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Factors Affecting the Distribution of Fishes in Whitewater Bay, Everglades National Park, Florida

Stephen H. Clark

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University of Miami Sea Grant Program
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PREFACE

The Sea Grant Colleges Program was created in 1966 to stimulate research, instruction, and extension of knowledge of marine resources of the United States. In 1969 the Sea Grant Program was established at the University of Miami.

The outstanding success of the Land Grant Colleges Program, which in 100 years has brought the United States to its current superior position in agricultural production, was the basis for the Sea Grant concept. This concept has three objectives: to promote excellence in education and training, research, and information services in the University's disciplines that relate to the sea. The successful accomplishment of these objectives will result in material contributions to marine oriented industries and will, in addition, protect and preserve the environment for the enjoyment of all people.

With these objectives, this series of Sea Grant Technical Bulletins is intended to convey useful research information to the marine communities interested in resource development quickly, without the delay involved in formal publication.

While the responsibility for administration of the Sea Grant Program rests with the Department of Commerce, the responsibility for financing the program is shared equally by federal, industrial, and University of Miami contributions. This study, Factors Affecting the Distribution of Fishes in Whitewater Bay, Everglades National Park, Florida, is published as a part of the Sea Grant Program. Graduate research support was provided by a National Science Foundation Fellowship and a Bureau of Commercial Fisheries contract.

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INTRODUCTION

The estuaries of south Florida are valuable and productive. It is well known that these shallow bays provide feeding and nursery areas for the young of many commercial and game fish species and that they are vital to the continued maintenance of many valuable fisheries. Surprisingly little is known, however, concerning the ecology of juvenile fishes occupying inshore areas in south Florida, and knowledge of the ecology of fishes utilizing mangrove habitats is particularly inadequate. As such areas are increasingly threatened by south Florida's rapidly expanding population, the need for quantitative studies to assess the relative value of various mangrove habitat types and their importance to the biota is at once apparent.

The fish fauna of southwestern Florida has received little attention until recently; research in this region to date has centered primarily in and around the Everglades National Park. The most significant of these studies appear to have been the work of Tabb and Manning (1961) on the biota of Florida Bay and adjacent estuaries and that of Roessler (1967) on fishes in Buttonwood Canal. Mimeographed reports (Tabb, 1966; Tabb and Kenny, 1967) are also available on the effects of fluctuations in fresh water supply on the distribution of species in brackish water marshes. Master's thesis studies have been conducted in the area by Croker (1960) on gray snapper (Lutjanus griseus), by Stewart (1961 on the spotted seatrout (Cynoscion nebulosus), by

Yokel (1966) on red drum (*Sciaenops ocellata*) and by Waldinger (1968) on three species of mojarras (Gerridae). In addition, Odum (1970) studied the food habits of 45 species of fishes captured in Whitewater Bay and the North River as part of his doctoral study of energy flow pathways. A considerable volume of quantitative data has also been collected in an otter trawl survey of the area by Tabb (personal communication); publications of this work are currently in preparation.

Data are also available relative to the Everglades sport fishery; beginning in 1958, catch and effort statistics from the Park have been recorded and analyzed by Marine Laboratory personnel. Results of the 1958-1965 period are summarized by Higman (1967); later work is covered by the mimeographed reports of Rouse and Higman (1967) and Higman (1969). Miscellaneous publications dealing with Everglades fish fauna include the work of Robins and Tabb (1965) on the ecology of the blue croaker (*Bairdiella batabana*), the study by Croker (1962) on growth and food of *Lutjanus griseus*, and the paper by Tabb and Jones (1962) dealing with the effects of Hurricane Donna on the fauna of Florida bay.

A number of studies have also been conducted in other areas of southwest Florida. The most pertinent publications of historical interest are papers by Henshall (1891) and Lonnberg (1894) describing the fish faunas of the Florida Keys and southwest coast areas and the checklist by Evermann and Kendall (1900) of Florida fishes. The Tortugas fauna was described in early publications (Jordan and Thompson, 1905; Gudger, 1929) and later by Longley and Hildebrand (1941). More recently, Springer and Woodburn (1960) studied the ecology of fishes of the Tampa Bay area, and Springer and McErlean

(1962) investigated seasonal population changes of inshore species at Matecumbe Key, where Starck (1964) later conducted his doctoral research on the biology of Lutjanus griseus. The work of Gunter and Hall (1965) on the fish populations of the Caloosahatchee Estuary is also worthy of mention. Other investigations in this region include those of Storey and Gudger (1936) and Storey (1937) relative to cold-induced fish mortality at Sanibel Island; growth and tagging studies have also been conducted on the southwest coast by Volpe (1959) and Moffett (1961) on snook (Centropomus undecimalis) and Cynoscion nebulosus.

A number of contributions from other areas of the Gulf of Mexico are pertinent to the present investigation and should be mentioned. These include studies by Gunter (1938, 1945) in Louisiana and Texas, work by Reid in northern Florida (1954) and in Texas (1955a, b) and the study by Joseph and Yerger (1956) at Alligator Harbor, Florida. The doctoral study of Kilby (1955) in salt marsh habitats of northwest Florida should also be noted.

The above survey of the existing literature indicates a definite need for further comprehensive studies of the ecology of juvenile fishes in the mangrove habitats of southwest Florida. The opportunity for such an investigation became available in September of 1968, when the Division of Fishery Sciences of the University of Miami's School of Marine and Atmospheric Sciences began a long term study of the ecology of juvenile pink shrimp (Penaeus duorarum) in Whitewater Bay. As the gear used quantitatively sampled both shrimp and the juvenile fishes of several species, the latter were used as the basis for the present study, which was conducted from September 1968 to November 1969.

The objectives of this investigation were:

1) To study the ecology of fishes in Whitewater Bay with particular reference to factors determining species distributions within the estuary, and

2) To assess the variation observed in the data and to determine the nature of the underlying mathematical distributions so as to form a basis for valid parametric procedures.

Description of the Study Area

The Whitewater Bay - Oyster Bay complex is a large, shallow embayment located on a low coastal plain in the southwest corner of Everglades National Park, Florida. It is approximately 14 miles in length and over 7 miles wide at its widest point; its average depth is between 5 and 6 feet. The entire bay is surrounded by mangrove swamps and dominated by numerous islands of mangrove peat (Davis, 1946) supporting primarily growths of red mangrove (*Rhizopora mangle*) interspersed with black mangroves (*Avicenna nitida*); the white mangrove (*Laguncularia racemosa*) and the buttonwood (*Conocarpus erectus*) appear to be rare or absent in such areas. Drainage is to the south via Coot Bay and Buttonwood Canal and to the west into the Gulf of Mexico. As Whitewater Bay and Oyster Bay are very similar ecologically there appears to be no reason to differentiate between them, and the above complex will for convenience be designated simply as Whitewater Bay after the manner of Tabb *et al*. (1962).

The geology of south Florida has been reviewed by Davis (1943). Events of late Cenozoic times were of great importance to this region;

sedimentary strata formed during this period have profoundly influenced present topography, hydrography, and vegetation. Of particular importance is the Miami Limestone formation, deposited during the last interglacial period (Hoffmeister _et_ _al_., 1967); this underlies all but the extreme northwest corner of Whitewater Bay. The soils are organic and are composed of peat, muck, and calcium carbonate marl; reference should also be made to the freshwater marl deposits formed in the Everglades during recent times, which retard downward seepage and thereby insure a southward flow of fresh water.

The ecology and hydrography of the area are comprehensively described by Tabb _et_ _al_. (1962) and only those features most relevant to the present study will be considered here. The reader is referred to the above publication for additional details.

Climate

The climate of south Florida is an insular one, chiefly affected by oceanic rather than continental weather conditions. The area has been classified by Hela (1952) as a "tropical savannah" having a long dry season followed by a wet period with inadequate rainfall to compensate for drought effects. Thus, water deficits in the Park must be made up by inflow from areas to the north. The dry season usually lasts from November to April, followed by a much wetter period from May to October; prevailing winds are from the southeast in summer and may be either easterly or westerly during the winter depending upon the location and movement of polar air masses to the north.

Average rainfall is approximately 55 inches per year in the regions south of Lake Okeechobee. Precipitation appears to be quite variable, however, in that 83 inches were recorded in Flamingo in 1960 and 24 inches the following year (Tabb _et al_., 1962). In the present study, precipitation was heavier than usual, particularly during the 1969 rainy season when monthly averages for the region totaled approximately 8 inches above normal (U. S. Weather Bureau, 1969).

Climatological summaries for the 1955-1962 period at Flamingo (_in_ Tabb _et al_., 1962) showed an average yearly temperature of 74.7°F, with a January minimum of 64.5° and an August maximum of 81.8°. In the present study, monthly averages were usually lower than those recorded by Tabb, with deviations of up to 5 degrees occurring in the November 1968 - March 1969 period. From April to July of 1969, however, temperatures were slightly higher than usual.

Physical Factors

As Whitewater Bay lies at the focal point of drainage from the Everglades, salinities are strongly dependent upon seasonal and annual variations in freshwater influx. In fact, Tabb _et al_. (1962) have shown that a close relationship exists between minimum salinity values in Whitewater Bay and earlier peaks in runoff across the Tamiami Trail north of the Everglades National Park; the time lag involved was found to approximate three months. Using this relationship, these investigators inferred that, given normal to heavy summer rains, annual lows in salinity values would occur in the Bay during November and December, followed by gradual increases over a 3 to 5 month period.

In the present study, a gradual decline occurred during the summer of 1969, with lows occurring in October of 1968 and November of 1969 (Figure 1). The lowest salinities in the latter year, however, were actually observed in July. In view of later declines, it is possible that the July data represent a deviation from normal associated with heavy rainfall occurring in the area in June (U. S. Weather Bureau, 1969).

Water temperatures in shallow Gulf estuaries have been shown to be closely correlated with air temperatures (Collier and Hedgpeth, 1950; Dawson, 1955). Thus, night water temperatures would be expected to fall roughly between the daily maxima and minima recorded for the area. This pattern appeared to be true throughout the course of the present study, although recorded values usually approached the recorded daily maxima at Flamingo more closely during summertime. The annual low occurred in December and the annual high in July, again closely agreeing with air temperatures.

Dissolved oxygen concentrations usually equalled or exceeded saturation values in all areas sampled. These results are in agreement with those reported by Tabb _et_ _al_. (1962). The wet season deficits reported by these investigators (due to runoff and oxidation of transported organic material) were also observed during the present study but did not appear to be critical.

Average bottom salinities, temperatures, and dissolved oxygen concentrations for the stations studied (Figure 2) are given by month in Appendix I; seasonal cycles for the entire estuary are given in Figure 1. Only bottom data was used, as the present study was primarily concerned with bottom-dwelling species. Surface values, however, usually agreed closely with readings obtained in bottom sampling.

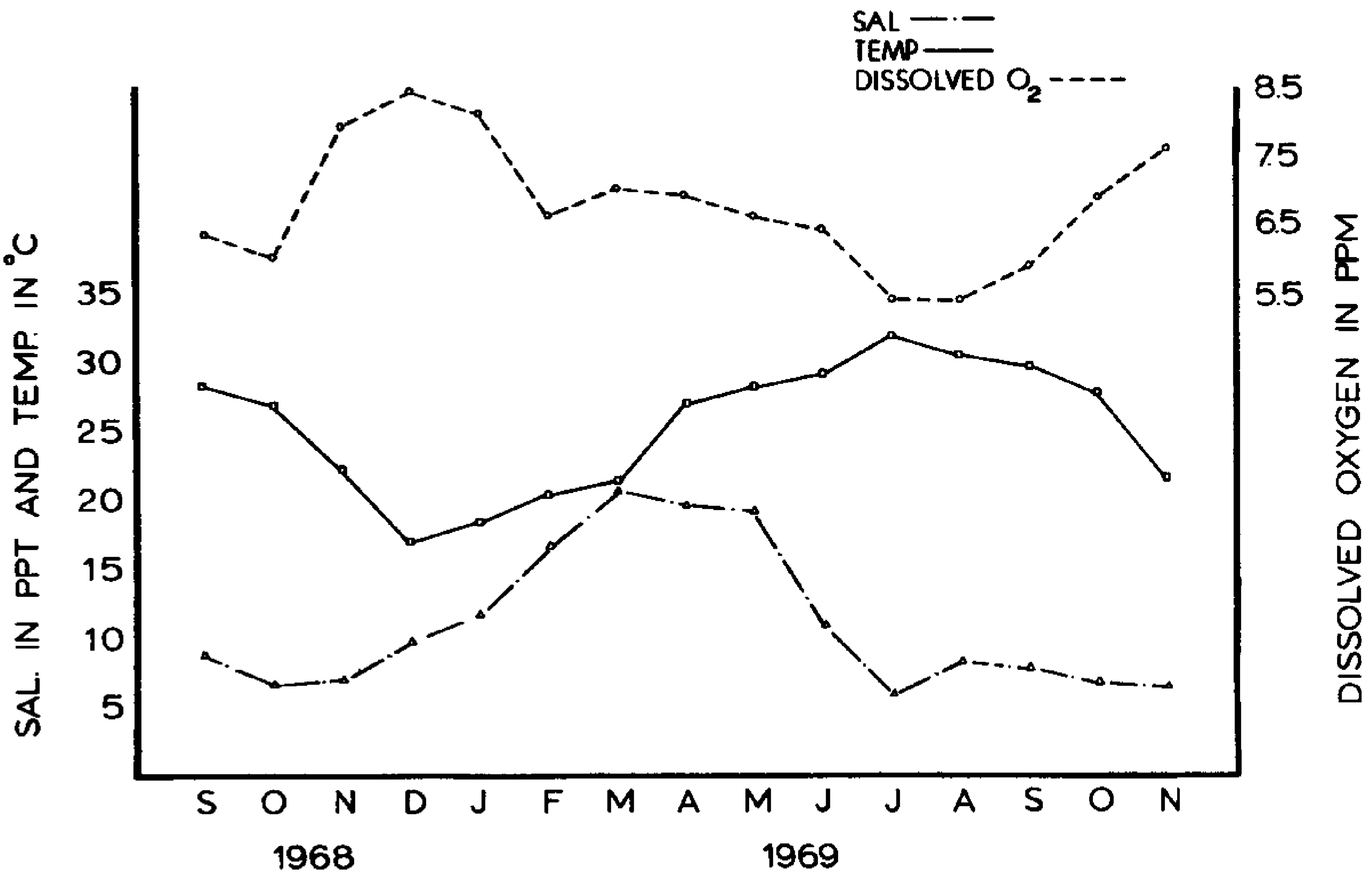

Figure 1. Seasonal variation in salinity, temperature, and dissolved oxygen content for Whitewater Bay, September 1968 to November 1969.

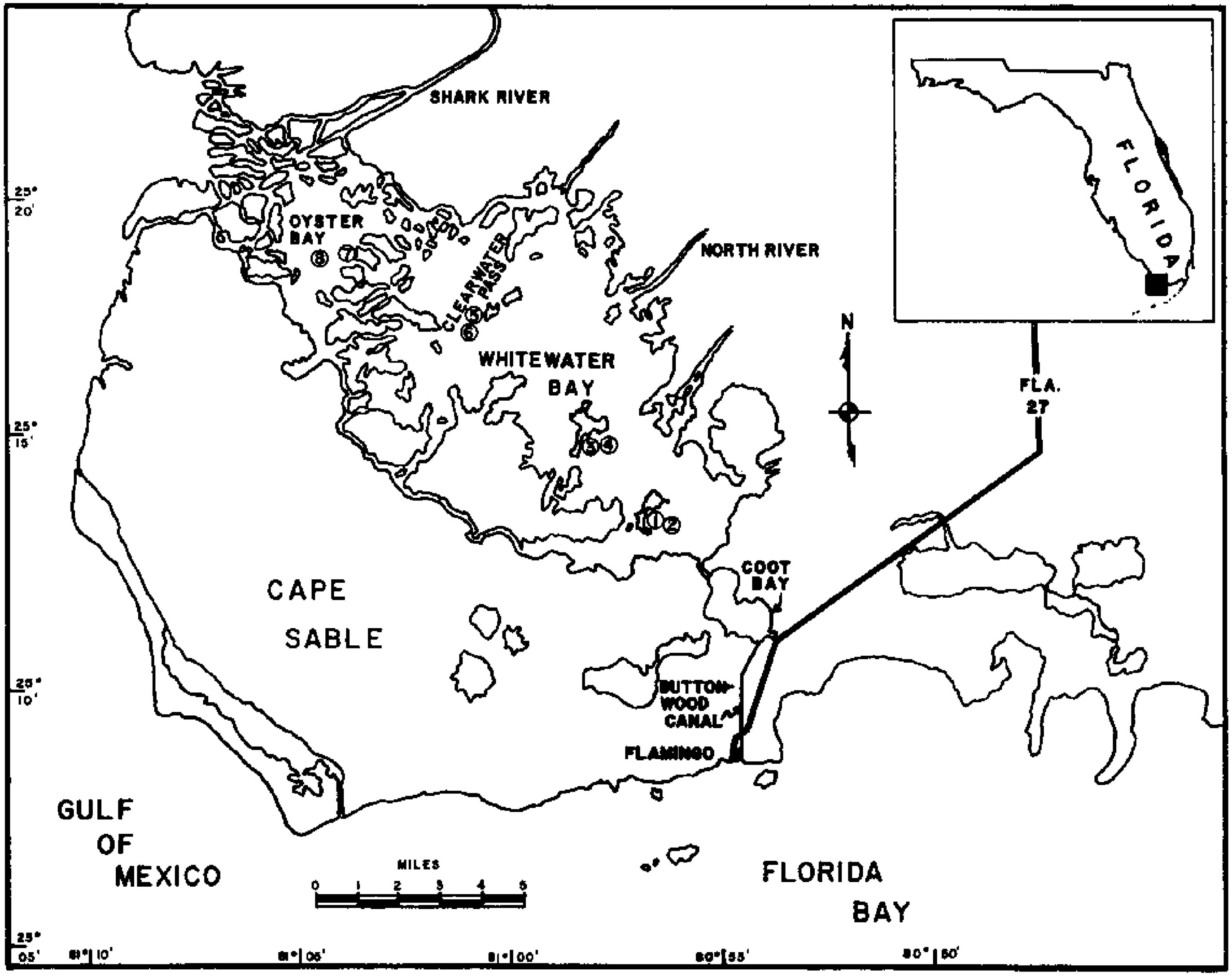

Figure 2. Map of Whitewater Bay, Florida, giving locations of sampling stations.

