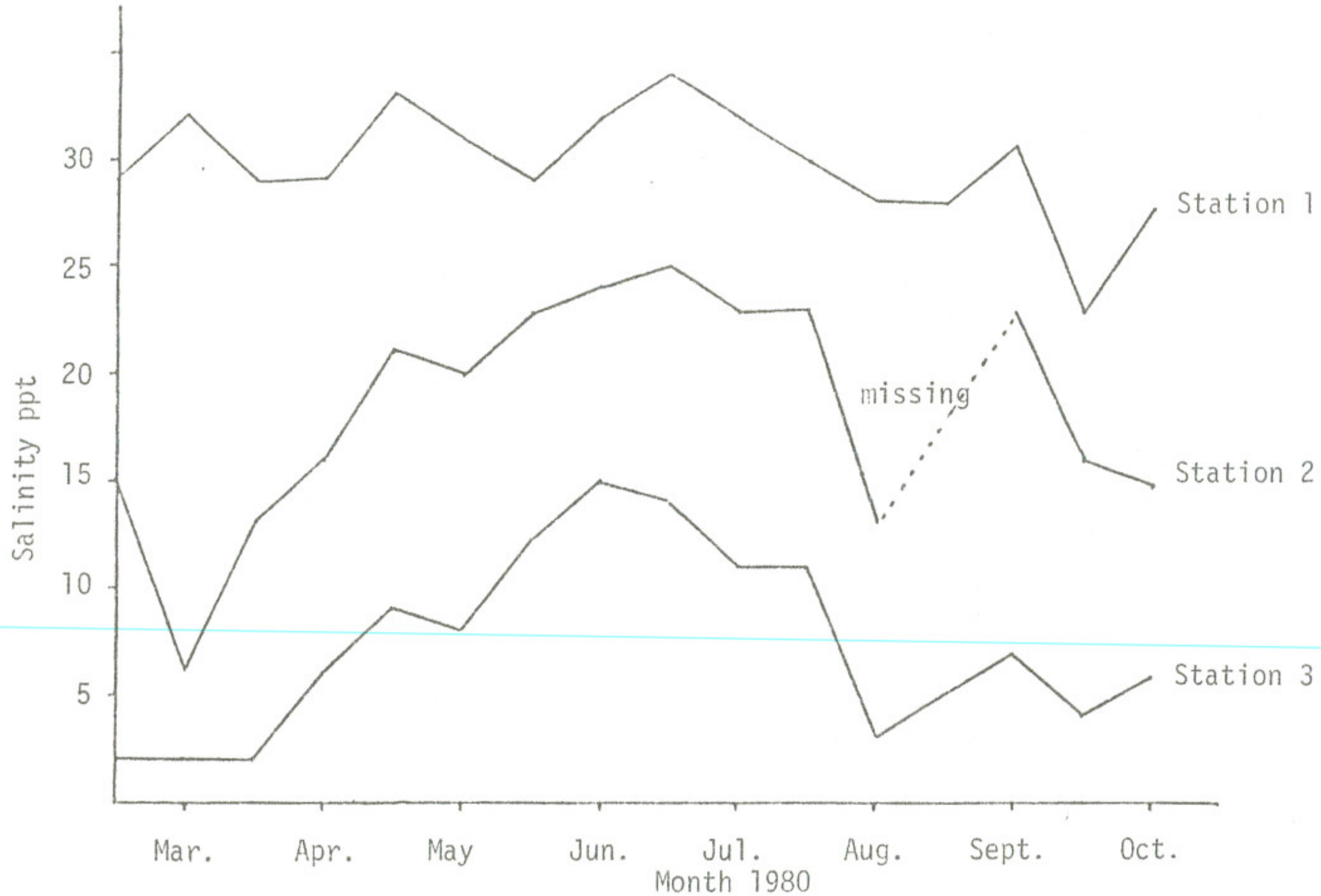


Figure 5. Salinity measurements from stations 1, 2, and 3 Anclote River Estuary, Tarpon Springs, Fla.

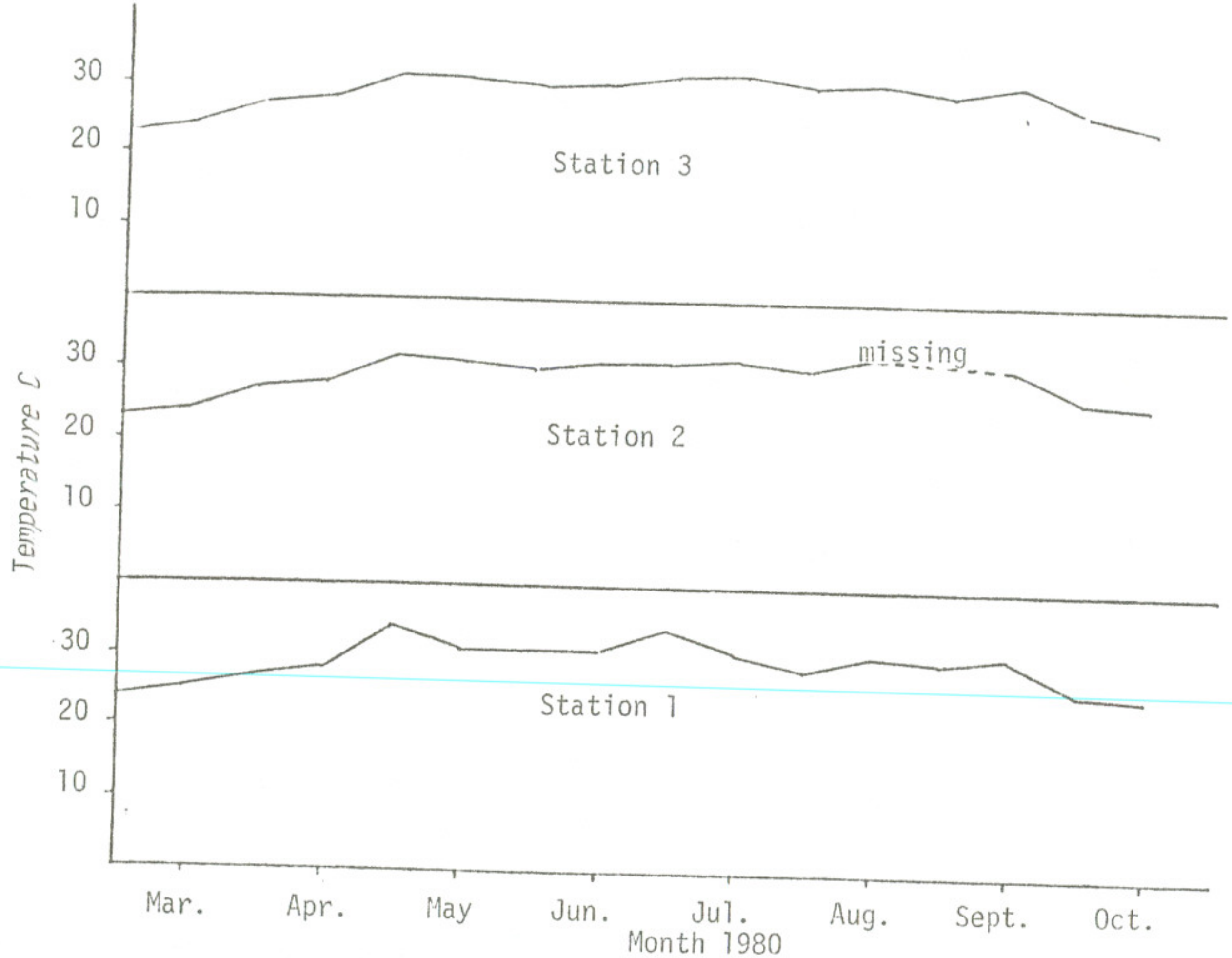


Figure 6. Temperature recorded from stations 1, 2, and 3 Anclote River Estuary, Tarpon Springs, Fla.