Although not measured directly, turbidity appeared to be variable both by area and by season. According to Tabb _et al_. (1962) changes may result from wind action or from variation in the content of tannins and particulate organic matter associated with the hydrologic cycle; in the present study, values appeared to be highest during periods of heavy runoff. At any given time, turbidity appeared to be lowest in the vicinity of Clearwater Pass, where Stations 5 and 6 were located (Figure 2).

The tides of the southwest Florida coast are of the mixed semi-daily type (Marmer, 1954), being characterized by two daily tides of unequal amplitude. The daily range is small throughout most of the area studied; (Tabb _et al_. 1962) reported an average maximum daily fluctuation of 7.5" during calm weather in southeast Whitewater Bay, while an approximate range of 2 feet was observed on the most seaward stations during the present study. Normal changes were often obscured or obliterated by wind induced water movements; this occasionally caused some confusion as to the true tidal stages existing at the time of sampling.

Selection of Sampling Areas

Eight stations were selected in the Bay for detailed study. These were arranged in pairs in four zones differing in salinity, bottom type, and vegetation density and were further subdivided according to depth, one shallow and one deep station being established per pair. "Shallow" stations, located inshore, were approximately 3 feet deep at low tide, while "deep" stations were established some distance out into the Bay and averaged between 5 and 6 feet in depth.

The locations of these sampling stations were shown in Figure 2.

The above arrangement was originally designed to permit sampling under differing conditions of salinity, vegetation density, and bottom type. During the rainy season, salinities were usually lowest at Stations 3 and 4, as saline intrusions via Buttonwood Canal and Tarpon Creek raised values on Stations 1 and 2 to a slight degree. At other times, salinities were roughly equal on Stations 1 through 4 and then increased proceeding westward, with maximum values occurring at Stations 7 and 8. Average bottom salinities for all stations during the period of study are given in Appendix I.

The areas selected differed markedly in vegetation composition and density. The dominant plant on the study area proved to be *Udotea conglutinata*, a species of calcareous green algae which occurred in dense stands and reached heights of 15 centimeters or more when conditions were favorable. This plant was very abundant on Stations 5 and 6, less dense on Stations 3 and 4, and scattered or absent on the remaining stations. Epiphytes, chiefly *Batophora oerstedi*, were often found growing on the *Udotea*, particularly during summer when it became very abundant at Station 5. The marine grass *Diplanthera wrightii* was of some significance locally, occurring in scattered patches on Stations 2 and 3 and in dense clumps on Station 7 during the summer months. Uncommon species included the fresh-water calcareous green alga *Chara hornemannii*, which occurred primarily at Station 3, and various species of red algae (mostly *Dasya pedicillata* and *Gracilaria* sp.) which drifted onto Station 7 during the dry season and remained until killed by falling salinities or increasing temperatures in late spring and early summer. Another plant, the phanerogam Halophila baillonis, appeared to follow a similar cycle of abundance on Station 8.

As Station 1 appeared to be devoid of vegetation, no bottom sampling was conducted there during this study (see METHODS). Vegetation data collected on the remaining stations are given in Appendix II.

A number of substrate types were also considered. The bottoms at Stations 1 through 6 were usually composed of varying combinations of silt, marl and shell, although peat predominated at Station 3. On Stations 7 and 8, sediments were found to be much coarser, consisting of sand with large shell fragments.

Relative salinity, vegetation density, and substrate conditions by station may be summarized as follows:

Station No.	Salinity	Vegetation density	Substrate type
1	Low	--	Silt, marl and shell
2	Low	Very low	Silt, marl and shell
3	Low	Low	Peat
4	Low	Low to moderate	Silt, marl and shell
5	Moderate	High	Marl and shell
6	Moderate	High	Marl and shell
7	High	Moderate	Sand and shell
8	High	Very low	Sand and shell

METHODS

Trawling was conducted using a 21 foot fiberglass boat equipped with two 100 horsepower outboard motors. The boat was modified by addition of a winching apparatus and platform on the stern to facilitate handling the sampling gear (Figure 3) which consisted of a specially constructed roller frame trawl with paired nets one meter in width. The nets were manufactured of 3/4-inch stretched mesh; nylon linings with openings 1/8 inch in diameter were used in the cod ends.

Samples were taken monthly during the new moon phase of the lunar cycle; four stations were trawled each night. As all stations were sampled both on the ebb and on the flood tides, four nights were required to finish a given month's sampling. In September and October of 1968, all stations were trawled in order on the first two nights and in reverse order on the last two nights; in all other months, sampling at a given station was scheduled at two night intervals to allow equal opportunity for population recovery between stations. All samples were taken between the hours of nautical twilight except in the months of June and July when slight over-runs occurred in two instances. In such cases, the data were omitted from statistical analysis wherever possible, and it is not believed that any appreciable bias resulted.

Prior to sampling a given station, the tidal stage was determined by reference to gauges located on the adjacent shoreline; vertical rise

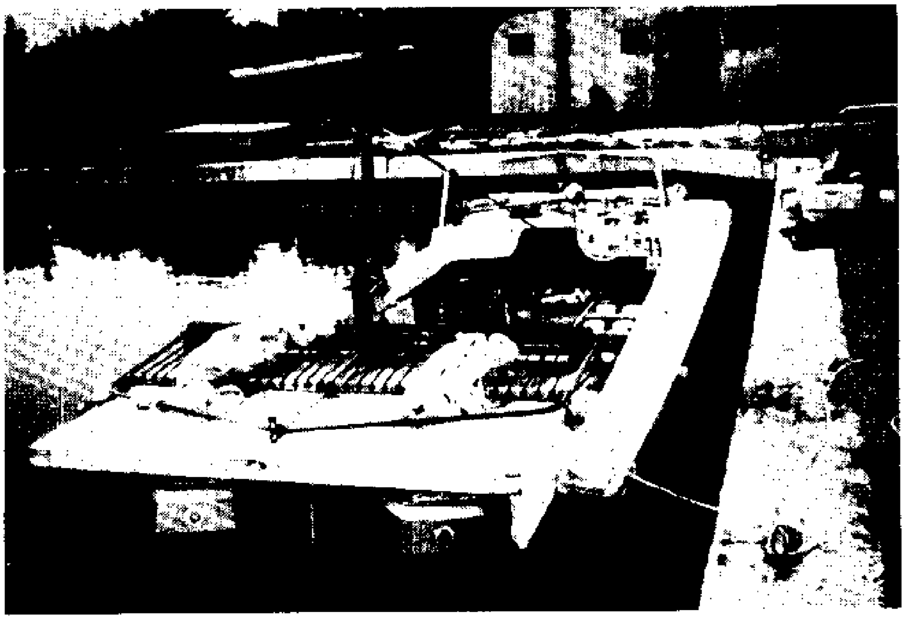

Figure 3. Boat and trawling apparatus used during the present study (Gary L. Beardsley).

and fall was recorded to the nearest tenth of a foot. Surface and bottom samples for salinity and dissolved oxygen measurements were then taken using a modified Niskin sampler constructed from polyvinyl chloride (PVC) piping. Salinity samples were stored in polyethylene bottles and returned to the laboratory, where determinations were made within the week to the nearest tenth of a part per thousand using a Goldberg temperature compensated refractometer. Dissolved oxygen concentrations were measured in the field to the nearest tenth of a part per million using a Hach OX-2-P kit. Surface and bottom temperatures were measured with a bucket thermometer and recorded to the nearest tenth of a degree Celsius.

Current and wind direction was determined by reference to a compass mounted in the boat. Wind velocity was measured with a hand-held Dwyer wind gauge calibrated in statute miles per hour.

Trawling was conducted in parallel paths following compass bearings of 30° and 210° at all stations. After lowering the trawl, the boat was run at a speed of 2 knots for 90 seconds, during which time each net sampled approximately 100 square meters. The trawl was then winched in and the samples removed. Trawling was normally conducted by a three-man crew.

The collected samples were stored in 10% formalin and taken to the laboratory for sorting. All fishes captured were identified to species and counted; total length measurements were taken to the nearest millimeter. In cases where over 50 fish of a given species occurred in a given sample, subsamples of 50 specimens were measured.

To determine the effects of trawling on the habitat and to monitor seasonal changes, vegetation sampling was conducted monthly at each station from February to November of 1969. Salinity, temperature, and dissolved oxygen data were recorded as above. Ten samples were then taken in a limited area judged to be representative of conditions on the station as a whole, using a 1/50 square meter sampler constructed of sheet metal; samples were taken simply by thrusting this device into the substratum. Samples were stored individually in plastic bags in a 5% buffered formalin solution and taken to the laboratory, where species identifications and stem counts of rooted vegetation were made. Stem heights were also measured to the nearest millimeter; for large samples, a subsample of 15 stems was taken and measured. All samples were then oven-dried and weighed to the nearest gram. The resulting data proved to be inadequate for valid estimates of mean density per station, but appeared to be reliable for between station comparisons and study of seasonal trends. No evidence was found to indicate that trawling affected vegetation density during this study.

RESULTS AND DISCUSSION

Checklist of Fishes

A total of 68 species representing 14 orders and 36 families were collected during this study. A seasonal summary of catch data for the entire bay is given in Table 1; total summaries by station may be found in Appendix III. For purposes of the present investigation seasons were considered to be as follows:

Winter	December - February
Spring	March - May
Summer	June - August
Fall	September - November

The arrangement of orders and families used follows the classification scheme proposed by Greenwood *et al*. (1966) in their recent studies of teleostean phylogeny.

The species distribution observed appears to be typical of comprehensive estuarine studies in that a handful of species comprise the bulk of the catch. In the present investigation, the silver jenny (*Eucinostomus gula*) and the pinfish (*Lagodon rhomboides*) contributed 62.7 percent of the total, with the former being most abundant (34.9 percent). The code goby (*Gobiosoma robustum*) and the clown goby (*Microgobius gulosus*) were next in order of importance, each furnishing over 6 percent, while the pigfish (*Orthopristis chrysopterus*),

Table 1. List of fishes collected by roller-frame trawling in Whitewater Bay, September 1968 to November 1969, summarized by season.

Species	Percent taken in					Total
	Fall	Winter	Spring	Summer	Fall	
Elopiformes						
Elopidae						
Elops saurus	0.0	0.0	0.0	100.0	0.0	1
Anguilliformes						
Ophichthidae						
Bascanichthys scuticaris	0.0	0.0	0.0	100.0	0.0	1
Myrophis punctatus	12.5	50.0	12.5	8.3	16.7	24
Ophichthus gomesii	0.0	50.0	50.0	0.0	0.0	2
Clupeiformes						
Clupeidae						
Harengula pensacolae	4.7	4.7	62.0	23.9	4.7	21
Opisthonema oglinum	9.2	0.0	31.8	27.2	31.8	22
Engraulidae						
Anchoa hepsetus	3.5	0.0	55.1	34.5	6.9	29
Anchoa mitchilli	25.6	8.1	26.4	19.0	20.9	682
Anchoa sp.	0.0	0.0	50.0	16.7	33.3	18
Salmoniformes						
Synodontidae						
Synodus foetens	13.7	10.1	13.7	16.7	45.8	418
Siluriformes						
Ariidae						
Arius felis	5.9	0.0	0.0	30.3	63.8	69
Batrachoidiformes						
Batrachodidae						
Opsanus beta	29.9	37.5	7.9	13.4	11.4	1198
Porichthys porosissimus	60.0	0.0	40.0	0.0	0.0	5

Table 1.--(Continued)

Species	Fall	Winter	Percent taken in Spring	Summer	Fall	Total
Gobiesociformes						
Gobiesocidae						
Gobiesox strumosus	37.5	50.0	0.0	12.5	0.0	8
Gadiformes						
Ophidiidae						
Ophidion holbrooki	0.0	100.0	0.0	0.0	0.0	1
Ogilbia cayorum	0.0	0.0	0.0	100.0	0.0	2
Ogilbia sp.	0.0	0.0	100.0	0.0	0.0	1
Atheriniformes						
Belonidae						
Strongylura notata	100.0	0.0	0.0	0.0	0.0	1
S. timucu	44.4	0.0	11.1	22.2	22.2	9
Exocoetidae						
Hyporhamphus unifasciatus	0.0	0.0	12.5	50.0	37.5	8
Cyprinodontidae						
Floridichthys carpio	0.0	0.0	0.0	100.0	0.0	5
Lucania parva	36.7	3.1	2.1	44.9	13.2	98
Rivulus marmoratus	0.0	0.0	0.0	0.0	100.0	1
Poecilidae						
Gambusia affinis	33.3	33.3	0.0	33.3	0.0	3
Atherinidae						
Membras vagrans	0.0	5.9	26.4	64.9	2.8	34
Menidia beryllina	75.0	0.0	0.0	0.0	25.0	4
Gasterosteiformes						
Sygnathidae						
Hippocampus erectus	0.0	0.0	0.0	0.0	100.0	1
H. zosterae	0.0	0.0	0.0	33.3	66.7	12
Syngnathus floridae	21.0	0.0	5.3	15.8	58.0	19
S. louisianae	16.7	10.3	5.1	25.6	42.4	78

Table 1.--(Continued)

Species	Percent taken in					
	Fall	Winter	Spring	Summer	Fall	Total
S. scovelli	3.9	1.9	4.6	73.6	16.1	1140
Scorpaeniformes						
Triglidae						
Prionotus scitulus	6.7	15.0	40.0	13.3	25.0	60
P. tribulus	15.6	59.4	3.2	6.3	15.6	32
Perciformes						
Serranidae						
Diplectrum formosum	0.0	50.0	0.0	50.0	0.0	2
Apogonidae						
Astrapogon alutus	0.0	100.0	0.0	0.0	0.0	1
Carangidae						
Oligoplites saurus	0.0	0.0	0.0	75.0	25.0	8
Selene vomer	0.0	0.0	0.0	33.3	66.7	3
Lutjanidae						
Lutjanus griseus	64.6	17.7	9.8	0.6	7.3	164
L. synagris	19.9	1.1	0.4	2.4	76.3	761
Gerridae						
Eucinostomus argenteus	7.9	2.7	7.9	11.8	69.8	76
E. gula	18.7	7.2	4.3	42.4	27.4	21623
Pomadasyidae						
Haemulon sciurus	14.6	0.0	0.0	16.8	68.6	137
Orthopristis chrysopterus	1.7	3.2	43.9	43.7	7.4	2397
Sparidae						
Archosargus probatocephalus	21.7	4.5	6.6	59.2	8.0	534
Lagodon rhomboides	9.1	9.8	33.3	38.4	9.4	17167
Sciaenidae						
Bairdiella batabana	0.0	0.0	0.0	100.0	0.0	1
B. chrysura	15.7	1.4	17.5	48.7	16.8	1186
Cynoscion nebulosus	9.0	1.5	4.8	67.0	17.8	134

Table 1.--(Continued)

Species	Fall	Winter	Percent taken in Spring	Summer	Fall	Total
Sciaenops ocellata	0.0	0.0	100.0	0.0	0.0	1
Ephippidae						
Chaetodipterus faber	0.0	0.0	0.0	100.0	0.0	2
Mugilidae						
Mugil cephalus	0.0	0.0	100.0	0.0	0.0	1
Sphyraenidae						
Sphyraena barracuda	14.3	0.0	0.0	7.1	78.7	14
Scaridae						
Sparisoma radians	0.0	0.0	0.0	100.0	0.0	2
Blenniidae						
Chasmodes saburrae	40.0	24.2	7.4	18.9	9.5	95
Gobiidae						
Bathygobius soporator	21.6	21.6	20.0	23.3	13.3	60
Gobionellus smaragdus	30.2	17.4	17.4	17.4	17.4	69
Gobiosoma robustum	15.5	34.6	10.5	19.8	19.6	3743
Lophogobius cyprinoides	49.7	15.6	13.6	14.7	6.4	1140
Microgobius gulosus	14.9	12.4	6.4	41.5	24.8	3876
M. thalassinus	0.0	0.0	0.0	14.0	86.0	14
Pleuronectiformes						
Bothidae						
Etropus crossotus	0.0	0.0	0.0	100.0	0.0	1
Paralichthys albigutta	2.1	53.0	34.7	8.1	2.1	49
Soleidae						
Achirus lineatus	30.2	27.8	19.5	9.0	13.6	1460
Trinectes maculatus	13.6	25.4	22.7	8.2	30.1	110
Cynoglossidae						
Symphurus plagiusa	16.0	19.7	16.6	33.4	14.3	2859

Table 1.--(Continued)

Species	Fall	Winter	Percent taken in Spring	Summer	Fall	Total
Tetraodontiformes						
Balistidae						
Stephanolepis hispidus	10.5	7.9	10.5	36.9	34.2	38
Tetraodontidae						
Sphoeroides nephelus	16.5	24.1	25.9	9.4	24.1	170
Diodontidae						
Chilomycterus schoepfi	7.7	7.7	30.8	46.1	7.7	13
Total						61918

lined sole (*Achirus lineatus*) and blackcheek tonguefish (*Symphurus plagiusa*) were less numerous but were on occasion locally abundant, each contributing over 2 percent of the total. The bay anchovy (*Anchoa mitchilli*), gulf toadfish (*Opsanus beta*) and silver perch (*Bardiella chrysura*) were common at most stations and provided between 1 and 2 percent of the catch, as did the gulf pipefish (*Syngnathus scovelli*), the lane snapper (*Lutjanus synagris*) and the crested goby (*Lophogobius cyprinoides*). Less abundant forms, important only locally or seasonally, included the inshore lizardfish (*Synodus foetens*) and the sheepshead (*Archosargus probatocephalus*). The remaining species appeared to be of importance only incidentally, due either to their infrequent occurrence or to their capability of avoiding the gear.

The results of Table 1 are in agreement with those obtained in this area by earlier investigators. Odum (1970) captured 55 species in the North River, of which 33 were collected by roller-frame trawling in the present study. Also, 51 of the 91 species observed by Tabb and Manning (1961) in brackish water areas of the Everglades National Park were collected. The discrepancies observed appear to be primarily attributable to differences in areas sampled and to the more comprehensive nature of the above studies, which employed several types of collecting methods and were of a more qualitative nature. In particular, Odum's intensive North River sampling program resulted in proportionally more fishes tolerant of lower salinity conditions.

Roessler (1967) has noted the close similarity of the estuarine fish fauna of the Everglades to that of the Gulf of Mexico and believed it to be derived primarily from the Gulf rather than from the insular fauna of the Florida Keys.

Data Distributions

As noted previously, the objectives of this investigation were (1) quantitative study of the ecology of estuarine fishes with special reference to factors determining their areal distributions, and (2) analysis of the variability inherent in the catch data, including determination of the mathematical nature of the underlying distributions involved. As some knowledge of the nature of the parent distributions is required for valid parametric testing, this aspect of the study was considered first.

The relationships between the types of distributions followed by biological data have been reviewed by Greig-Smith (1964). "Random" patterns will occur when the occurrence of individuals results from chance alone; such data tend to follow the Poisson distribution in which μ, the population mean, equals σ^2, the population variance. More often, a departure from randomness will occur due to biological or ecological factors; this in turn will almost always result in "overdispersion" (Bliss, 1953) or "contagion" (Lambou, 1963) in which the sample units become clustered or aggregated in groups and $\mu<\sigma^2$. Repulsion between organisms on the other hand, may lead to a "regular" distribution form, in which the units become equally spaced and $\mu>\sigma^2$. As the latter condition appears to be rare in biological situations (Greig-Smith, 1964), most attention has been focused on contagious forms. This is also true of the present study, which in this section will be primarily concerned with determination of the distributions followed by species catch data but will also consider the distribution of the number of species per sample and that of the total catch data for all species by stations.

Species catch data

Clustering of sample units (hereafter referred to as contagion) often complicates the valid analysis and interpretation of fishery catch data. The condition is in fact very common in biological sampling, and numerous mathematical models have been proposed to deal with different situations; these represent attempts to describe the observed patterns in a stable mathematical form amenable to statistical treatment. Both unimodal and polymodal models have been proposed; as nearly all of the Whitewater Bay trawling data appeared to be unimodal, the present investigation will be primarily concerned with this type.

Contagion in unimodal situations may best be reviewed by beginning with a consideration of the Poisson distribution in which all sample units are randomly and independently distributed; as indicated above, σ^2 equals μ under these conditions. As the tendency towards clustering increases, $\bar{x}$, the sample mean, varies from sample to sample (Taylor, 1953) and will be exceeded by the sample variance (S^2). In such situations the negative bionomial will often apply; its relation to other distributions has been described by Bliss (1953: 177) as follows:

> "The negative bionomial is an extension of the Poisson series in which the population mean m, the parameter of the Poisson distribution, is not constant but varies continuously in a distribution proportional to that of χ^2. As the variance of a negative bionomial approaches the mean, or as the over-dispersion decreases, k [the coefficient of contagion] $\rightarrow\infty$ and p [the positive bionomial p] $\rightarrow 0$. Under these conditions, it

> can be shown (Fisher et al., 1943) that the distribution converges to that for the Poisson....Conversely, if the over-dispersion increases sufficiently, $k \to 0$..... If we disregard the number of units containing no individuals the negative bionomial then converges to Fisher's logarithmic series (Fisher et al., 1943) which describes effectively the apparent abundance of different species."

Goodall (1952, in O'Gower and Wacasey, 1967) has stated that the difference between the logarithmic and "log-normal" series is too slight to warrant separate treatment. As k approaches 0, therefore, we may consider the data to approximate the "discrete log-normal" type of distribution, which is a somewhat more skewed form. This distribution appears to be a rather intractable one and suffers from the disadvantage that its frequency function contains an untabulated integral (Anscombe, 1950).

It should be noted that in cases in which the negative bionomial applies, the relation between the population variance and mean may be expressed by

$$\sigma^2 = \mu + \mu^2/k$$

where

$$k = \mu^2/_{\sigma^2 - \mu}$$

Thus, the reciprocal of k is equivalent to the Charlier coefficient of disturbance from the Poisson distribution (Beall, 1942: 247).

Another relation between the negative bionomial and other distributions has been noted by Quenouille (1949) who proved that if groups of individuals were distributed at random and numbers of individuals per group were logarithmically distributed, the distribution of individuals in random samples would conform to the negative bionomial. He further indicated that if any two of these distributions could be demonstrated as applicable, the third would be implied; this is to say that if the distribution of species by sample is Poissonian, and the number of individuals per species follows the negative bionomial, the summarized catch data for all species will conform to Fisher's logarithmic series. The validity of the relation for fishery catch data in general has been demonstrated by Roessler (1965) and accepted by Taylor (1953) and Lambou (1963) who also found their species catch data to conform to the negative bionomial. In addition, other fishery workers (Kutkuhn, 1958; Moyle and Lound, 1960; Taft, 1960) have been successful in fitting the negative bionomial distribution to similar data.

Thus, both theory and the results of earlier studies indicate that the Whitewater Bay trawling data could follow this distribution. It was therefore deemed desirable to test the hypothesis of the negative bionomial for these data, both to gain an insight into the type and degree of contagion present and to obtain the necessary statistics for later use in variance stabilizing transformations.

Catch data for 15 of the fishes collected during roller-frame trawling were summarized and tabulated for distribution testing; these species are indicated in Table 2. Only the more common species which appeared to have been sampled in proportion to their true abundance were considered. For each, the data were arranged seasonally by station; the seasonal units representing the yearly cycle of abundance at a given station were then tested individually for agreement with the negative bionomial except for units in which the Poisson form was clearly more applicable. The seasons used were as described under Checklist of Fishes except in infrequent instances in which recruitment patterns made slight modifications more logical.

Table 2. Means and variances of catch data for 16 species by station and season, together with results of tests for homogeneity and agreement with the negative bionomial, September 1968 to November 1969.

Station & Season	$\bar{x}$	S^2	χ^2	df	k	T	S_eT
Synodus foetens							
7-Sp[1]	0.26	0.46	146.0**	83	0.352	-0.13	0.47
Su	0.46	0.69	122.5**	83	0.893	-0.20	0.45
F[2]	1.74	3.40	162.3**	83	1.392	-4.22	4.66
Opsanus beta							
3-W	0.46	0.66	118.2**	83	0.950	-0.19	0.42
Sp	0.20	0.28	116.4**	83	0.327	-0.13	0.29
4-F[3]	0.70	1.13	133.2**	83	1.012	-0.48	0.92
W	0.14	0.20	114.0*	83	0.272	-0.07	0.18
5-F[3]	0.82	1.31	131.9**	83	1.317	-0.60	0.93
W	2.96	8.35	233.7**	83	1.270	-13.89	20.21
Sp	0.16	0.17	82.0 ns	83	--	--	--
6-W	1.25	3.27	217.4**	83	1.022	0.57	3.34
Sp	0.70	1.01	119.0**	83	1.970	0.09	0.45
Su	0.17	0.25	113.8*	83	0.330	-0.10	0.23
F	1.07	1.25	96.7 ns	83	--	--	--
7-Sp	0.16	0.14	70.0 ns	83	--	--	--
Su	0.51	0.52	83.9 ns	83	--	--	--
F	0.44	0.64	119.7**	83	1.248	0.04	0.28
8-Sp	0.18	0.17	79.1 ns	82	--	--	--
Su	0.35	0.43	98.8 ns	83	--	--	--
F	0.06	0.06	79.0 ns	83	--	--	--
Syngnathus scovelli							
2-Su	0.32	0.37	94.3 ns	83	--	--	--
3-Su	0.45	1.05	191.9**	83	0.254	-1.19	2.95
6-Su	0.42	0.49	97.0 ns	83	--	--	--
7-Sp	0.20	0.33	136.1**	83	0.215	-0.19	0.57
Su	8.06	45.55	469.1**	83	1.082	-299.8	413.4
F	1.69	5.01	246.0**	83	0.857	-1.60	9.25
8-Su	0.42	0.49	97.0 ns	83	--	--	--
Lutjanus griseus							
5-F	0.27	0.29	90.2 ns	83	--	--	--
6-F	0.79	0.82	86.7 ns	83	--	--	--
L. synagris							
6-F	0.85	1.38	136.0**	83	0.998	-0.96	1.40
7-F[3]	1.10	1.62	119.6**	81	1.993	-0.90	1.10
7-F	5.06	19.58	321.1**	83	1.060	-76.00	116.2

Table 2.--(Continued)

Station & Season	$\bar{x}$	S^2	χ^2	df	k	T	S_eT
Eucinostomus gula							
1-Sp	0.06	0.05	79.0 ns	83	--	--	--
Su	0.50	0.95	158.0**	83	0.475	-0.49	1.26
F	0.53	0.81	124.9**	83	0.662	-0.59	0.90
2-Sp	0.06	0.06	79.0 ns	83	--	--	--
Su	0.35	0.52	124.5**	83	0.762	-0.04	0.30
F	0.06	0.06	79.0 ns	83	--	--	--
3-W	2.46	8.37	282.0**	83	0.921	-14.61	21.61
Sp	1.26	3.59	236.3**	83	0.576	-4.99	8.80
Su	3.63	50.36	1151**	83	0.340	-364.4	473.9
F	3.54	16.35	383.4**	83	1.036	4.81	45.7
4-W	3.25	11.01	281.3**	83	1.262	-14.92	25.94
Sp	1.75	2.38	113.0*	83	4.210	-1.64	1.45
Su	4.88	23.09	392.7**	83	1.580	-16.24	51.83
F	2.62	4.31	133.2**	81	3.396	-4.27	4.08
5-W	8.02	19.66	203.3**	83	5.344	-18.75	32.34
Sp	5.46	13.19	200.3**	83	3.153	-34.16	24.49
Su	15.30	248.04	1345**	83	1.043	-1654	2817
F	9.13	41.32	375.6**	83	2.844	25.52	106.3
6-W	3.07	4.07	109.9*	83	8.724	-3.28	2.68
Su	1.50	4.16	230.0**	83	1.236	5.83	3.89
F	7.07	10.88	127.7**	83	12.980	-6.22	10.92
7-W	1.13	2.31	169.3**	83	1.120	-0.80	2.32
Sp	0.82	1.79	180.5**	83	0.604	-1.64	2.77
Su	76.87	4268.60	4609**	83	0.712	-33387	75701
F	47.96	1215.75	2103**	83	1.969	-7730	22727
8-Sp	0.33	0.44	111.3*	82	0.866	-0.09	0.23
Su	3.42	19.90	483.0**	83	0.441	-114.5	225.8
F	0.39	0.70	147.7**	83	0.482	-0.27	0.71
Orthopristis chrysopterus							
4-Sp	0.88	1.77	166.6**	83	0.698	-1.68	2.60
5-W	1.19	2.28	158.7**	83	1.360	-0.74	2.01
Sp	5.77	15.86	228.0**	83	3.210	-14.89	27.33
Su	0.62	0.84	112.8*	83	1.445	-0.32	0.47
6-W	0.48	0.54	92.2 ns	83	--	--	--
Sp	8.35	18.08	179.8**	83	6.182	-44.20	30.09
Su	3.88	9.67	206.8**	83	2.484	-8.39	14.50
7-Sp	0.27	0.37	112.1*	83	0.874	-0.03	0.16
Su	4.04	10.76	221.1**	83	2.153	-16.80	19.51
F	0.79	1.28	135.1**	83	1.189	-0.49	0.96
8-Su	0.63	1.10	145.1**	83	0.638	-0.72	1.37
Archosargus probatocephalus							
5-Su	2.41	3.64	125.7**	83	4.457	-1.92	2.63
F	0.39	0.48	101.9 ns	83	--	--	--

Table 2.--(Continued)

Station & Season	$\bar{x}$	S^2	χ^2	df	k	T	S_eT
Archosargus probatocephalus (continued)							
6-Su	1.29	2.09	134.7**	83	2.026	0.10	1.49
F	0.12	0.10	74.0 ns	83	--	--	--
Lagodon rhomboides							
3-Sp	2.60	11.52	368.5**	83	0.397	-46.46	129.5
Su	2.13	12.65	490.1**	83	0.336	-34.23	107.8
F	0.12	0.20	141.2**	83	0.147	-0.08	0.32
4-F[3]	4.12	8.23	165.7**	83	3.724	-8.13	10.10
W	2.29	5.85	212.2**	83	1.552	0.54	7.71
Sp	0.94	1.60	141.1**	83	1.209	-0.90	1.38
Su	1.06	1.65	129.0**	83	1.630	-0.99	1.25
F	0.31	4.37	116.0**	81	0.636	-0.13	0.29
5-F[3]	2.08	3.09	123.1**	83	4.033	-1.25	2.13
W	8.29	68.98	690.9**	83	0.695	-565.7	1099
Sp	20.0	117.70	488.4**	83	3.478	-512.0	656.1
Su	15.16	133.02	728.6**	83	1.482	-915.3	1366
F	4.28	8.25	159.8**	83	4.120	-9.49	9.89
6-W	7.54	46.08	507.7**	83	1.360	-199.6	221.4
Sp	40.91	292.04	592.6**	83	5.952	2709	2065
Su	45.93	511.56	924.5**	83	4.429	-4241	4639
F	10.18	26.07	212.6**	83	6.829	-8.30	43.4
7-W	0.38	2.53	550.8**	83	--	--	--
Sp	3.04	35.38	967.5**	83	0.453	-20.72	152.6
Su	14.91	109.63	610.4**	83	1.998	-540.7	742.6
F	4.18	29.69	589.7**	83	0.899	27.31	93.93
Bairdiella chrysura							
3-Sp	0.60	0.92	128.1**	83	1.121	-0.15	0.57
Su	0.93	1.78	158.9**	83	0.766	-1.58	2.55
F	0.08	0.08	77.0 ns	83	--	--	--
5-Su	1.94	3.45	147.7**	83	2.378	-1.29	3.04
F	0.91	0.98	89.8 ns	83	--	--	--
6-Su	2.25	3.54	130.5**	83	4.240	-0.27	2.38
F	0.46	0.47	83.8 ns	83	--	--	--
7-Su	1.91	5.46	237.9**	83	1.150	-2.05	7.74
F	0.41	0.44	89.5 ns	83	--	--	--
Gobiosoma robustum							
3-F[3]	2.02	6.65	272.7**	83	1.014	-1.00	11.02
W	1.25	3.35	222.2**	83	0.808	0.26	4.80
Sp	0.61	1.09	148.3**	83	0.671	-0.50	1.16
Su	0.13	0.26	164.6**	83	0.183	-0.03	0.28
4-F[3]	1.75	2.84	134.7**	83	2.965	-0.29	1.94
W	1.56	3.77	200.5**	83	1.108	-1.37	5.03
Sp	0.38	0.53	115.0*	83	0.783	-0.20	0.34