3 had intermediate abundance and number of species compared to other stations: 2495/400 m^2 and 32 species (Table 1).

All three stations were dominated by a few common species with most species low in abundance. Menidia beryllina, the tidewater silverside; Anchoa mitchilli; and Lagodon rhomboides made up 94% of the total fish catch for the estuary station. Anchoa mitchilli, M. beryllina, and Leiostomus xanthurus made up 84% of the salt marsh station and 90% of the river station in total catch (Table 2).

Certain species showed significant differences in numbers between stations, i.e., Fundulus similis, the longnose killifish; Eucinostomus gula; Lagodon rhomboides; and Cyprinodon variegatus, the sheepshead minnow, had greater numbers at station 1. Also *Gobiosoma bosci, the naked goby; Microgobius gulosus, the clown goby; and Eucinostomus argenteus, the spotfin mojarra, had significantly greater numbers at stations 2 and 3.* Menidia beryllina had greater numbers at stations 1 and 3 (0.05 level, ANOVA, Duncan's multiple range test; Fig. 7). Figure 7 also shows that Poecillia latipinna, the sailfin molly, and Gambusia affinis, the mosquitofish, were collected mainly at the low salinity river station. Ubiquitous species that did not show significant differences in numbers between stations included: Mugil cephalus; Leiostomus xanthurus; Syngnathus scovelli, the Gulf pipefish; Strongylura marina, the Atlantic needlefish; Fundulus grandis, the Gulf killifish; Oligoplites saurus, the leatherjacket; and Strongylura notata, the redfin needlefish.

Table 1. Total number of individuals and species collected at sampling stations 1, 2, and 3 Anclote River Estuary, Tarpon Springs, Fla. * = Significance at 0.05 level, Wilcoxon signed rank test (Zar 1974).

STATION	TOTAL NUMBER m^2	NUMBER OF SPECIES	SAMPLE SIZE DAYS COLLECTED	STANDARDIZED ABUNDANCE/ $400m^2$
1	56069 4982 m^2	37 *	16	4502
2	8155 3807 m^2	23 *	15	857
3	21603 3463 m^2	32 *	16	2495

Table 2. Pooled species abundance for all collections at stations 1, 2, and 3 Anclote River Estuary, Tarpon Springs, Fla. Listed in order of abundance are species composing more than 0.1% of the total. Percentage and the standardized abundance per 400m² are shown for comparison.

STATION 1				STATION 2				STATION 3			
Species	Total number	%	400 m²	Species	Total number	%	400 m²	Species	Total number	%	400 m²
Menidia beryllina	47018	83.9	3775	A. mitchilli	4725	57.9	496	M. beryllina	17532	81.3	2025
Anchoa mitchilli	3156	5.6	253	L. xanthurus	1097	13.5	115	L. xanthurus	1224	5.7	141
Lagodon rhomboides	2328	4.2	187	M. beryllina	1027	12.6	108	A. mitchilli	572	2.6	66
Leiostomus xanthurus	1004	1.8	81	Microgobius gulosus	367	4.5	39	Gambusia affinis	481	2.2	56
Cyprinodon variegatus	909	1.6	73	E. argenteus	265	3.2	28	G. bosci	469	2.2	54
Eucinostomus gula	693	1.2	56	L. romboides	209	2.6	22	Brevoortia patronus	378	1.7	44
Sardinella anchovia	410	0.7	33	Gobiosoma bosci	165	2.0	17	L. parva	306	1.4	35
Lucania parva	100	0.2	8	Mugil cephalus	139	1.7	15	E. argenteus	205	0.9	24
Eucinostomus argenteus	98	0.2	8	F. grandis	43	0.5	5	M. gulosus	134	0.6	15
Strongylura notata	95	0.2	8	E. gula	39	0.2	4	Poecilia latipinna	76	0.4	9
Oligoplites saurus	54	0.1	4	S. scovelli	19	0.2	2	M. cephalus	71	0.3	8
Fundulus grandis	45	0.1	4	S. notata	13	0.2	1	Micropterus salmoides	33	0.2	4
Fundulus similis	40	0.1	3	O. saurus	13	0.2	1	S. notata	27	0.1	3
Syngnathus scovelli	38	0.1	3	S. marina	11	0.1	1	Achirus lineatus	17	0.1	2
Strongylura marina	37	0.1	3	F. similis	7	0.1	1	O. saurus	11	0.1	1

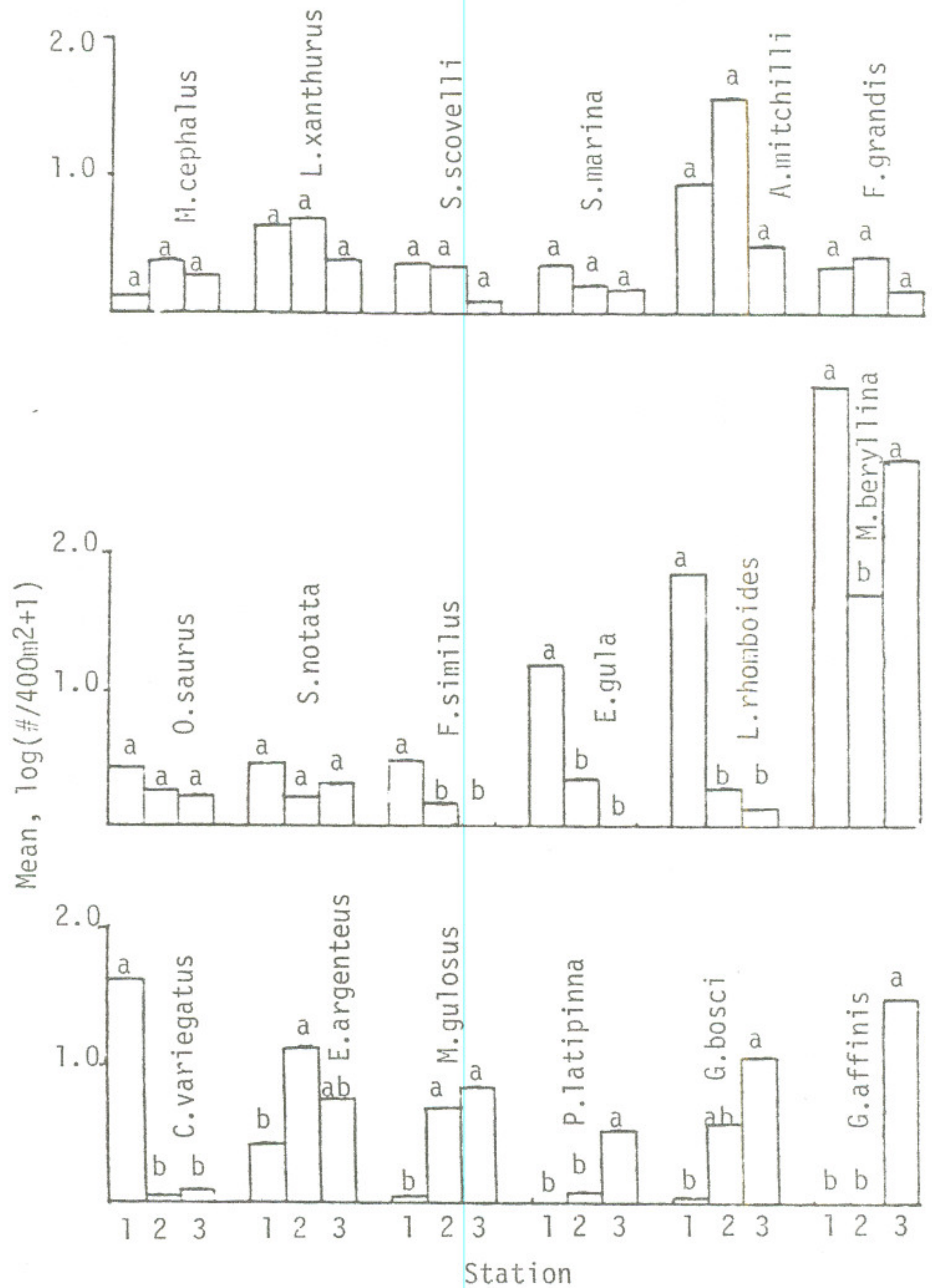


Figure 7. Standardized (#/400m2) log transformed abundances for selected species. Different letters denote significant change between stations, ANOVA, 0.05 level, Duncan's multiple range test (SAS 1979).

Significant differences in fish length were detected for a few species between stations, with the smallest size class generally found upriver in low salinity waters (0.05 level, ANOVA, Duncan's multiple range test; Fig. 8). Two species, Leiostomus xanthurus and Fundulus grandis, which were not significantly different in abundance between stations, did have significantly smaller size classes at station 3.

Menidia beryllina and Lagodon rhomboides both showed significant differences in fish length between all three stations. The largest specimens of M. beryllina ($\bar{x}$ = 45 mm) occurred at station 2, intermediate sized ($\bar{x}$ = 33 mm) at station 1, and the smallest fish ($\bar{x}$ = 31 mm) frequented the farthest station from the Gulf, station 3 (Fig. 8). The largest specimens of L. rhomboides ($\bar{x}$ = 43 mm) were associated with station 1, intermediates ($\bar{x}$ = 36 mm) with station 2, and small fish ($\bar{x}$ = 23 mm) with station 3. Young Gobiosoma bosci ($\bar{x}$ = 12 mm) frequented station 2, and Eucinostomus argenteus was not significantly different between areas sampled (Fig. 8). Anchoa mitchilli again demonstrated a smaller size class of fish at the upriver stations: station 3 ($\bar{x}$ = 20 mm), station 2 ($\bar{x}$ = 21 mm), and station 1 ($\bar{x}$ = 26 mm; Fig. 8).

A detailed analysis of Menidia Beryllina length frequency was possible because of its abundance. In figure 9, a steady change in modal size frequency is seen for station 1. As time progresses from spring to fall, the size classes shift from early juveniles (20 mm) to juvenile-adult status (30 - 60 mm). Stations 2 and 3 show a different pattern, with larger fish showing peak abundance in early

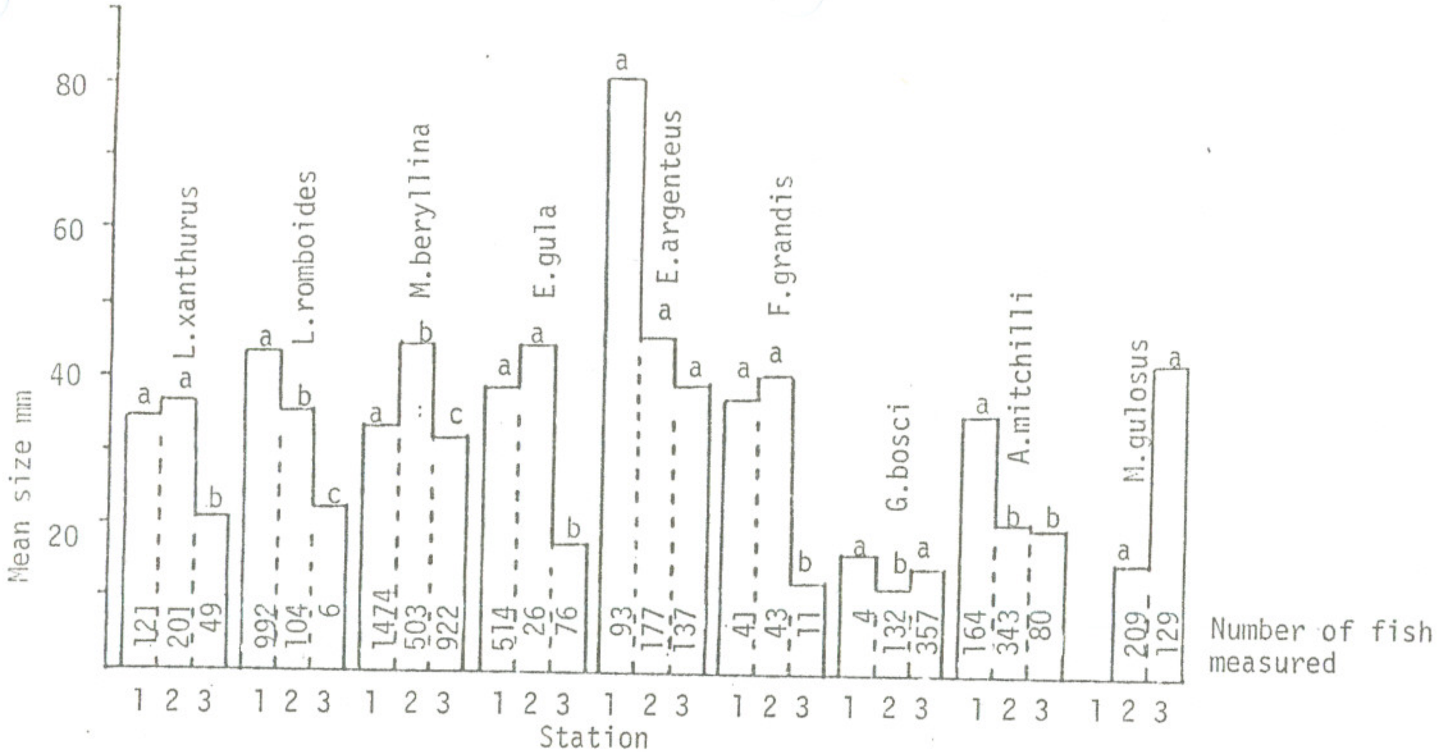
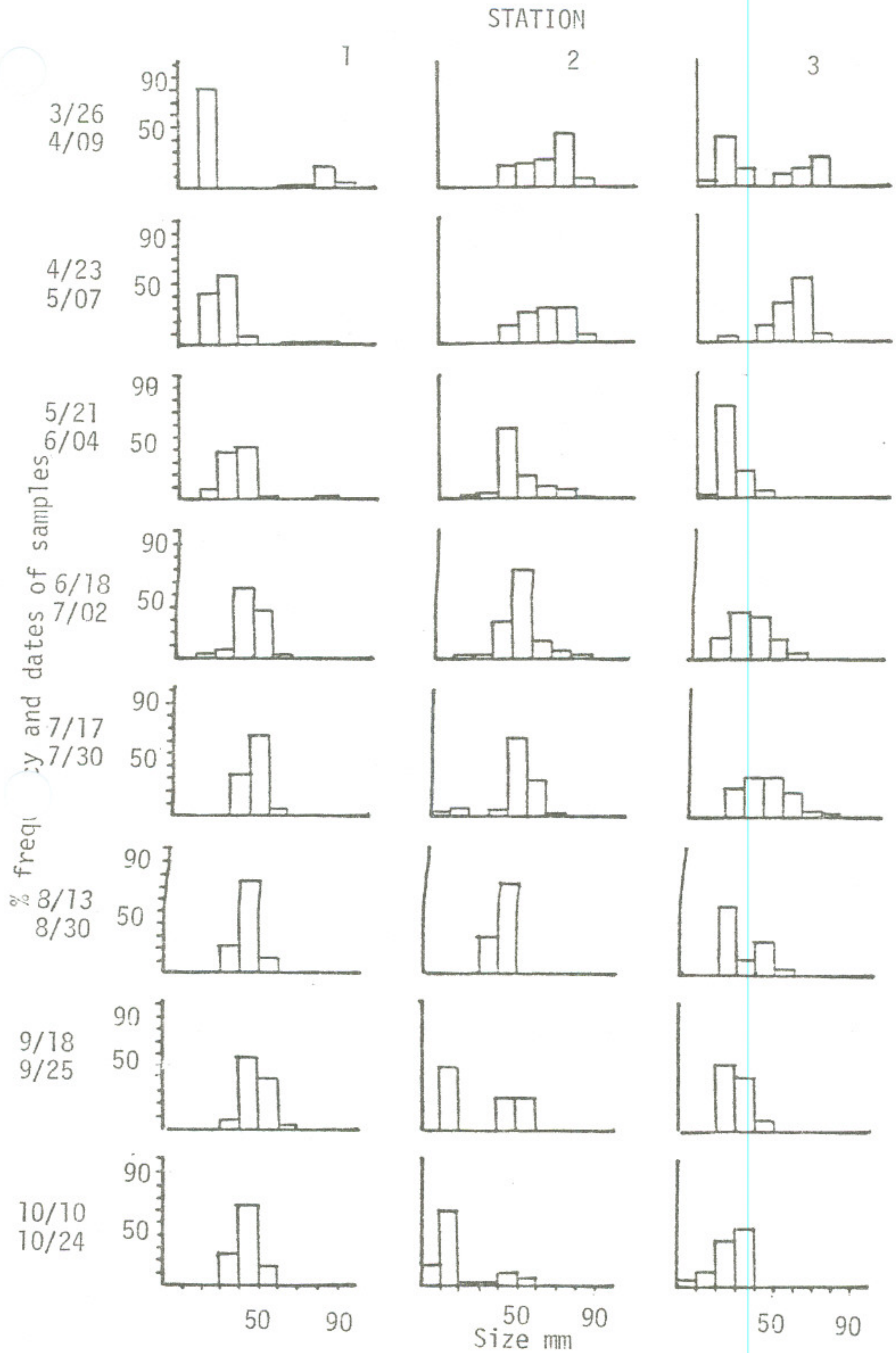