Table 2.--(Continued)

Station & Season	$\bar{x}$	S^2	χ^2	df	k	T	S_eT
Gobiosoma robustum (continued)							
5-F[3]	1.45	3.91	223.6**	83	0.835	-0.84	6.60
W	6.23	34.54	460.1**	83	1.505	41.12	108.7
Sp	0.43	0.73	141.3**	83	0.659	-0.18	0.55
6-F[3]	1.21	2.46	168.1**	83	1.136	-1.00	2.68
W	5.64	18.64	274.2**	83	2.375	-28.81	39.62
Sp	1.06	4.35	340.4**	83	0.281	-10.58	22.28
Su	1.12	2.54	188.3**	83	0.879	-0.84	3.21
7-Sp	0.19	0.42	183.5**	83	0.225	0.01	0.46
Su	4.50	43.57	803.8**	83	0.659	-0.16	213.5
F	2.12	4.56	178.7**	83	1.534	-4.23	6.53
8-W	0.22	0.40	146.0**	81	0.190	-0.27	0.86
Sp	1.86	6.30	278.4**	82	0.756	-8.65	15.09
Su	2.45	11.75	397.1**	83	0.557	-34.71	56.70
Lophogobius cyprinoides							
3-F[3]	1.12	3.65	270.1**	83	0.520	-4.60	7.77
5-F[3]	5.19	23.92	382.4**	83	1.498	-12.78	66.96
W	1.82	2.37	107.8*	83	5.850	-0.91	1.26
Sp	1.66	2.93	146.8**	83	2.058	-1.38	2.53
Su	1.58	3.81	199.8**	83	1.362	1.25	3.86
F	0.73	1.14	130.4**	83	1.796	0.51	0.52
6-Su	0.33	0.35	86.0 ns	83	--	--	--
Microgobius gulosus							
1-Sp	0.26	0.22	69.6 ns	83	--	--	--
Su	5.37	27.44	424.2**	83	0.973	-119.9	161.9
F	3.91	7.49	159.1**	83	4.134	-3.26	7.98
2-Sp	0.44	0.39	74.2 ns	83	--	--	--
Su	5.55	27.50	411.5**	83	1.154	-68.14	128.2
F	2.32	4.70	168.1**	83	2.029	-5.19	5.54
3-Sp	1.02	1.23	99.5 ns	83	--	--	--
Su	3.31	21.66	543.3**	83	0.775	-35.65	65.76
F	1.24	4.83	324.7**	83	0.605	2.11	7.68
4-F[3]	1.70	7.44	362.7**	83	0.592	12.27	18.27
W	0.16	0.16	83.9 ns	83	--	--	--
Sp	0.17	0.22	102.6 ns	83	--	--	--
Su	2.00	4.09	170.0**	83	1.705	-1.47	4.91
7-W	1.18	1.69	119.1**	83	2.525	-0.53	1.00
Sp	0.42	1.19	236.2**	83	0.150	-1.90	6.68
Su	2.30	13.51	488.1**	83	0.437	-42.44	75.32
F	1.88	6.23	274.7**	83	1.363	13.25	5.81
8-W	0.94	1.59	137.1**	81	1.320	-0.70	1.25
Sp	0.58	0.93	131.8**	82	0.813	-0.45	0.81
Su	1.69	3.52	172.7**	83	1.036	-5.60	6.79
F	1.44	2.39	137.9**	83	1.879	-1.47	2.06

Table 2.--(Continued)

Station & Season	$\bar{x}$	S^2	χ^2	df	k	T	S_eT
Achirus lineatus							
3-W	0.30	0.33	92.6 ns	83	--	--	--
Sp	0.56	0.80	119.2**	83	1.080	-0.31	0.52
Su	0.12	0.11	74.0 ns	83	--	--	--
4-W	0.17	0.19	94.0 ns	83	--	--	--
Sp	0.13	0.12	73.0 ns	83	--	--	--
5-W	0.48	0.72	123.8**	83	0.834	-0.25	0.51
6-W	0.36	0.42	98.8 ns	83	--	--	--
Sp	0.41	0.68	138.9**	83	0.784	0.08	0.39
Su	0.27	0.39	119.4**	83	0.827	0.05	0.17
F	0.54	0.71	109.9*	83	2.051	0.16	0.26
7-F[3]	3.65	10.03	222.9**	83	1.744	-19.69	20.96
W	3.20	10.48	271.5**	83	1.206	-18.88	26.94
Sp	2.04	6.95	283.4**	83	0.655	-15.21	24.22
Su	0.17	1.05	122.0**	83	1.208	-0.55	0.77
8-F[3]	1.40	2.49	143.8**	81	1.555	-1.38	2.48
Su	0.25	0.24	79.0 ns	83	--	--	--
F	0.66	0.98	123.7**	83	1.286	-0.17	0.59
Symphurus plagiusa							
5-W	0.98	1.20	102.4 ns	83	--	--	--
Sp	0.31	0.29	77.3 ns	83	--	--	--
6-Sp	0.29	0.28	79.2 ns	83	--	--	--
Su	0.79	1.63	169.9**	83	1.096	2.09	1.09
F	0.57	0.63	92.0**	83	5.770	-0.10	0.17
7-W	2.29	7.39	268.3**	83	0.852	-12.14	20.39
Sp	1.56	7.09	377.5**	83	0.407	-11.30	29.99
Su	3.68	37.11	837.4**	83	0.455	-79.44	260.7
F	0.95	1.64	142.6**	83	1.658	0.98	0.98
8-W	3.06	4.90	129.6**	81	5.164	-1.06	3.87
Sp	3.46	5.41	126.6**	81	4.905	-7.30	5.25
Su	6.68	35.31	438.1**	83	1.734	-38.11	102.9
F	3.00	14.02	388.1**	83	1.005	0.34	31.16

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[1] Sp = spring, Su = summer, F = fall, and W = winter.

[2] All "fall" tests involved 1969 data unless otherwise stated.

[3] Fall of 1968

* Significant at $P \leq .05$

** Significant at $P \leq .01$

The remaining species captured were usually much less abundant and appeared to follow the Poisson distribution. The single exception to this rule, Anchoa mitchilli, was not considered in that it did not appear to have been sampled effectively by roller-frame trawling.

Each unit of data was first tested for homogeneity (i.e., randomness) using the index of dispersion formula given by Steel and Torrie (1960: 397). In cases in which low Chi-square values were obtained, tests for a regular form of distribution were made by comparing the observed value with the appropriate values at the 95 percent probability level as recommended by Greig-Smith (1964: 63). If, however, results indicated that contagion was present ($P \leq .05$), the null hypothesis was rejected and the negative bionomial was fitted to the data using the maximum likelihood equation of Bliss (1953: 181) which derives an optimum value of k by computing trial scores of Z_i in the equation

$$Z_i = \Sigma\left(\frac{A_x}{k_i+x}\right) - N \ln \left(1+\bar{x}/_{k_i}\right)$$

where A_x represents the accumulated frequency of all units containing more than x organisms, k_i represents the ith approximation of k, and N refers to sample size. If the initial approximation was found to exceed 20 (thus indicating convergence towards the Poisson form) iterations were not attempted. For all initial values less than 20, successive scores of Z_i were computed using k value changes of .5 until scores bracketing 0 were obtained; the final approximation was then made using successively smaller changes until $Z_i \leq .005$. If over 25 iterations were required, the operation was terminated.

The index of dispersion test indicated that most of the data were contagiously distributed; no instances were found in which the underlying distributions appeared to be regular rather than random. The need was therefore evident for a test for agreement with the negative bionomial or some other contagious form. Anscombe (1950) has listed eight contagious distributions of which three besides the negative bionomial might apply to fishery catch data (Taylor, 1953); these are the Neyman Type A, the Thomas double Poisson, and the Polya-Aeppli forms, all of which are potentially multimodal. The first two models appear to be rather specialized, and Anscombe (1950) has pointed out that in the absence of a series of equally spaced modes one may reasonably feel reluctant to use the Neyman type A form; such a spacing of modes is not evident in the Whitewater Bay trawling data. The Thomas double Poisson has likewise been criticized by Anscombe (1950) as being of doubtful validity. The Polya-Aeppli form, however, appears to approximate that of the negative bionomial much more closely; Bliss (1953) has pointed out that the Polya-Aeppli is very similar to the negative bionomial in some respects, while Anscombe (1950) believed that close approximations to both these distributions might be observed in studies of growing populations. Consequently, it was of some interest to discriminate between these forms, and the moment test derived by Anscombe (1950) was used for this purpose; the test compares the difference between the observed and expected third moments of the sample (T) with its standard error (S_eT). Bliss (1953) has stated that such a test is less likely to be distorted by chance irregularities than is Chi-square goodness of fit; also, it has the further advantage of utilization of the few large values that are missed by grouping the tail of an observed distribution in computing χ^2. Lambou (1963) also believed that such tests are often more sensitive than goodness of fit tests, especially with small samples.

The tendency to approach the log-normal form as k →0 should also be considered. In such cases, however, the data would necessarily be skewed, and it is therefore probable that the above test would be comparable or even superior to Chi-square goodness of fit in detecting this. An additional moment test (Anscombe, 1950) is in fact available which is sensitive to such a departure but was not employed as the k statistic required is computed by a different iterative procedure.

The computed means, variances, and k statistics for the data tested are tabulated in Table 2, together with the results of tests for homogeneity and agreement with the negative bionomial. These appear to indicate that the underlying pattern was often random at low densities but conformed to the negative bionomial where contagion was present. Three disturbing factors (as evidenced by T being exceeded by S_eT) appeared to exist in the latter tests; these were (1) a tendency to approach the Poisson distribution at low densities, thus resulting in higher k values, (2) a tendency towards higher k values and poorer agreement with the negative bionomial at higher densities, and (3) an apparent tendency for departure in the direction of the lognormal form, noted rarely with lower k values.

Departure towards the Poisson form occurred in two instances for Eucinostomus gula (at Station 4 in spring and Station 6 in winter) in which the variance approached the mean although enough contagion was present ($P \leq .05$) to allow a maximum likelihood estimate of k. (It should be noted that when the initial index of dispersion test failed to reject the null hypothesis, supplementary testing usually indicated k to approach infinity.) As only two such instances were observed, it is evident that this tendency was not of major importance.

The second type of discrepancy was observed for Eucinostomus gula at Stations 4 in fall and 5 in spring, for Orthopristis chrysopterus and Lagodon rhomboides at Station 6 in spring and for Symphurus plagiusa at Station 8 in spring. In each case, the catch data tested appeared to be bimodal and could have represented a deviation towards the Polya-Aeppli form; however, it would appear justifiable to attribute this tendency to chance in view of the limited number observed.

An apparent deviation towards the log-normal form was also observed in four cases; these involved Eucinostomus gula (Station 6, summer), Microgobius gulosus (Station 7, fall), and Symphurus plagiusa (Station 6, summer). In addition, one test for Lagodon rhomboides showed k to approach 0, thus indicating convergence to the lognormal form.

Of the 145 tests conducted on contagiously distributed data, only 10 instances were noted in which T exceeded its standard error and most of the T/S_eT ratios involved were not large; only two exceeded 1.5. The available evidence, therefore, strongly supports the hypothesis of the negative bionomial distribution for the Whitewater Bay species catch data.

Number of Species Per Sample

As noted above, Quenouille (1949) has shown that if the number of individuals per species conforms to the negative bionomial and the distribution of species per sample is Poissonian, the total number of individuals in all species collected will then conform to Fisher's logarithmic series. It was desired to test the validity of this relationship for the Whitewater Bay trawling data, and a test of the null hypothesis of the Poisson distribution for the number of species per tow was therefore required. Accordingly, the Chi-square goodness of fit test procedure described by Steel and Torrie (1960: 395) was used for this purpose; expected values of less than one were combined as recommended. As in the previous section, data were arranged seasonally by station and the total annual cycle tested. Results are given in Table 3.

Of the 32 tests conducted, 13 were found to be significant; this was a much greater number than would have been expected by chance. There is, therefore, evidence that the number of species per tow did not conform to the Poisson distribution, at least in certain instances.

It is believed that the results observed are attributable to a tendency towards regularity, rather than contagion, in the species per tow data. In 10 of the 13 cases in which significance was observed the variance was less than the mean, indicating regularity. This could result from a mutual repulsion between species, the limited number of species involved, or slight differences in habitat preference. The cases observed in which the variance exceeded the mean are believed to be of little consequence in that two of these instances occurred on Station 3, an area characterized by considerable local variation in vegetation density. Thus, the "contagion" observed in these tests may merely result from restriction of the various fishes to better cover conditions. It is therefore believed that the underlying form of the distribution of species per sample in this study is random to regular, rather than contagious, in nature.

Similar analyses have been made by Taylor (1953) and Roessler (1965) who both failed to reject the null hypothesis of a Poisson

Table 3. Results of Chi-square goodness of fit comparisons of the observed distribution of species per tow by station and season and values expected on the hypothesis of a Poisson distribution, December 1968 to November 1969.

Station & Season	$\bar{x}$	S^2	χ^2	df
1-W[1/]	1.25	1.40	5.11 ns	3
Sp	1.00	0.87	3.26 ns	3
Su	1.44	0.85	14.73**	4
F	1.67	0.66	25.89**	4
2-W	1.17	0.84	4.18 ns	3
Sp	1.02	0.70	8.17*	3
Su	1.94	1.57	7.22 ns	5
F	1.42	0.77	11.95*	4
3-W	2.80	3.41	3.68 ns	6
Sp	3.63	5.15	21.90**	8
Su	3.31	4.80	20.93**	7
F	1.93	1.13	12.64*	5
4-W	2.85	1.45	16.37*	6
Sp	2.74	2.36	6.15 ns	6
Su	3.08	2.05	13.87 ns	7
F	2.08	1.35	6.25 ns	5
5-W	6.29	4.26	9.63 ns	11
Sp	5.49	2.98	14.55 ns	9
Su	6.10	3.05	23.78**	10
F	6.25	4.05	9.90 ns	10
6-W	5.35	2.64	16.69 ns	9
Sp	4.51	1.92	21.60**	7
Su	7.17	3.49	16.79 ns	10
F	6.46	2.93	21.03*	9
7-W	3.88	5.41	15.09 ns	8
Sp	3.99	4.56	9.30 ns	8
Su	9.44	8.27	25.27**	11
F	10.04	6.04	12.79 ns	10
8-W	2.67	2.67	5.35 ns	6
Sp	4.02	5.12	16.69*	8
Su	5.12	4.95	6.51 ns	9
F	3.62	3.93	2.70 ns	7

[1/] W = winter, Sp = spring, Su = summer, and F = fall.

* Significant at $P \leq .05$

** Significant at $P \leq .01$

distribution. The discrepancy between the results of these studies and those of the present investigation may be attributable to ecological differences, as the above studies were conducted in marine situations; certainly the distribution of species in such areas would be expected to differ from that observed in estuarine situations characterized by fewer species and a proportionally higher abundance of certain forms. The data for the present study, in particular, are dominated by a few species occurring in considerable abundance; this could readily have resulted in the lower variation observed.

Total Data for all Species

Following the tests for randomness in the distribution of species per sample, the total catch data for all species for the December 1968 to November 1969 period were summarized by station and tested for agreement with Fisher's logarithmic series, again using Chi-square goodness of fit. Values of the index of diversity α required in fitting the distribution were calculated according to the procedure given by Williams (1947: 266) in which values of log N/α are interpolated from tabulated values of log N/S (where N represents the total number of organisms and S the total number of species). Expected values were pooled to avoid values of less than 4 wherever possible. The data for these tests, and the results obtained, are tabulated in Table 4.