Figure 8. Mean size of selected species from different stations on the Anclote River Estuary. Size data were pooled for all collections for each station and species. The number of fish measured, station and significance of size are shown (bars with different letters are significantly different, 0.05 level, ANOVA, Duncan's multiple range test, SAS 1979).



igure 9. *Menidia beryllina* length frequency distribution, over a salinity gradient: station 1, sal.= 22 - 34 ppt., station 2, sal. = 6 - 25 ppt., and station 3, sal. = 2 - 15 ppt.

summer, increasing size through late summer, then decreasing again in early fall (Fig. 9).

Dominance of fish communities for the Anclote area was determined by comparing numbers of individual species. The percentage of total abundance contributed by the two most abundant species was used as a dominance index (Krebs 1978). Dominance was related to the number of species positively; as dominance increased, richness increased (Fig. 10).

In qualitative cluster analysis of fish collections[1], a stopping rule of greater than 50% similarity was used. This resulted in clusters forming according to spatial aspects rather than temporal criteria; i.e., estuarine station samples were clustered (group A), tidal salt marsh station samples were clustered (groups B, C), and river station samples were clustered (group D) with little tendency for monthly clusters (Czekanowski's similarity coefficient of log transformed abundances, average sorting cluster analysis, Boesch 1977; Fig. 11). Qualitative cluster analysis did reveal some grouping of estuarine and tidal salt marsh stations for the months of June, July, August, September, and October, but we also still see a strict spatial cluster for the river station, group U ([similarity = 2(# of species in common)/(# of species in the first group + # of species in the second group)], Krebs 1978; average sorting cluster analysis, Boesch 1977; Fig. 12). Since both quantitative and qualitative cluster analysis revealed spatial

1. One collection = pooled samples from each consecutive four weeks: 2(8 seine hauls/day station).

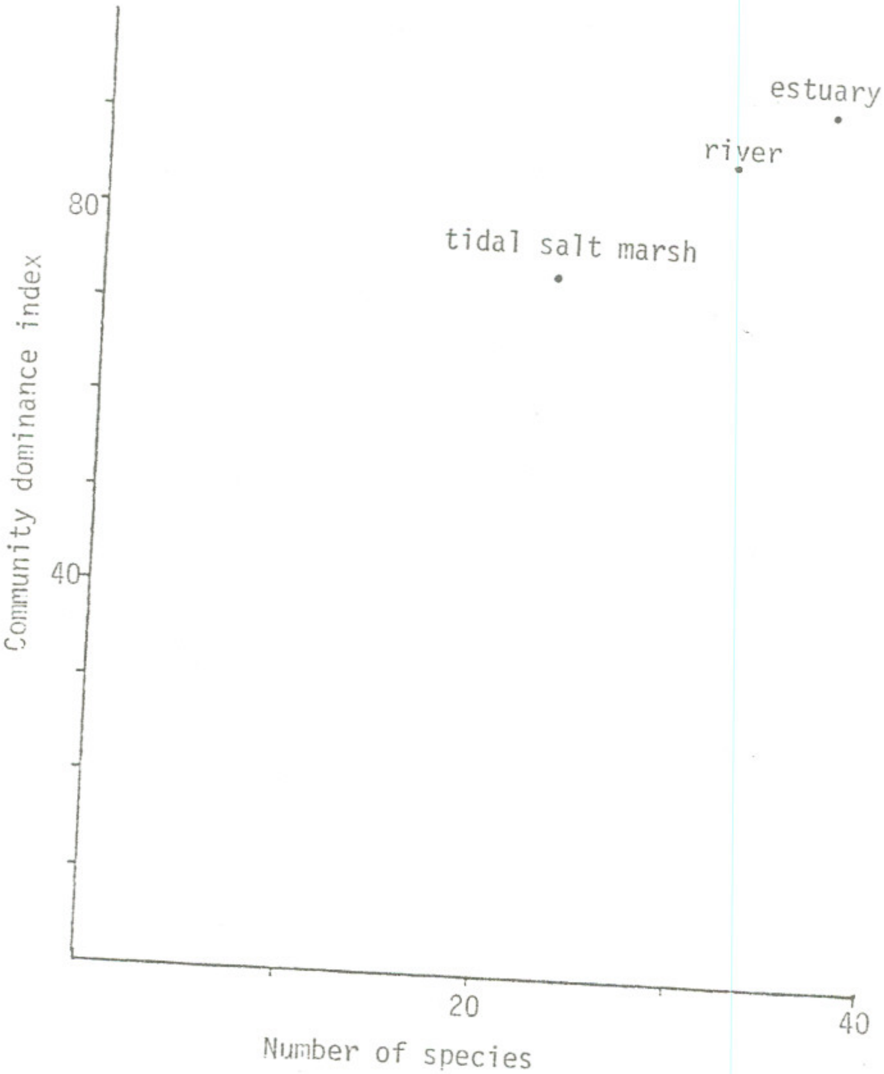


Figure 10. Dominance vs. the number of species for each station. Community dominance index = 100(A + B)/C, where A = most abundant species, B = the second most abundant species, and C = total abundance (Krebs 1978).