These findings are similar to those of the preceding section in that the null hypothesis must be rejected for much of the data. This is to be expected, as the hypothesis of the negative bionomial for species catch data appears to be valid. (From Quenouille's

Table 4. Frequency of occurrence of species with different numbers of individuals and expected frequency of occurrence on the hypothesis of a logarithmic series distribution by station, December 1968 - November 1969.

No. of Individuals	Observed	Expected	χ^2		No. of Individuals	Observed	Expected	χ^2	
	Station 1					Station 2			
1-5	17	11.10	3.14		1-5	12	8.49	1.45	
6-10	4	3.07	0.29		6-20	4	4.73	0.11	
11-20	1	4.05	3.85		21-50	3	4.96	0.78	
21-100	3	4.62	0.56		50+	2	2.82	0.24	
100+	2	3.38	0.55		Total	21	21.00	2.57 ns	with 1 df
Total	48	48.00	8.39*	with 2 df					
	Station 3					Station 4			
1-5	19	12.06	3.99		1-5	14	9.44	2.12	
6-20	4	6.82	1.16		6-20	3	5.34	1.03	
21-50	1	4.47	2.70		21-100	5	6.00	0.17	
50-150	5	4.84	0.01		100+	4	5.22	0.28	
150+	4	4.81	0.14		Total	26	26.00	3.68 ns	with 1 df
Total	33	33.00	8.00*	with 2 df					

Table 4.--(Continued)

No. of Individuals	Observed	Expected	χ^2		No. of Individuals	Observed	Expected	χ^2	
	Station 5					Station 6			
1-5	19	11.99	4.10		1-5	19	11.24	5.35	
6-20	7	6.87	0.00[1/]		6-20	4	6.45	0.93	
21-50	5	4.66	0.03		21-50	4	4.39	0.04	
51-150	1	5.48	3.67		51-150	5	5.20	0.01	
150+	8	11.00	0.82		150+	7	11.72	1.90	
Total	40	40.00	8.61*	with 2 df	Total	39	39.00	8.23*	with 2 df
	Station 7					Station 8			
1-5	18	14.68	0.75		1-5	24	18.98	1.33	
6-10	6	4.14	0.83		6-10	6	5.29	0.10	
11-20	4	4.28	0.00[1/]		11-20	4	5.38	0.35	
21-50	7	5.73	0.28		21-50	7	6.92	0.00	
51-100	3	4.32	0.40		51-100	3	4.78	1.06	
100+	13	17.85	0.13		100+	6	8.65	0.81	
Total	51	51.00	2.40 ns	with 3 df	Total	50	50.00	3.65 ns	with 3 df

[1/] Less than .01

* Significant at $P \leq .05$

relationship, rejection of the hypothesis of the Poisson distribution must in this case lead to rejection of that for the logarithmic series; acceptance of either one but not both will not conform to theory). It will be noted that tests involving Stations 1, 3, 5 and 6 indicate a significant departure from the logarithmic series, and as species distributions on three of these stations occasionally deviated considerably from randomness it may be inferred that these distributions are indeed related.

In summary, the evidence available clearly supports the hypothesis of the negative bionomial distribution for the contagiously distributed species catch data. The number of species per tow, however, often did not conform to the Poisson, while the total catch data for all species likewise showed only partial agreement with Fisher's logarithmic series. It is believed that as the negative bionomial hypothesis appears to be valid for the species catch data the latter results are directly related.

Variation Associated With Trawling Procedures

This investigation was also concerned with variation caused by trawling procedures and tidal effects. In this phase of the study, parametric analysis of variance techniques were employed; these in turn required the use of transformations to insure that the underlying assumptions would not be violated.

Steel and Torrie (1960: 128) have stated that the basic assumptions of the analysis of variance are:

1) Treatment and environmental effects are additive, and

2) Experimental errors are random, independently and normally distributed about zero mean and with a common variance.

Violation of Assumption (1) in fishery catch data usually implies proportional rather than additive effects; under such conditions transformation to a logarithmic scale is appropriate (Snedecor and Cochran, 1967). Assumption (2), however, implies normally distributed data and homogeneity of variance between treatments, both requirements that are often difficult to satisfy.

It is currently believed that the usual disturbances resulting from departure from normality are unimportant (Steel and Torrie, 1960). Cochran (1947) has stated that the results of non-normality may be twofold: (1) a slight change in the probability levels associated with the F-test, and (2) a slight loss in efficiency. Extreme skewness, on the other hand, may be more serious (Bartlett, 1947; Cochran, 1947). Cochran has also indicated that heterogeneity of variance may affect a given analysis to an unpredictable extent. Accordingly, it was desired to evaluate appropriate transformations in some detail, particularly with regard to their relative effectiveness in normalizing the data and stabilizing the variance.

Transformations Used

Anscombe (1948) considered two transformations applicable to negative bionomial situations. For k values <2 (and for larger k where the mean was large) Anscombe recommended

$$y = \ln (r+k/_2)$$

where r represents an individual observation. For larger k values and smaller means, a more complicated inverse hyperbolic sine transform was given. As most of the contagious data fitted in this study gave k values of less than 2, only the former transformation will be considered here.

More recently, Taylor (1961) assumed the variance for contagiously distributed data (with means exceeding 1) to be related to the mean by a simple power law, i.e.

$$S^2 = am^b$$

where a and b are characteristic of the population in question. Thus, the value b may be obtained by regressing the logarithms of the variances upon those of the means over the observed range of conditions; this is then used to compute an exponent used in transforming the data.

The above transformations appeared to be most appropriate for the present study. Accordingly, a sample of 43 sets of catch data (previously tested for agreement with the negative bionomial) was transformed using both procedures; comparisons were then made of the relative effectiveness of these methods in normalizing the data and stabilizing the variance. Skewness was tested by computing the moment ratio $\sqrt{b_1}$ according to the method of Snedecor (1956: 201). The amount of kurtosis was determined using the method of Geary (1936); homogeneity of variance was evaluated by Bartlett's Chi-square as described by Steel and Torrie (1960: 347). In the latter test, variances were compared between nights, thus resulting in 5 degrees of freedom. Results of these analyses are given in Table 5.

It is apparent that both transformations were usually quite effective in stabilizing the variance and reducing skewness. Occasionally, the latter was accompanied by an increase in kurtosis, as might be expected for small samples. The results for both transformations appeared similar with Anscombe's logarithmic scale transform being slightly more effective. Out of the 43 tests conducted, it

Table 5. Results of tests for skewness, kurtosis and homogeneity of variance using both Anscombe's and Taylor's transformations and untransformed data.

	Skewness, $\sqrt{b_1}$			Kurtosis, a			Bartlett's χ^2 with 5 df		
Station & Season	Raw Data	Anscombe's trans.	Taylor's trans.	Raw Data	Anscombe's trans.	Taylor's trans.	Raw Data	Anscombe's trans.	Taylor's trans.
Opsanus beta									
5-W[1]	1.0649**	-.2641	-.0103	.803	.849*	.826	37.95**	18.65**	14.69*
6-W	2.5289**	.4625*	.1809	.661**	.861**	.907**	56.63**	3.75	3.41
Syngnathus scovelli									
7-Su	.5717*	-.7356**	-.2442	.842*	.839*	.841*	13.58*	16.95**	3.74
F[2]	2.1350**	.2215	.2957	.740**	.861**	.858**	39.09**	2.42	1.83
Eucinostomus gula									
3-W	1.4514**	.0173	-.5592*	.777	.849*	.861**	33.90**	13.15*	21.31**
F	2.1901**	-.2365	-.4813*	.703**	.823	.800	37.69**	9.59	10.05
4-F	.6823**	-.2070	.0283	.813	.812	.807	9.85	2.33	3.51
5-W	.6886**	-.4674*	-2.2876**	.769	.761*	.666**	5.27	4.14	22.43**
F	1.3980**	-.5113*	-4.4974**	.737**	.741**	.490**	14.44**	4.48	61.31**
7-F	1.2886**	-.2168	.5477*	.753*	.812	.801	44.77**	12.34*	16.67**
Orthopristis chrysopterus									
5-W	1.7155**	.4067	.3111	.733**	.863**	.882*	30.15**	4.26	2.91
7-Su	.8763**	-.3590	-.9649**	.819	.813	.749*	25.33**	6.16	12.76*
Archosargus probatocephalus									
5-Su	.8160**	.0261	-.5057*	.804	.795	.764	8.22	3.65	4.14
6-Su	1.6452**	.1023	.1953	.784	.884**	.877**	23.47**	5.67	6.76
Lagodon rhomboides									
4-W	1.8046**	.0336	-.2766	.733**	.837*	.808	20.73**	2.76	3.25
5-Sp	.6133*	-.9595**	-.6814**	.770	.783	.767	10.85	5.57	5.57

Table 5.—(Continued)

Station & Season		Skewness, $\sqrt{b_1}$			Kurtosis, a		Bartlett's χ^2 with 5 df		
	Raw Data	Anscombe's trans.	Taylor's trans.	Raw Data	Anscombe's trans.	Taylor's trans.	Raw Data	Anscombe's trans.	Taylor's trans.
Lagadon rhomboides (continued)									
Su	.8687**	-1.0460**	-.2354	.788	.783	.799	15.26**	25.04**	14.88*
F	.6145*	-.4106	-.3352	.810	.801	.785	10.13	5.48	7.14
6-W	1.0499**	-.3928	.1927	.808	.822	.823	33.72**	13.24*	2.59
Su	.5953*	-.3220	.5707*	.819	.813	.805	28.68**	13.55*	14.48*
F	.7726**	-.0033	-.1632	.805	.822	.814	9.38	2.63	2.75
7-Sp	3.7863**	.2866	.3684	.566**	.819	.820	118.03**	157.60**	85.69**
Bairdiella chrysura									
5-Su	1.2193**	.0445	-.1250	.775	.848*	.818	15.08*	2.15	1.10
6-Su	1.1407**	.2244	-.2043	.775	.790	.770	13.62**	2.40	1.50
7-Su	1.934**	.1643	.2067	.698**	.818	.790	40.86**	2.40	2.77
Gobiosoma robustum									
3-F[3]	2.1797**	.1540	-.5053*	.670**	.819	.874**	54.63**	10.04	9.04
4-W	1.8522**	.2162	.2171	.743*	.852**	.859**	41.70**	8.68	9.08
5-W	1.9908**	-.6191**	.4948**	.690**	.752**	.735**	32.63**	5.10	4.26
6-F[3]	1.7468**	.3688	.1848	.750*	.888**	.921**	28.57**	6.00	3.80
W	.9752**	-.3907	-.3613	.800	.777	.759*	18.96**	3.05	2.45
7-F	1.1552**	-.0677	-.1567	.804	.868**	.841*	8.40	1.67	1.84
8-Su	1.6980**	.2091	.3183	.755*	.872**	.858**	73.50**	6.07	3.29
Microgobius gulosus									
1-Su	.9599**	-.4326*	.0542	.826	.848*	.839*	49.05**	7.78	3.10
1-F	.9086**	-.2229	-1.6015**	-.799	.815	.695**	11.50*	8.51	17.29**
2-Su	1.2729**	.5595*	-.1728	.774	.815	.794	48.53**	23.08**	20.96**
2-F	.9317**	-.0062	-.0529	.824	.847*	.821	17.11**	7.04	7.80
3-Su	2.3266**	.1467	-1.3974**	.697**	.803	.813	49.18**	2.77	5.64
4-Su	1.8154**	.3014	.2589	.732**	.881**	.877**	26.00**	6.30	6.74

Table 5.--(Continued)

Station & Season	Skewness, $\sqrt{b_1}$ Raw Data	Skewness, $\sqrt{b_1}$ Anscombe's trans.	Skewness, $\sqrt{b_1}$ Taylor's trans.	Kurtosis, a Raw Data	Kurtosis, a Anscombe's trans.	Kurtosis, a Taylor's trans.	Bartlett's χ^2 with 5 df Raw Data	Bartlett's χ^2 with 5 df Anscombe's trans.	Bartlett's χ^2 with 5 df Taylor's trans.
<u>Achirus lineatus</u>									
7-W	1.1983**	-.2299	-.5869*	.795	.816	.801	28.91**	14.93*	22.83**
Sp	1.4314**	.1805	.3742	.778	.875**	.845*	32.91**	5.66	3.29
<u>Symphurus plagiusa</u>									
7-W	1.4571**	.0476	.0671	.797	.855**	.834	46.81**	9.05	9.04
Su	2.8994**	.1527	-.2070	.657**	.846*	.878**	113.58**	11.23*	20.17**
8-Su	1.4819**	-.2516	-1.2507**	.752*	.791	.704**	32.49**	6.95	25.82**

[1] W = winter, Sp = spring, Su = summer, and F = fall.
[2] All "fall" analyses were conducted on 1969 data unless otherwise stated.
[3] Fall of 1968
* Significant at P≤ .05
**Significant at P≤ .01

proved superior to Taylor's procedure in 27 tests of skewness and 23 Chi-square tests of homogeneity of variance. Consequently, Anscombe's transformation was used in parametric analysis of variance testing.

It should also be noted that the logarithmic transform was usually effective even for data with low means and high k values. Out of 12 such cases, skewness or heterogeneity of variance was observed in the transformed data in only four instances, none of which were highly significant. This compares reasonably well with the results from the remaining analyses. When it is further considered that only 15% of the original negative bionomial fits gave k values exceeding 2, it becomes apparent that little would be gained from using the more complicated inverse hyperbolic sine transform of Anscombe, at least under the conditions of the present study.

The data of Table 5 also reveal that when the partitioned variances were homogeneous the transformed data also closely approximated normality in most cases, the chief deviation being toward kurtosis. Some departure from normality is to be expected from theory; Bartlett (1947) has pointed out that the condition of normality may not be satisfied if the choice of a transformation scale has already been selected to stabilize the variance although such transformations often have a normalizing effect. As previous studies have indicated skewness to be the more serious form of distortion, it is improbable that the analysis of variance would be invalidated in such cases.

In summary, the results observed indicated that Anscombe's logarithmic transform would be most applicable to the present data and that its use would permit valid parametric tests of monthly catch data at a given station. Accordingly, such procedures were used to test hypotheses concerning variation associated with trawling procedures.

Analysis of Variance

As noted previously, the actual trawling procedure entailed three primary sources of variation; these were (1) nights (including tides), (2) tow direction, and (3) nets. It was desired to determine if catch rates were affected by these factors, and three-way analysis of variance was used for this purpose with factors A, B, and C corresponding to the sources of variation listed above. It was assumed that all treatment effects were random; accordingly, two-way interactions and main effects were tested following the "nonpooler" procedure of Brownlee (1965: 509). As the number of observations per cell were less than 5, the M-test procedure of Pearson and Hartley (1954: 57) was used to check for homogeneity of variance.

The analysis was conducted as follows. Data for the twelve most common species were selected for factorial testing by station and season whenever abundance appeared to be adequate, with the limitation that no more than six factorials were run for a given species per station. Infrequently, the true tidal stages could not be determined due to wind effects (see METHODS), but the data were included. Tests were not made if engine trouble had delayed the second night's trawling or if morning drags had been made after nautical twilight. Also, data for September and October of 1968 were excluded as the order of trawling the various stations during these months differed from that of the remainder of the study. The F-values obtained in these tests are given in Table 6.

It is apparent that the null hypothesis cannot be rejected for most of the data tested. Considering the results as a whole, it will be noted that out of some 672 F-tests, only 21 were significant--even fewer than would be expected by chance. Most of these instances, however, were accounted for by two species, Eucinostomus gula and Gobiosoma robustum. Accordingly, the results for these fishes are considered in more detail.

For main effects, night appeared to be the primary source of variation, accounting for five of the six significant differences observed for these species. The data did not appear to follow any definite pattern, however, as different tests for each species showed catches to be higher on different nights (and for Eucinostomus gula, at different tidal stages). It therefore appears likely that the results observed were primarily dependent on random fluctuations in population levels associated with schooling movements. The significant night x direction interactions may be associated with changes in tidal flow direction although as only two instances were observed for each species the exact influence of this factor is difficult to assess. Similarly, the night x net interactions observed for Gobiosoma robustum may imply that variations in personnel efficiency occurred in handling the paired nets. For the study as a whole, however, the importance of all main effects and interactions tested would appear to be negligible.

Thus, the results of these analyses indicate that tides and trawling procedures were not important sources of variation in the present study; catch rates appear to have been primarily determined

Table 6. Results of factorial analysis of variance tests of the effects of tide changes and trawling procedures on catch rates for 12 selected species, November 1968 to October 1969.