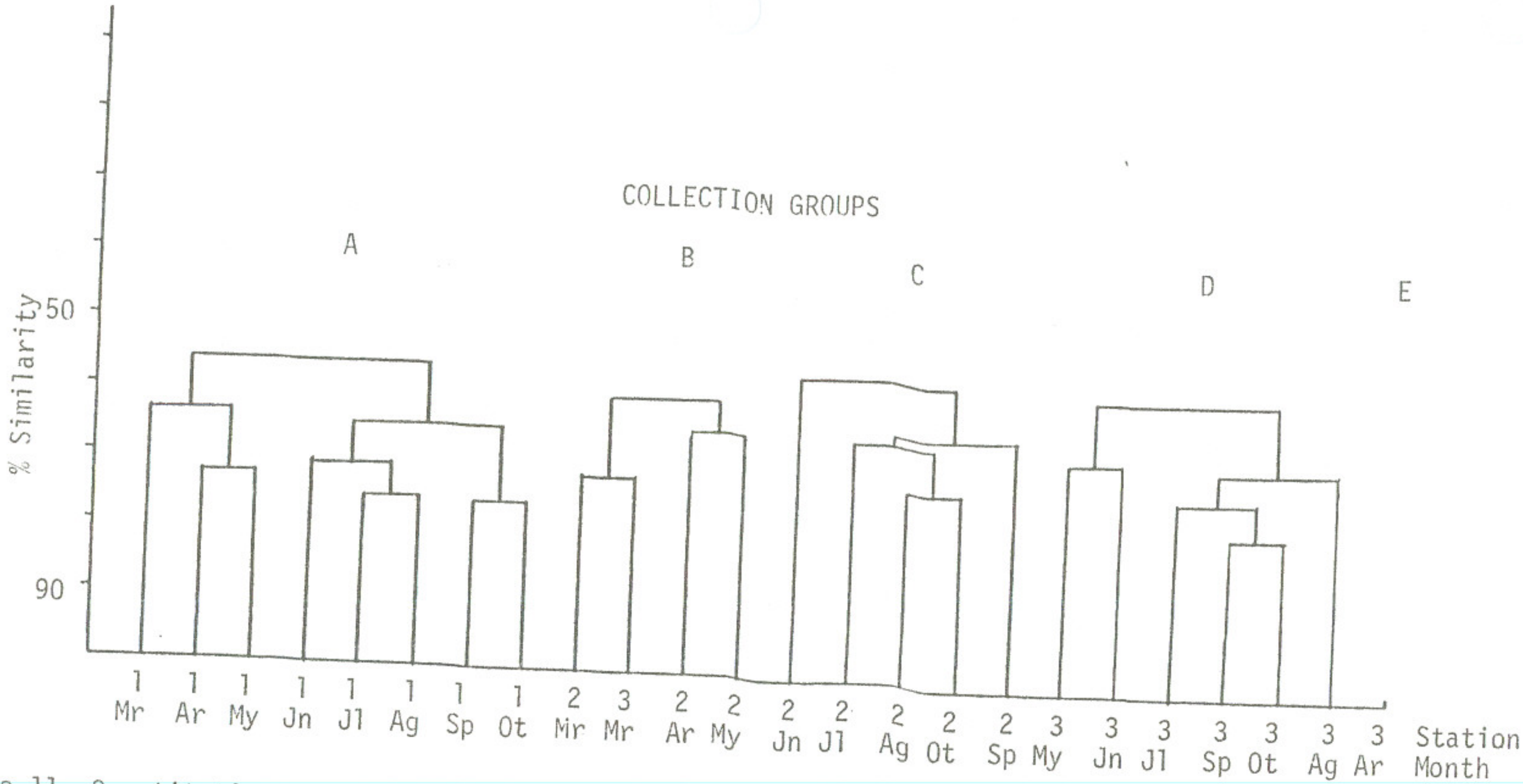


Figure 11. Quantitative analysis of collection similarity (normal) of log transformed species abundance using Czekanowski's coefficient and group average sorting. A cluster group was considered as any group with a > 50% similarity (fixed stopping, Boesch 1977).

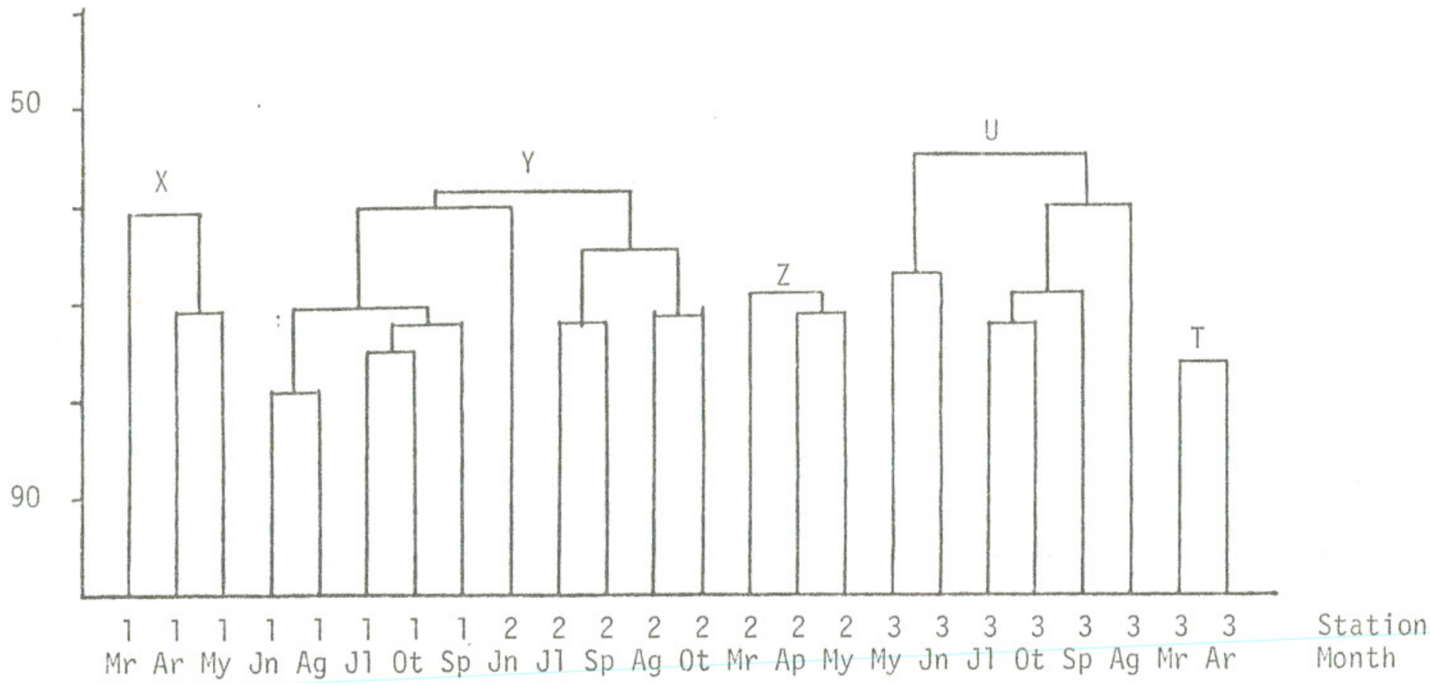


Figure 12. Qualitative analysis of collection similarity (normal) by presence absence criteria. Similarity = 2c/(a+b), where c = number of species in common, a = number of species in the first collection, and b = number of species in the second collection. A cluster was considered as any with a greater than 50% similarity (fixed stopping, Boesch 1977).

clusters, habitat effects were considered more important than temporal effects in determining the species composition of different stations.

Quantitative species co-occurence cluster analysis (inverse), with a stopping rule of greater than 34% similarity, revealed nineteen species groups. Seven groups had more than three species: groups 1, 3, 9, 11, 13, 16, and 19 (Czekanowski similarity coefficient with log-transformed data, average sorting cluster analysis, Boesch 1977; Fig. 13).

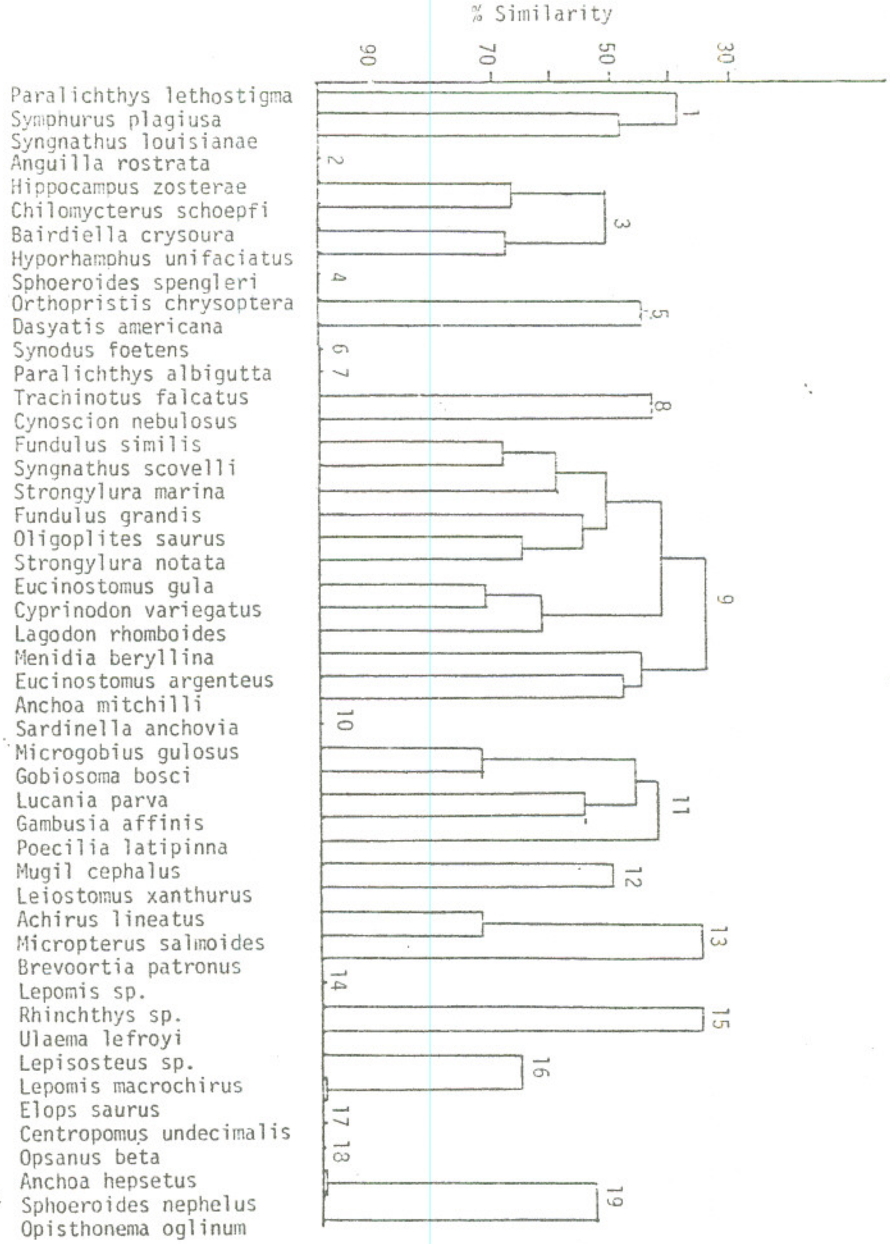


Figure 13. Quantitative analysis of species co-occurrence (inverse) of log transformed data by Czekanowski's similarity coefficient and group average sorting. A cluster was considered as any with a greater than 34% similarity (fixed stopping, Boesch 1977).

DISCUSSION

The nursery role of the Anclote River is apparently similar to other rivers. As has been found in other studies (Gunter 1957; Herke 1971; Dunham 1972; Marshall 1976; Chao and Musick 1977; Weinstein 1979a) the young of many species are found in low salinity waters: Leiostomus xanthurus, Lagodon rhomboides, Menidia beryllina, Eucinostomus gula, Anchoa mitchilli, and Fundulus grandis in the present study (Fig. 8). However, in agreement with Hoff (1977) and McErlean et al. (1973) the equitability of these species indicates that the Anclote system is dominated by permanent residents of the area rather than transients, meaning that most individuals stay in the immediate area for their entire life cycle as opposed to offshore migrations.

The principal evidence that stations are dominated by permanent residents of the Anclote area comes from the size distribution and abundance data of Menidia beryllina. Figure 9, indicates that M. beryllina is spawning somewhere in the Anclote River up from the estuarine station, because of the influx of new recruits seen at the tidal marsh station and river station in early and late summer. If spawning occurred offshore with larvae and juveniles subsequently moving into the area, we would expect to see new recruits at the estuary station: on the contrary, there was no indication that spawning was offshore.

The conclusion that Menidia beryllina is spawning in the backwaters and not the open Gulf is supported by other studies (Lippson and Moran 1974). The most compelling evidence that M. beryllina is a resident fish of the Anclote River Estuary is that adult fish (greater than 64 mm, Roessler 1970) were caught at all stations. Anchoa mitchilli, another common fish in the Anclote, is also a resident fish, because adults (greater than 34 mm, Stevenson 1958) were caught and spawning was reported in harbors, estuaries, and sounds (Dovel 1971). Other species that have been identified as inshore estuarine spawners in this and other studies include: Lucania parva, the rainwater killifish; Gambusia affinis; Cyprinodon variegatus; Gobiosoma bosci; and Microgobius gulosus (Fanara 1964; Foster 1967; Dawson 1969; Fritzshe 1978; Hardy 1978a). The above species are considered here as residents of the Anclote system and together make up 91.3% of the total abundance for the estuarine station, 77.0% for the tidal salt marsh station, and 90.2% of the river station (Table 2).

Other species that showed smaller size classes in the low salinity waters fit the role of transients in that the literature indicates they are offshore spawners: Lagodon rhomboides, Leiostomus xanthurus, and Eucinostomus gula (Springer and Woodburn 1960; Parker 1971; Joseph 1972). Previous studies of the Anclote estuary station are not supported by the present study in that they indicate a general dominance by transient species (Table 3). Lagodon rhomboides, Mugil cephalus, L. xanthurus, and Mugil trichodon, all transients, made up 67% of the total abundance (Fable 1973);

L. rhomboides, 62% of the total abundance (Throhaugh et al. 1977); and L. rhomboides, L. xanthurus, and M. cephalus 54% of the total abundance in a study by Baird et al. (1971).

There are several possible explanations for the dominance of Menidia beryllina and other permanent species in the present study. Four of the most plausible reasons include: 1), gear selectivity 2), cyclic fluctuations with periods greater than one year 3), alteration of the Anclote environment to the extent that a faunal change has occurred 4), the Anclote River Estuary is not a primary nursery area of ocean spawned species.

The effect of gear bias is well discussed in the fisheries literature (Ben-Tuvia and Dickson 1969; Weinstein 1980b). Springer et al. (1960) in an investigation of Tampa Bay, Fla. noted that Menidia beryllina was abundant in small minnow seine samples but absent from trawl samples; therefore, gear selectivity may explain the difference between dominance by transients of previous studies of the Anclote and the dominance by residents in the present study (Table 3).

Cyclic fluctuations of estuarine fishes with season and periods greater than one year were reported in Virginia by Markle (1976). In that study, transient species were maximally abundant for one or two months, usually in the summer. In contrast, resident species were abundant for longer periods and dominated winter catches. However, because the Anclote estuarine area has been studied for seven years and changes in dominant species were not reported, it seems unlikely that natural fluctuations explain the observed differences between present and previous studies (Table 3).