				Factor				
Station	Month	A =Night	B =Direction	C =Nets	AB	AC	BC	ABC
Opsanus beta								
5	Dec.	8.51	1.18	0.73	1.31	1.48	1.59	0.69
	Jan.	1.74	2.20	1.08	21.41	4.36	4.78	0.11
6	Dec.	17.25	2.45	3.96	0.42	0.65	0.16	0.97
Syngnathus scovelli								
7	July	2.42	0.03	0.17	47.34	0.01	26.76	0.02
	Sept.	1.77	0.18	0.20	1.84	1.81	4.31	0.57
Eucinostomus gula								
3	Feb.	185.39*	6.08	0.42	1.32	2.41	5.00	0.01
	Mar.	0.12	0.11	0.92	17.77	0.57	3.89	0.11
	July	5.50	4.39	9.77	1615.4*	362.6*	40.00	0.00[1]
4	Dec.[2]	0.01	0.02	5.99	5851.6**	47.3	276.33*	0.00[1]
	April	0.27	1.39	0.76	1.58	3.75	0.46	1.08
	Sept.	2.35	8.74	1.21	0.01	1.09	0.37	1.14
5	Feb.	114.54**	3.30	1.23	3.63	2.71	56.55	0.01
	April	0.38	4.42	0.39	9.92	10.62	14.84	0.08
	May	26.92*	1.11	7.11	0.26	0.33	0.67	0.76
	July	0.34	0.04	0.17	29.55	1.85	4.54	0.12
	Aug.	3.04	31.92	1.98	0.09	1.16	0.00[1]	0.42
	Sept.	1.21	0.91	2.41	2.79	0.00[1]	0.47	0.57
7	Sept.	62.36	2.12	1.72	1.69	0.05	7.91	0.09
Orthopristis chrysopterus								
5	April	0.07	0.65	0.75	16.52	12.40	1.64	0.08
	May	3.73	0.96	31.04	5.29	0.00[1]	0.03	0.21

Table 6.--(Continued)

				Factor				
Station	Month	A =Night	B =Direction	C =Nets	AB	AC	BC	ABC
<u>Orthopristis</u> <u>chrysopterus</u> (continued)								
	Sept.	3.30	2.18	9.03	0.31	0.00[1]	0.19	4.52
6	April	0.47	9.92	0.49	11.94	43.44	0.00	0.05
	May	0.60	0.10	4.37	10.31	0.35	1.17	0.41
	July	1.66	1.52	0.42	0.66	3.33	0.00[1]	0.62
	Aug.	4.56	8.42	1.95	0.25	0.72	0.08	0.24
7	July	6.54	1.27	0.80	3.45	1.08	1.41	0.11
	Aug.	8.95	5.50	0.51	5.08	9.94	3.11	0.33
	Sept.	11.34	1.66	2.85	0.22	0.10	3.53	0.53
<u>Archosargus</u> <u>probatocephalus</u>								
5	July	28.69	10.48	164.47	0.09	0.00[1]	0.01	6.41*
	Aug.	3.05	1.43	0.25	0.17	3.41	0.57	0.60
6	July	3.50	32.99	8.36	0.36	1.00	0.11	0.08
<u>Lagodon</u> <u>rhomboides</u>								
3	Feb.	0.03	0.11	0.42	66.25	2.06	1.08	0.02
4	Nov.	11.83	1.28	0.40	28.20	2.46	0.12	0.05
	Dec.[2]	52.72	0.72	1.81	0.17	0.03	1.23	0.60
	Feb.	0.11	0.23	0.50	1.00	8.37	5.39	0.34
	Aug.	0.47	0.18	0.08	0.56	21.47	4.94	0.40
5	April	0.04	0.10	0.05	54.09	0.03	32.91	0.08
	May	1.12	0.13	1.71	6.44	3.00	2.17	0.11
	July	1.26	3.94	0.47	12.50	53.34	2.03	0.02
	Aug.	12.63	0.35	1.18	40.14	41.75	31.56	0.01
	Sept.	0.38	0.60	16.29	2.48	0.20	0.17	2.38
6	Feb.	1.06	1.18	0.43	2.03	2.05	2.43	0.47
	April	632.2*	53.1	43.1	0.01	0.01	0.04	1.87

Table 6.--(Continued)

Station	Month	Factor A =Night	 B =Direction	 C =Nets	AB	AC	BC	ABC
<u>Lagodon</u> <u>rhomboides</u>	(continued)							
	May	2.16	1.82	1.41	1.75	1.19	0.23	1.22
	July	0.17	0.06	0.50	18.82	7.11	0.37	0.20
	Aug.	4.44	0.17	0.51	87.83	5.17	140.67	0.02
	Sept.	11.62	1.81	3.69	0.38	0.00[1]	0.27	5.77
7	May	0.08	0.77	1.73	12.24	1.70	0.63	0.92
	Aug.	2.31	1.11	1.29	5.49	0.86	0.00[1]	1.11
<u>Bairdiella</u> <u>chrysura</u>								
5	June	0.78	1.30	0.81	1.49	6.27	2.60	0.11
6	July	7.21	4.19	13.13	58.50	8.10	0.78	0.01
	Aug.	2.49	0.14	0.29	0.29	4.10	7.19	1.07
7	May	3.12	0.16	2.16	1.00	0.22	5.33	0.20
	July	0.61	0.41	0.25	6.44	7.97	0.06	0.14
<u>Gobiosoma</u> <u>robustum</u>								
3	Nov.	7.65	1.00	14.19	1.00	0.23	0.04	0.67
	Feb.	13.36	0.47	1.10	70.47	1.63	10.73	0.01
4	Jan.	15.04	0.01	0.10	0.99	43.91	462.28*	0.00[1]
5	Nov.	162.53*	10.51	14.33	0.23	0.01	0.23	0.31
	Dec.	0.13	0.02	0.22	275.64*	484.37*	8.45	0.01
	Jan.	3.47	0.11	2.70	6.51	1.35	2.87	0.90
	Feb.	2.97	10.07	1.33	4.13	3.09	0.01	0.16
6	Dec.	44.72	10.38	11.75	0.04	0.16	0.20	1.73
	Jan.	1.80	0.41	4.50	1.88	0.15	1.01	3.43
	Feb.	4.61	0.00[1]	0.16	306.83*	302.53*	62.25	0.01
	Aug.	12.99	197.77*	10.96	0.00[1]	0.13	0.01	1.39
7	July	5.62	0.52	8.64	0.54	0.04	2.21	0.20

Table 6.--(Continued)

Station	Month	A =Night	B =Direction	Factor C =Nets	AB	AC	BC	ABC
<u>Gobiosoma robustum</u> (continued)								
	Aug.	25.98*	0.33	1.01	1.52	1.92	1.77	0.19
	Sept.	0.14	0.57	3.25	12.54	0.40	0.05	0.46
8	May[2]	11.90	1.12	17.31	1.13	0.04	0.10	0.26
<u>Lophogobius cyprinoides</u>								
5	Nov.	19.92	0.28	0.76	167.54*	68.37	799.11*	0.00[1]
	April	2.15	0.31	0.43	0.24	0.38	3.38	0.36
	July	1.17	2.72	1.14	1.39	1.35	0.09	0.60
<u>Microgobius gulosus</u>								
1	July	1.83	4.11	2.95	0.25	0.31	0.05	3.61
	Aug.	15.68	1.44	1.46	0.03	0.46	0.92	1.77
	Sept.	18.04	5.06	5.11	0.15	0.09	0.13	2.25
2	Aug.	2.67	2.00	0.33	0.26	2.35	0.93	1.78
3	July	1.07	0.12	0.28	5.30	0.60	3.53	0.25
	Aug.	0.06	0.16	0.21	62.08	26.40	6.55	0.04
4	Aug.	6.02	4.87	0.44	1.13	0.00[1]	2.35	0.31
7	Dec.	1.09	0.44	0.86	0.70	0.31	3.84	0.26
	Aug.	5.02	1.43	0.04	10.39	31.81	28.66	0.01
	Sept.	97.64	0.413	0.919	0.01	0.00[1]	10.43	0.20
8	Jan.	0.14	0.10	0.48	11.77	0.38	1.70	0.16
	Aug.	18.73	0.68	3.16	56.06	37.20	34.69	0.01
<u>Achirus lineatus</u>								
3	April	8.45	1.00	0.57	1.00	0.01	2.92	0.40
7	Nov.[2]	0.56	0.09	10.85	20.12	0.46	0.18	0.40
	Dec.	0.31	0.25	0.65	4.82	0.97	1.09	0.26
	Feb.[2]	15.69	92.24	0.59	.06	161.06	11.86	0.00[1]

Table 6.--(Continued)

Station	Month	A =Night	B =Direction	Factor C =Nets	AB	AC	BC	ABC
Symphurus plagiusa								
7	Feb.[2]	1.49	0.03	0.62	6.38	85.16	32.57	0.07
	July	0.27	0.15	1.99	6.66	0.76	1.78	0.43
	Aug.	6.38	0.11	1.24	20.23	0.41	4.32	0.11
8	Dec.[2]	0.10	0.32	0.04	19.41	24.61	4.27	0.15
	April	2.34	15.65	0.73	0.05	1.07	0.51	1.17
	July	0.94	1.09	0.26	0.51	5.79	2.60	0.35
	Aug.[2]	61.33	72.65	41.12*	0.01	0.03	0.03	0.78
	Sept.	0.96	1.70	0.01	75.12	448.29*	14.57	0.00[1]

[1] Less than .01

[2] Tidal stage(s) uncertain

* Significant at P≤ .05

** Significant at P≤ .01

by other variables. The remainder of this investigation will be concerned with isolation of these factors and study of their relative influence in determining the areal and seasonal differences observed.

Differences in Catch Rates Among Stations

As indicated in the preceding sections, use of Anscombe's (1948) logarithmic transform on monthly catch data by species and station usually resulted in homogeneity of variance. For every species, however, variances were found to fluctuate so widely between different areas and seasons that use of parametric procedures on transformed data appeared to be futile. Consequently, non-parametric methods were employed to test the null hypothesis of no differences in catch rates in such cases.

In this phase of the study, ten of the most common species were used, selection being dependent both on abundance and on extent of distribution throughout the study area. As occasional delays between nights could have biased total mean catch rates due to differences in population recovery time between stations, only data from the first night's trawling were used. Means were tabulated by station for the December 1968 to November 1969 period and tested for differences in catch rates using Friedman's two-way analysis of variance. The results of these tests are given in Table 7.

It is obvious that areal differences did exist for these species; tests were in most cases highly significant ($P \leq .01$). The results observed appear to be primarily attributable to differences in salinity, vegetation density, and substrate conditions. These factors are, however, closely interrelated, for the distribution and density of

Table 7. Friedman's two way analysis of variance comparisons of the mean catch per tow (Night 1) of 10 species and total number of species among stations, December 1968 to November 1969.

Species	Average catch taken on station								Friedman's	
	1	2	3	4	5	6	7	8	χ_r^2	df
Opsanus beta	0.04	0.03	0.39	0.17	2.31	1.93	0.80	0.39	41.32**	7
Sygnathus scovelli	--	--	0.37	0.21	0.09	0.36	5.97	0.29	12.98**	5
Eucinostomus gula	0.67	0.26	6.45	6.25	20.07	7.66	63.54	1.92	91.01**	7
Orthopristis chrysopterus	--	--	0.17	0.56	4.16	6.13	2.95	0.32	30.80**	5
Lagodon rhomboides	0.05	0.05	2.95	2.54	27.33	52.19	11.53	0.70	68.56**	7
Bairdiella chrysura	0.01	0.03	0.92	0.10	2.08	1.79	1.34	0.15	23.73**	7
Gobiosoma robustum	0.06	0.07	1.18	1.57	3.43	7.36	4.45	1.92	38.05**	7
Microgobius gulosus	4.44	5.25	4.10	1.76	0.17	0.03	2.94	1.86	53.83**	7
Achirus lineatus	0.05	0.07	0.46	0.32	0.51	0.74	3.69	0.58	52.69**	7
Symphurus plagiusa	0.07	0.07	0.04	0.14	0.24	0.61	4.14	8.01	55.81**	7
Mean No. of Species	1.27	1.15	1.61	1.68	2.58	2.56	3.36	2.70	67.05**	7

* Significant at $P \leq .05$

** Significant at $P \leq .01$

Udotea sp. has been found to be dependent upon salinity (Tabb et al., 1962) while the uptake of carbon dioxide by these plants would lead to increased precipitation of calcium carbonate in areas of high vegetation density. Consequently, it is difficult to assess the relative importance of these factors in determining the areal distributions of the species considered.

The evidence available, however, suggests that differences in vegetation density were primarily responsible for the results observed. Inspection of mean catches by station (Table 7) reveals that most of the species tested reached their highest levels of abundance on Stations 5-7, where vegetation density was greatest. The two exceptions to this rule, Microgobius gulosus and Symphurus plagiusa, apparently responded more closely to factors other than vegetation density; Birdsong (1969) has noted that the former species is a burrower and suggested that sediment particle size is a factor of importance in its distribution. Local variation in abundance of Symphurus plagiusa, on the other hand, may have been determined by salinity, substrate conditions, or some interaction between them.

It might be argued that salinity gradients could have also been significant in determining the areal distributions of the remaining species. This is in fact possible for Achirus lineatus and Syngnathus scovelli, both of which were more common in higher salinity areas. The remaining fishes, however, were much more abundant on Stations 5 and 6 than on Stations 3 and 4 from June to November, and as the average recorded salinity difference between these areas was only 2.2^{o}/oo during this period it is highly improbable that salinity was the controlling factor, particularly when one considers the ranges of salinity tolerance exhibited by estuarine fishes. Similarly, Achirus lineatus and Syngnathus scovelli were captured much more frequently on Station 7 than on Station 8.

The possibility for a salinity induced seaward movement with increased size should also be considered; indications have been found (Pearse and Gunter, 1957) of a correlation between size and salinity gradients. Some evidence of such a trend was noted in the present study, but its importance appears to have been minor in most cases. The point is discussed further under Size Frequency Distributions.

It should be noted that local differences in catch rates did exist that cannot be explaned in terms of vegetation density. Although Station 5 was found to support denser stands of vegetation than Station 6 (Appendix II) catches of Lagodon rhomboides and Gobiosoma robustum appeared to be consistently higher at the latter station. This could result from a preference for deeper water on the part of these fishes; length frequency distributions for Lagodon rhomboides do indicate that larger individuals were primarily restricted to deeper areas in winter months (Figure 7). For Gobiosoma robustum, differences in current action may have also been responsible for the difference observed; the significant interactions between night and tow direction in earlier analysis of variance testing for this species would appear to indicate that differences in current action between stations could have influenced the observed catch rates.

For the entire study, however, mean catches usually appeared to be similar at adjacent stations or higher on shallow stations where vegetation density was greatest. It was, therefore, impossible to determine the relative influence of these factors, but it is probable that they are inter-related in that vegetation density may be expected to be a function of depth due to light penetration differences.

A similar analysis was also conducted to determine if differences existed in the mean number of species captured among areas during the December 1968 - November 1969 period (Table 7). Again, the results proved to be significant ($P \leq .01$). The data reveal a general trend of increasing numbers of species proceeding westward into higher salinity areas, apparently reflecting both a tendency for incidental entry to the estuary by marine forms and a tendency towards increased abundance of fishes in the more densely vegetated areas. The influence of vegetation is particularly evident for data on Stations 7 and 8, in which the mean number of species drops sharply between these stations (Table 7) although salinities remain relatively constant (Appendix I).

In summary, differences in vegetation density, modified to some extent by salinity, bottom type and other variables, appeared to be the primary factor determining the species distributions observed. The following section will consider the influence of salinity induced movements resulting from growth and seasonal temperature changes.

Size Frequency Distributions

Considerable evidence has accumulated indicating a correlation between size distributions of juvenile fishes and salinity in estuarine situations (Gunter, 1945, 1956; Pearse and Gunter, 1957). Although other factors may be involved, such trends apparently result primarily from physiological influences; the point has been made (Keys, *in* Pearse and Gunter, 1957) that smaller individuals of a given species are able to osmoregulate better due to their higher metabolic rate. Thus, an increase in mean size should occur moving from low to high salinity areas.

To determine if seaward movements with increased size could have influenced the areal distributions observed, size frequency diagrams were prepared for six of the more common fishes by station and month, using catch data for vegetated areas. Data for the December 1968 to November 1969 period were used except in the case of Bairdiella chrysura, where only the May to October period of maximum abundance was considered. Selection of species was based both on abundance and extent of distribution throughout the estuary; all measurements for a given station and month were included unless the total number exceeded 250, in which case a subsample of 250 observations was used.

The gulf toadfish (Opsanus beta) was found to be recruited primarily during the summer although the numbers involved were not large. Tabb and Manning (1961) believed this species to spawn inshore during summer and fall in the Florida Bay area. Examination of the size frequency distributions for this species reveals no consistent differences among stations that would indicate a movement towards higher salinity areas with increased size (Figure 4).

Juveniles of Eucinostomus gula under 20 mm in size were taken from May to January, with an apparent peak occurring in the May to July period (Figure 5). Reid (1954) reported an almost identical recruitment period at Cedar Key, while Tabb and Manning (1961) found a peak of abundance from September to November.

Throughout the present study, there appeared to be a consistent size difference between individuals caught on Station 7 and those taken on the lower salinity stations; this was evidenced by a slight,

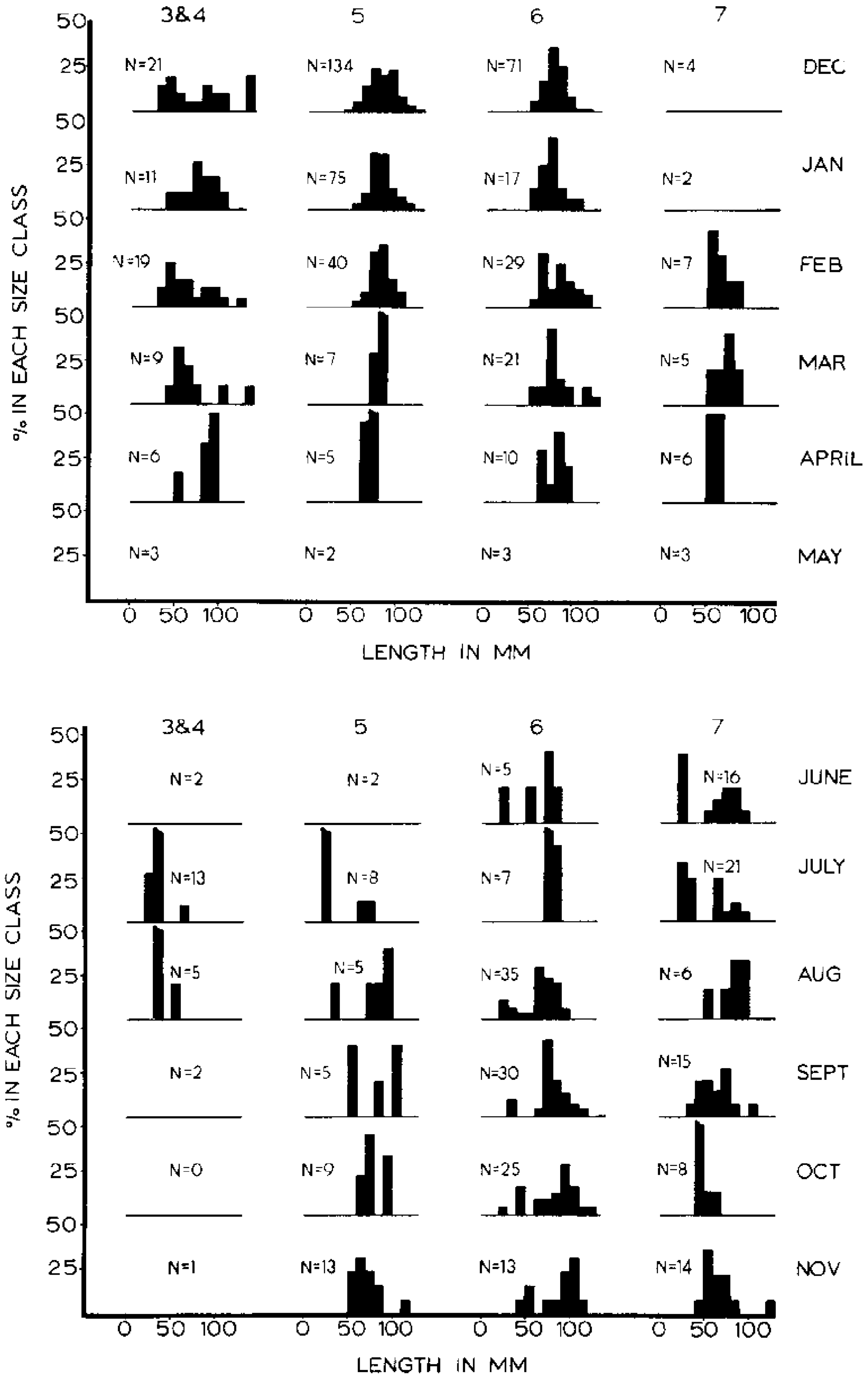

Figure 4. Size frequency distributions of *Opsanus beta* for Stations 3-7, collected from December 1968 to November 1969.

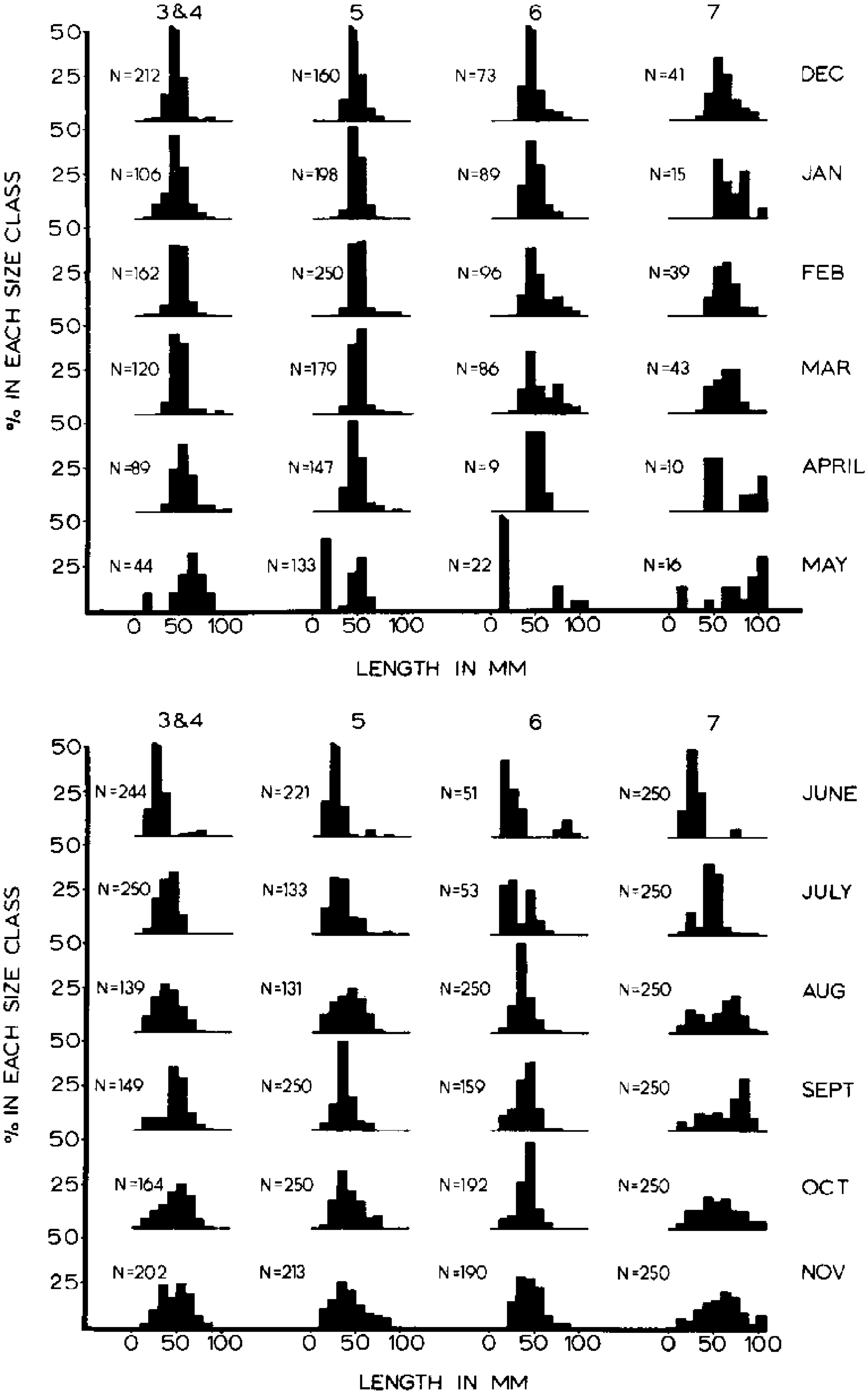

Figure 5. Size frequency distributions of *Eucinostomus gula* for Stations 3-7, collected from December 1968 to November 1969.

but regular, increase in modal size between these areas in the post recruitment period and higher percentages of larger individuals on Station 7 from August to November (Figure 5). Thus, there is some evidence that areal distributions of Eucinostomus gula were influenced by seaward movements associated with increased size, particularly in late summer and fall; Springer and Woodburn (1960) observed a similar movement for this species in the Tampa Bay area, which they attributed to seasonal effects. As the total number involved was appreciable, it would appear that this factor is in part responsible for the high populations observed on Station 7 during the warm months, when 98 percent of the total catch at this station was taken. The influence of vegetation is therefore less clear in this case, although as marked vegetation density increases occurred on Station 7 at this time (Appendix II) it is quite possible that this factor was also important in determining the high catch rates observed in this area.

Spawning in Orthopristis chrysopterus has been reported to occur during spring at Beaufort (Hildebrand and Cable, 1930); Reid (1954) and Gunter (1945) have noted it to be most abundant in Gulf coast estuaries during summer. Tabb and Manning (1961) collected juveniles of this species in western Whitewater Bay during the July to October period; in the present study, juveniles under 20 mm in length entered Whitewater Bay from January to May, with the bulk of recruitment occurring from February to April (Figure 6). Hildebrand and Cable (1930) noted an offshore movement of this species to occur in fall at Beaufort; this also appeared to be true for Whitewater Bay.

During this study, few differences were observed in the size

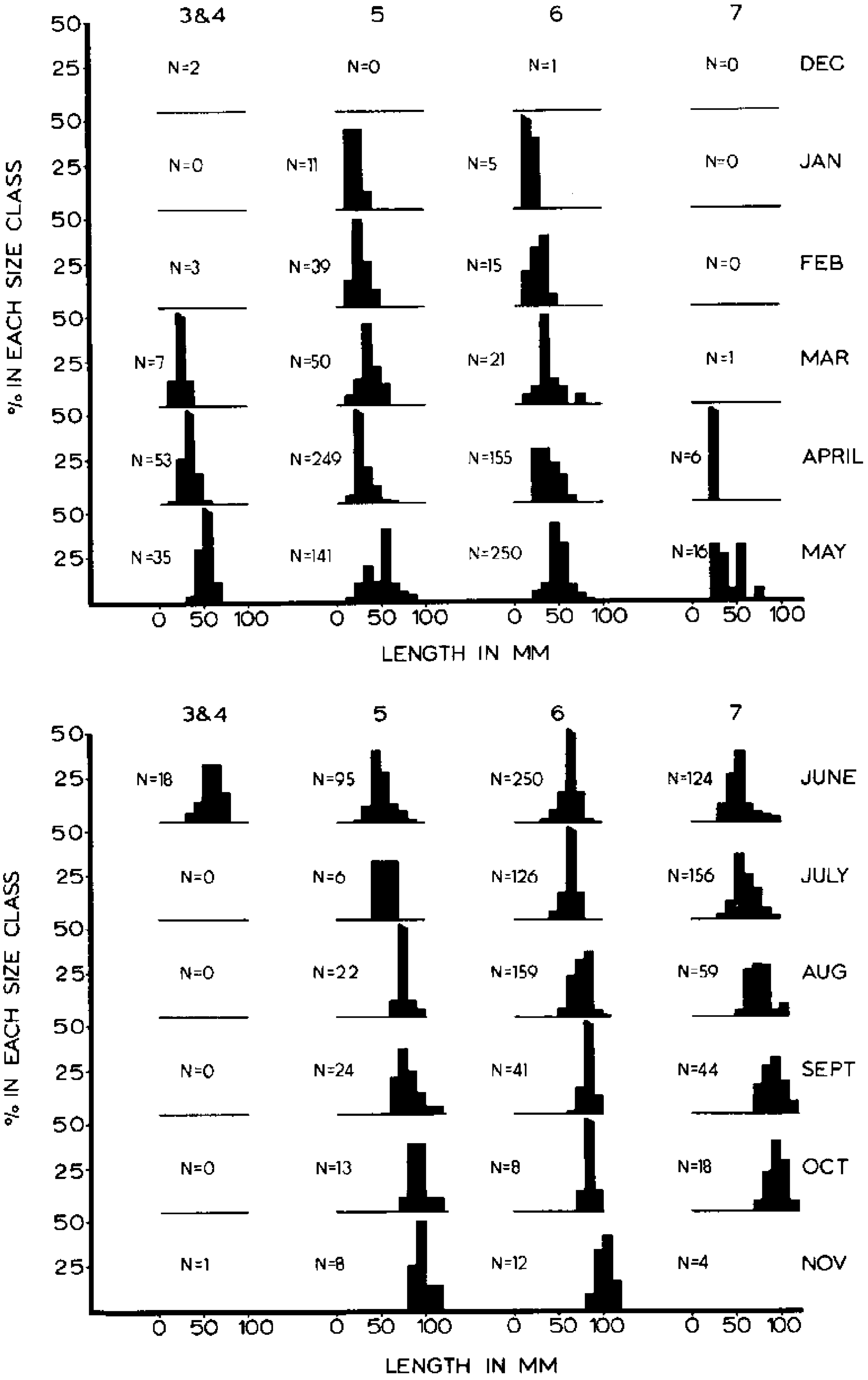

Figure 6. Size frequency distributions of Orthopristis chrysopterus for Stations 3-7, collected from December 1968 to November 1969.

frequency distributions of this species among stations, although Station 7 appeared to have a slightly higher proportion of larger fishes in summer. The percentage of the total population involved appeared to be small, however, indicating that seaward movements were of minor importance in determining the population differences observed among areas.

Spawning in <u>Lagodon rhomboides</u> occurs offshore in late fall and winter (Caldwell, 1957; Springer and Woodburn, 1960). Hildebrand and Cable (1938) reported that a peak of recruitment of 10 mm fish occurred at Beaufort in December and January, when juveniles entered sounds and bays and occupied vegetated areas. Fall offshore movements have been noted for this species by Gunter (1945), Joseph and Yerger (1956) and Caldwell (1957).

In the present study, recruitment of 20 mm individuals occurred from December to June, with a peak influx in January (Figure 7). Tabb and Manning (1961), however, reported that the smallest individuals of this species were captured in March and April. The seasonal decline referred to above was also evident; progressively lower catches occurred in late summer and early fall.