Alteration of the Anclote environment through power plant construction and development could explain the dominance of permanent residents. Menidia beryllina might be an opportunistic species, i.e., rapid development, small size (Robbins 1969), and continuous reproduction (Tabb and Manning 1961); and as such has capitalized on the altered environment of the Anclote area. In studying the effects of a power plant on a Maryland estuary, McErlean et al. (1973) reported a change in fish fauna with migrating species becomming less common and a shift toward dominance by permanent species. Livingston (1975) compared the polluted Fenholloway River and pristine Econfina system in northwest Florida. The ratio of residents to transients seen in the polluted Fenholloway River was approximately 1.3 to 1, while in the unpolluted Econfina system a 1 to 1.1 ratio was seen. McErlean et al. (1973) suggested that the important function as nursery grounds for offshore spawners was being lost in the polluted estuary. The present fish communities on the Anclote could be indicative of a polluted environment, i.e., being dominated by resident species.

The extensive seagrass beds located on the West Florida Shelf may also explain the dominance of residents observed in the Anclote system by serving as the primary nursery areas and not the low salinity upper tidal creek areas. Other locations such as the Cape Fear River, N. C., where transient species dominated the estuary, are characterized by a relatively short continental shelf (Shepard 1973; Smith 1976; Weinstein 1979a). Subrahmanyan

Table 3. Percent of common species comparison with other studies on the Anclote River.

Fable 1973	%	Thorhaug et al. 1977	%	Baird et al. 1971	%	Present study	%
Lagodon rhomboides	40.0	L. rhomboides	62.4	L. rhomboides	40.0	Menidia beryllina	76.4
Mugil cephalus	15.4	Gobiosoma robustum	10.4	C. variegatus	9.0	Anchoa mitchilli	9.8
Cyprinodon variegatus	11.1	Syngnathus scovelli	5.1	L. xanthurus	8.0	L. xanthurus	3.9
Leiostomus xanthurus	7.1	Lucania parva	4.2	M. cephalus	6.0	L. rhomboides	3.0
Mugil trichodon	5.3	Eucinostomus gula	5.7	Orthopristis chrysoptera	4.0	C. variegatus	1.1
Fyke net 2.54cm mesh, 1.2x1.2m mouth opening		Trawl 0.15x1.00m, 6mm mesh		Trawl 3.0m, 4.45cm mesh Seine 45x2m, 1.92 cm mesh Trammel 91m, 5cm mesh Fyke net 2.54cm mesh		Seine 7x2m, 1.5mm mesh	

and Drake (1975) in a study of a relatively pristine estuary, also adjacent to the West Florida Shelf, showed a dominance of residents similar to the present study. Thus, it may be that rivers adjacent to wide shelves with extensive seagrass beds are not influenced as much as other study areas by massive migrations of offshore fishes into estuary, tidal creek areas. The obvious next step would be to extend the present study out past the Anclote ancorage area, several km into the open Gulf of Mexico, and investigate the nursery role of seagrass beds found further offshore.

An important ecological question concerning the area sampled is whether or not the stations sampled are discrete habitats or one homogeneous environment, throughout which fish species interchange freely. The common species: Leiostomus xanthurus, Mugil cephalus, Syngnathus scovelli, Strongylura marina, Fundulus grandis, Oligoplites saurus, and Strongylura notata generally treated all three collection areas, estuary, tidal salt marsh, and river as a continuum. Differences in abundance between stations were not significant for these fishes (Fig. 7). In contrast, other species: Menidia beryllina, Fundulus similis, Eucinostomus gula, Lagodon rhomboides, Cyprinodon variegatus, Eucinostomus argenteus, Microgobius gulosus, Poecilia latipinna, Gobiosoma bosci, and Gambusia affinis were either restricted to particular stations or had significant differences in population densities between the stations (Fig. 7). It may be concluded from distributional abundance that it depends on what species is considered, whether or not discrete or continuous habitats were sampled. However, two species that did not show preference for any of the stations through abundance data did segregate the stations by size: L. xanthurus and F. grandis (Fig. 8). The species showing size separation may be utilizing different food sources among the three areas, for Dietz (1976) has shown that the diets of several species found in the Anclote anchorage change with the ontogeny of the fishes. Thus, species not segregating in numbers may still indicate discrete habitats through size frequencies.

Additional quantitative data analysis leads to a compromise between the discrete and continuum ideas. A two-way coincidence table illustrates a comparison of collection clusters (Fig. 11) with species clusters (Fig. 13) through total abundance (Table 4). Species groups 1, 3, 4, 5, 7, 8, 18, and 19 are essentially endemic to the estuarine area (cluster A). The river area (cluster D) was characterized by species clusters 11, 13, 15, 16, and 17. The tidal marsh area (clusters B and C) does not show any species groups endemic to the area and could be a transitional zone between the other two stations. Hence, the estuary and river stations appear to be discrete habitats while the tidal salt marsh is a transitional zone, but considerable amount of modification can be made on this general theme depending on the species considered.

The greater richness observed at the estuarine and river stations compared to the tidal salt marsh has been reported in other geographical locations: North Carolina (Weinstein 1979a), South Africa (Day et al. 1952), and Florida (Wang et al. 1971;

Table 4. Two-way coincidence table comparing species clusters with quantitative collection clusters.

	Species groups	Collection groups A	B	C	D	E
1	Paralichthys lethostigma	1				
	Symphurus plagiusa	5		2		
	Syngnathus louisianae	3			2	
2	Anguilla rostrata			1		
3	Hippocampus zosterae	2				
	Chilomycterus schoepfi	1				
	Bairdiella crysoura	2			1	
	Hyporhamphus unifaciatus	3				
4	Sphoeroides spengleri	23		3		
5	Orthopristis chrysoptera	5				
	Dasyatis americana	1				
6	Synodus foetens	4	3	1		
7	Paralichthys albigutta	1				
8	Trachinotus falcatus	14		1		
	Cynoscion nebulosus	4		1	1	
9	Fundulus similis	40	2	5	1	
	Syngnathus scovelli	38		19	3	
	Strongylura marina	35	3	8	7	
	Fundulus grandis	45	6	37	11	
	Oligoplites saurus	54		13	11	
	Strongylura notata	95		13	27	
	Eucinostomus gula	693		39		
	Cyprinodon variegatus	909		3	3	
	Lagodon rhomboides	2328	219	3		
	Menidia beryllina	47018	682	401	17436	40
	Eucinostomus argenteus	48	122	162	186	
	Anchoa mitchilli	3156	4725		572	
10	Sardinella anchovia	410			5	
11	Microgobius gulosus	3	2	365	134	
	Gobiosoma bosci	3		165	469	
	Lucania parva	10	8		298	
	Gambusia affinis		99		382	
	Poecilia latipinna		4	1	72	1
12	Mugil cephalus	8	198	11		
	Leiostomus xanthurus	1004	2306	15		
13	Achirus lineatus	5	1		11	5
	Micropterus salmoides		2		25	6
	Brevoortia patronus				1	377
14	Lepomis sp.		4		1	1
15	Rhinichthys sp.				1	
	Ulaema lefroyi				6	
16	Lepisosteus sp.				1	1
	Lepomis macrochirus				1	
	Elops saurus				1	
17	Centropomus undecimalis				5	
18	Opsanus beta	1				
19	Anchoa hepsetus	1				
	Sphoeroides nephelus	1				
	Olisthonema oglinum	5				
	Area m^2	4982	1782	2369	2673	446

Weinstein et al. 1977). Since these other geographical locations included a salinity gradient as well, the simplest explanation for the difference in species richness would be that the richness was salinity dependent.

Table 5 shows the salinity ranges of most of the species sampled in this study and only five out of thirty-two would be considered stenohaline: Trachinotus falcatus, the permit; Microgobius gulosus; Micropterus salmoides, the largemouth bass; Lepomis macrochirus, the bluegill; and Opisthonema oglinum, the Atlantic thread herring. All other species in table 5 have been recorded in salinities greater than or less than the present study, or have been shown in experimental laboratory conditions to be able to tolerate greater ranges of salinity than normally encountered in nature. Thus, the fish species collected in the present study are probably not limited by the field salinities measured.

To explain the greater richness at the estuary and river stations another theory, the "edge effect" has been described. In this theory estuarine areas form a mixing zone for euryhaline shelf and reef faunas while species composition upriver is influenced by freshwater faunas (Odum 1971; Weinstein 1979a). The existence of reef faunas (McHugh 1967) in the seagrass beds and its influence on species richness has been observed on the east coast of the U. S. and in areas where reefs are closely situated to the seagrass beds (Weinstein 1979a, 1979b). On the west coast of Florida a different biological and physical environment exists: extensive shallow shelf waters have little depth gradient and reef habitats

Table 5. Salinity tolerances of fish species collected in the Anclote River Estuary, Tarpon Springs, Fla., based upon previous work.

Species	Salinity tolerance range ppt	Reference
Orthopristis chrysoptera	0.0 - 44.1	Johnson 1978
Bairdiella crysoura	0.0 - 48.0	"
Trachinotus falcatus	23.0 - 35.6	" "
Cynoscion nebulosus	0.0 - 77.0	"
Oligoplites saurus	0.0 - 45.2	"
Eucinostomus gula	0.1 - 45.2	"
Lagodon rhomboides	0.0 - 44.5	"
Eucinostomus argenteus	0.2 - 45.2	"
Leiostomus xanthurus	0.0 - 60.0	"
Syngnathus louisianae	0.0 - 45.0	Hardy 1978a
Hyporhamphus unifaciatus	7.5 - 42.9	"
Strongylura marina	0.0 - 36.9	"
Cyprinodon variegatus	20.0 - 142.4	"
Lucania parva	0.0 - 48.2	"
Gambusia affinis	0.0 - 29.0	"
Micropterus salmoides	0.0 - 9.0	Hardy 1978b
Lepomis macrochirus	0.0 - 13.0	"
Symphurus plagiusa	0.0 - 42.9	Martin et al. 1978
Chilomycterus schoepfi	6.9 - 47.0	"
Sphoeroides spengleri	9.7 - 38.8	"
Menidia beryllina	0.0 - 75.0	"
Mugil cephalus	0.0 - 81.0	"
Hippocampus zosterae	9.7 - 35.0	Springer et al. 1960
Achirus lineatus	4.0 - 34.6	"
Opsanus beta	3.2 - 45.2	"
Synodus foetens	4.0 - 60.0	Jones et al. 1978
Anchoa mitchilli	0.0 - 80.0	"
Elops saurus	0.2 - 36.0	"
Anchoa hepsetus	2.5 - 80.0	"
Opisthonema oglinum	32.0 - 43.0	"
Microgobius gulosus	10.0 - 35.0	Fritzsche 1978
Gobiosoma bosci	0.1 - 45.0	"

are generally found greater than 11 km offshore, with the most complex existing about 141 km offshore (Smith 1976). In addition, seagrass studies on Florida's west coast, such as those in the area east of Panama City (Caldwell 1954) and Tampa Bay (Springer et al. 1960) indicate that seasonal recruitment of tropical reef species does not occur to any large extent. The present work also shows a lack of shelf and reef species. Therefore, some other mechanism must be operating which would result in greater species richness at the estuary station. In contrast, the edge effect model may fit the river station of the Anclote where immigration from fresh water has occurred: *Lepomis* sp., *Micropterus salmoides*, and *Lepisosteus* sp. were observed on occasion (Table 4).

Another explanation for the greater species richness observed at the estuary and river stations, although similar to the edge effect, is that of spatial heterogeneity (MacArthur and MacArthur 1961). The difference between the spatial heterogeneity theory and the edge effect is that the former would not rely on immigration from reef or shelf fishes. The spatial heterogeneity theory suggests that a greater physical diversity will increase niches and refuges; consequently, more species can survive in that habitat. Extensive seagrass beds intermingled with channels, sand shell areas, oyster bars, and mangrove stands probably create a more diverse physical habitat at station 1 compared to the other stations, resulting in a greater species richness. The river station, second in species richness, qualitatively is second in physical heterogeneity due to cattails, trees, shoals, and fallen debris but without benthic vegetation. The tidal salt marsh showed the lowest species richness and was also the lowest in physical diversity, characterized simply by black rush stands and algal mud bottoms.

Evidence that physical differences are more important than temporal criteria or month of collection in explaining the fish distribution observed comes from the quantitative and qualitative analysis of collections (Figs. 12, 13). The spatial aspect clustered almost exclusively in the quantitative analysis and in about half the cases for the qualitative analysis. Therefore, with grouping primarily according to habitats and the qualitative difference in physical aspects, the spatial heterogeneity theory is a workable model for explaining the richness differences between stations in the Anclote River.

Considering the evenness component of the fish diversity, it was surprising to observe a decrease in evenness as the richness increased (evenness indicated by the dominance index: the greater the dominance, the lower the evenness; Fig. 10). Precisely the opposite has been observed in many different ecological systems: in invertebrate communities of decaying oak logs (Fager 1968), annual grasslands (McNaughton 1968), polychaetous annelids (Santos and Simon 1974), and fish communities (Marshall 1976; Weinstein 1979a). However, another study concerning fish communities on the west coast of Florida has observed the same phenomenon. In Marco Island, seagrass stations had a greater degree of dominance concurrent with maximum numbers of species compared to sand areas

(Weinstein et al. 1977). The extensive seagrass beds on the west coast of Florida may possibly cause the relation seen for the diversity components (richness and evenness) with spatial heterogeneity increasing species richness, as previously discussed; in addition, productivity increase consistant with seagrass presence (Williams 1973) may cause a less even distribution, as Whiteside and Harmsworth (1967) have found or cladocerans in a series of Danish and Indiana lakes.

Other explanations: time stability (Sanders 1968), predation (Pain 1966), and competition (Connell 1961; Beauchamp and Ullyott 1932) of species diversity are difficult to infer for Anclote fish species without further investigation but are probably operating. Consequently, the increased spatial heterogeneity and productivity associated with the seagrasses of the estuarine zone are easily envisioned as important factors affecting the diversity of fish fauna there, while other factors more difficult to apply may also be operating.

CONCLUSIONS

1. A successional pattern was observed for some fish species on the Anclote River Estuary, Fla., with the youngest members found in low salinity waters and moving to higher salinities as they grew. The majority of individuals are not ocean spawned migrants, but permanent residents of the area. Possible explanations for the apparent dominance of permanent resident fish species compared to a dominance by transients in other studies include: gear sampling bias, alteration of the Anclote environment with concomitant faunal change, or that seagrass beds further offshore may be serving as the primary nursery areas for most ocean spawned fishes, but further work in these seagrasses is needed to affirm such a hypothesis.
2. The estuary and river stations on the Anclote system are apparently discrete community habitats. The tidal salt marsh station appears as a transitional zone; as indicated by presence-absence, abundance, and size frequency data of the fish fauna; but this theme may be modified depending on the species under consideration.
3. Spatial heterogeneity differences mainly due to the existence of seagrasses is suggested as the principle factor affecting the distribution and abundance of fish fauna in the Anclote River Estuary.

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