Examination of the size frequency distributions for this species reveals two noteworthy trends, which are (1) a tendency for larger individuals to occur at deep rather than shallow stations during winter (the larger individuals at Stations 3 and 4 were caught primarily at the latter station) and (2) a tendency towards increased average size in higher salinity areas, noted between Station 7 and the remaining lower salinity areas (Figure 7) during the July to November period. Thus, this species also gives some evidence of movement to higher

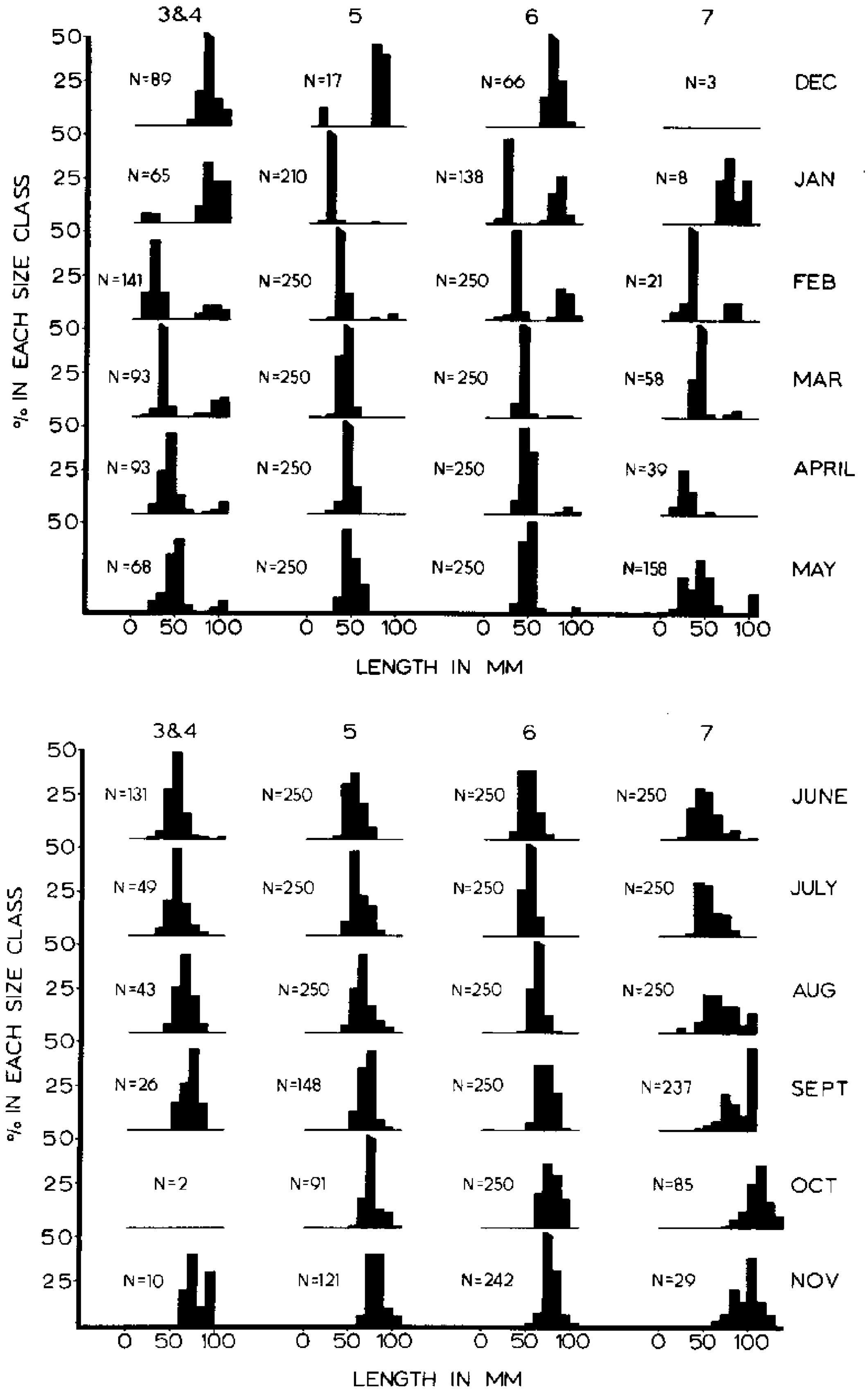

Figure 7. Size frequency distributions of *Lagodon rhomboides* for Stations 3-7, collected from December 1968 to November 1969.

salinity areas with increased size. As the proportion of the total catch involved in these trends was small, however, it is apparent that vegetation density was the most important factor controlling the areal distribution of *Lagodon rhomboides*, at least during most of the study (see Appendix III). Caldwell (1957) reported vegetation density to be the most important ecological factor in the distribution of this species and believed it to be indifferent to salinity.

The tendency for larger individuals to occur primarily in deeper areas was not observed for other species during this study. As this pattern occurred primarily during the cooler months, it is possible that these data represent a restriction of 1 year class individuals to deeper water by temperature influences. However, Caldwell (1957) reported that larger individuals of this species were found at greater depths.

The data for *Bairdiella chrysura* indicate that recruitment occurred from February to October with a peak in May and June. Tabb and Manning (1961) reported that juveniles were abundant in the Florida Bay area from March to June, while Reid (1954) noted it to be most abundant during warmer months. During the period of study, no evidence was found to indicate that salinity-induced movements influenced the areal differences in catch rates observed for this species (Figure 8).

Recruitment of *Gobiosoma robustum* occurred primarily in summer (Figure 9). The spawning season may be quite variable between different areas, however, as Springer and Woodburn (1960) found ripe individuals in Tampa Bay from November to May, while Reid (1954) reported both winter and summer spawning peaks at Cedar Key.

Again, there was some indication of increased size with increasing

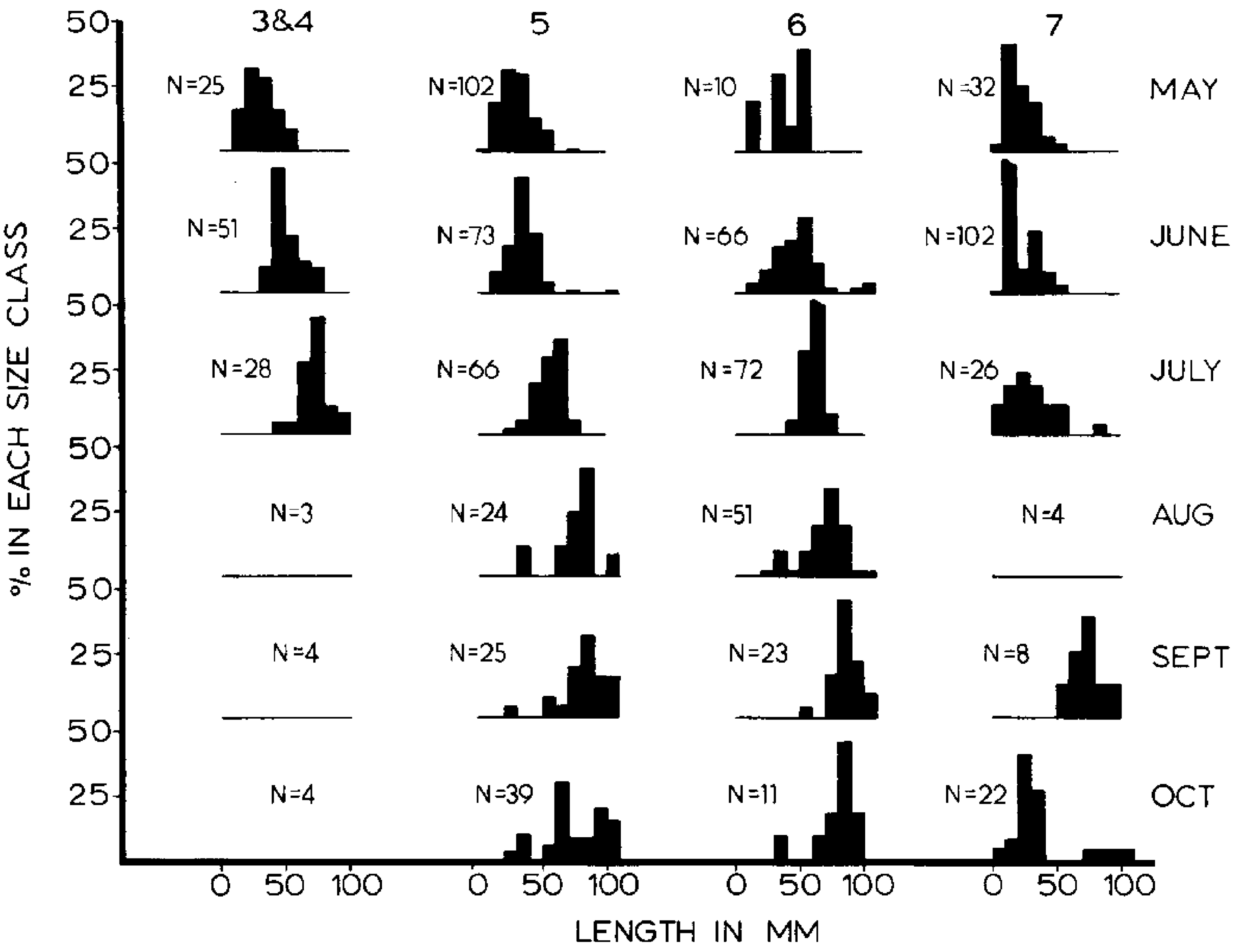

Figure 8. Size frequency distributions of Bairdiella chrysura for Stations 3-7, collected from May to October 1969.

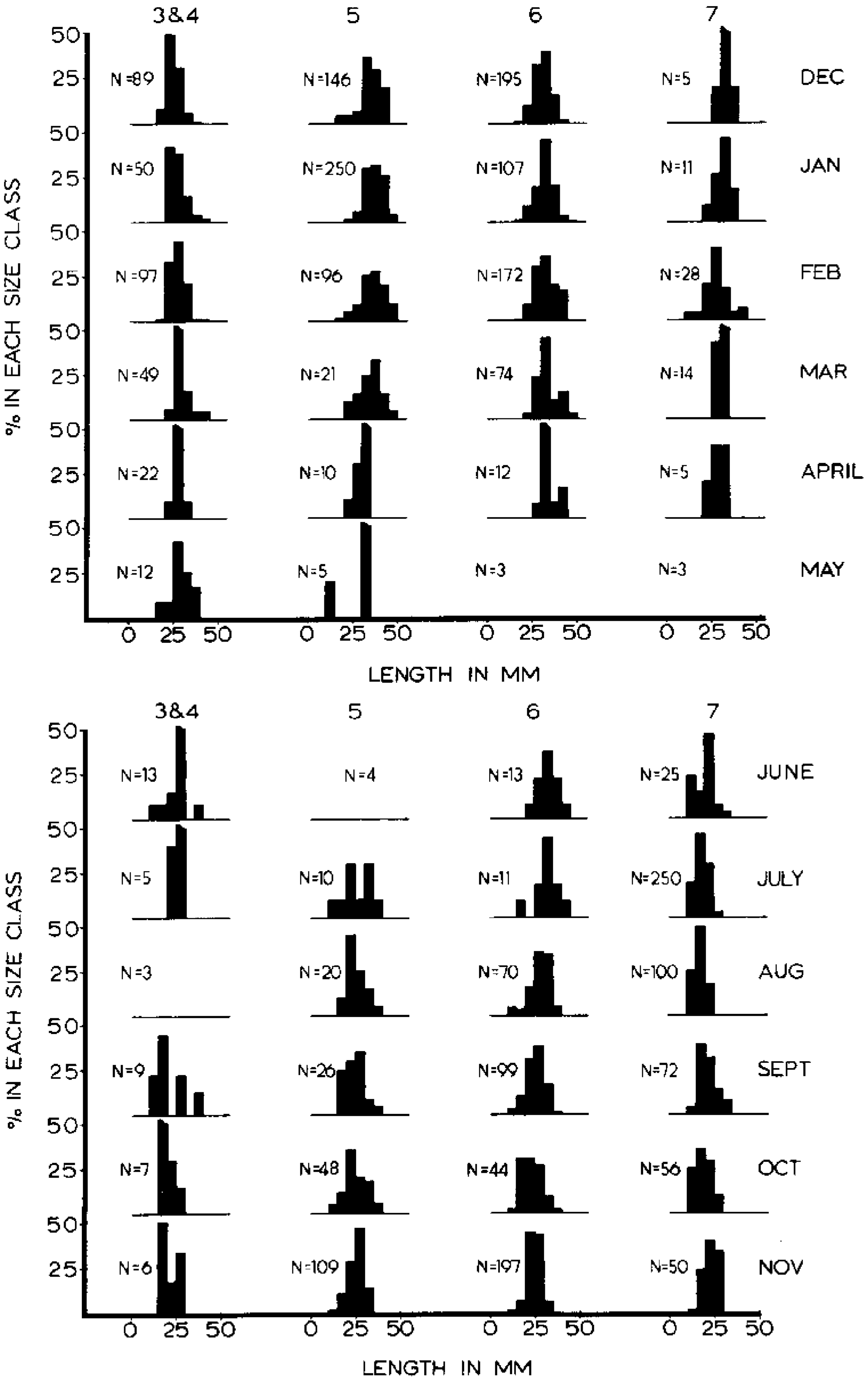

Figure 9. Size frequency distributions of <u>Gobiosoma robustum</u> for Stations 3-7, collected from December 1968 to November 1969.

salinity but in this case the evidence appears to be less clear. An increase in modal size is evident in winter and spring between the more inshore stations and Stations 5 and 6, but the differences observed were usually minor. During the remainder of the year, size frequency distributions appeared to be similar on all stations, with a slight decrease in modal size on Station 7 due apparently to increased recruitment (Figure 9). Thus, the results for this species must be regarded as inconclusive. It is possible that the increased modal sizes observed on Stations 5 and 6 are attributable to salinity influences, however.

To summarize, 3 of the 6 species considered in this analysis gave some indication of a salinity induced movement associated with increasing size. In the present investigation, such movements appear to have been of significance in determining the population increases of *Eucinostomus gula* and *Lagodon rhomboides* on Station 7 during summer and fall. For the study as a whole, however, the conclusion that vegetation density was the most important factor influencing the observed areal distributions remains unchanged.

It should be noted that as the physiological influence of salinity is strongly dependent upon temperature effects (Kinne, 1963) salinity-induced movements may be of major significance in determining seasonal population declines of estuarine fish populations; Pearse and Gunter (1957) believed the phenomenon to be in large measure temperature dependent. The point is discussed further in the following section.

Seasonal Fluctuations in Abundance

In addition to the population differences observed between areas, seasonal changes in catch rates were also evident. To determine the extent of such changes, the null hypothesis of no differences in catch rates among months was tested for the species considered in the preceding section, again using Friedman's two-way analysis of variance. Results are given in Table 8.

It is readily apparent that seasonal variations in abundance did occur for these fishes; the differences observed appeared to result primarily from recruitment peaks during the warmer months and from a seasonal offshore movement in winter. As indicated under *Size Frequency Distributions*, *Opsanus beta*, *Eucinostomus gula*, *Bairdiella chrysura*, and *Gobiosoma robustum* were recruited primarily in late spring and summer while *Orthopristis chrysopterus* and *Lagodon rhomboides* showed earlier peaks. Juveniles of *Syngnathus scovelli* were taken most frequently in summer, as were those of *Microgobius gulosus*. In the case of *Achirus lineatus*, however, spawning occurred in early fall, and small individuals were most common during fall and winter; Tabb and Manning (1961) observed a similar period of juvenile abundance for this species. As the seasonal peaks coincide with periods of maximum recruitment, the differences observed would appear to result both from population increases associated with seasonal influxes of juveniles and later declines due to offshore movement, mortality, or other factors. The lack of a significant difference in the data for *Symphurus plagiusa* is believed to result both from a long spawning season and from an apparent tendency to remain inshore during winter; juveniles of this species under 20 mm were common during summer and fall, and post recruitment catch rates did not decline to the extent noted for the remaining fishes considered (Table 1).

Table 8. Results of Friedman's two-way analysis of variance comparisons of the mean catch per tow (Night 1) of 10 selected species among months, December 1968 to November 1969.

Species	Average catch taken in				Friedman's
	W[1]	Sp	Su	F	χ_r^2[2]
Opsanus beta	1.71	0.28	0.51	0.57	22.28*
Syngnathus scovelli	0.05	0.16	2.97	0.58	27.22**
Eucinostomus gula	5.01	2.53	24.75	21.11	23.52**
Orthopristis chrysopterus	0.28	2.92	3.38	0.57	25.14**
Lagodon rhomboides	5.42	16.38	21.11	5.74	23.76*
Bairdiella chrysura	0.05	0.47	2.10	0.58	30.00**
Gobiosoma robustum	4.48	1.16	2.33	2.04	21.25*
Microgobius gulosus	1.69	0.70	5.30	2.59	31.09**
Achirus lineatus	1.42	0.77	0.43	0.57	24.10*
Symphurus plagiusa	1.76	1.12	2.75	1.03	8.68 ns

[1] W = winter, Sp = spring, Su = summer, and F = fall.

[2] With 11 df

* Significant at $P \leq .05$

** Significant at $P \leq .01$

Although not evaluated statistically, most of the other species observed showed pronounced seasonal peaks of abundance. Juvenile Louisiana pipefish (*Syngnathus louisianae*) were most common during summer, as were those of *Archosargus probatocephalus* and *Cynoscion nebulosus*. Sea catfish (*Arius felis*), snappers (*Lutjanus griseus* and *L. synagris*), spotfin mojarra (*Eucinostomus argenteus*) and bluestriped grunt (*Haemulon sciurus*) were recruited primarily in early fall. Fishes with more extended warm weather recruitment periods included *Anchoa mitchilli* and *Synodus foetens*; juvenile leopard searobins (*Prionotus scitulus*), gulf flounders (*Paralichthys albigutta*) and hogchokers (*Trinectes maculatus*) were caught primarily in late winter and spring. Wherever sample sizes were adequate for comparative purposes, the results observed agree with those of Tabb and Manning (1961) and Roessler (1967) for the same area.

Other seasonal influences were evident in isolated cases. The summer peak of abundance noted for the rainwater fish (*Lucania parva*) may have resulted both from juvenile recruitment and from movement from lower salinity areas associated with seasonal salinity changes. Similarly, the unusually high catch rates observed for *Lophogobius cyprinoides* in the fall of 1968 (Table 1) may have resulted from movement associated with seasonal oxygen depletions or other adverse conditions in low salinity zones, as few of the individuals captured were juveniles. Odum (1970) reported this species to be abundant in the North River area, but it was uncommon on most of the stations sampled in Whitewater Bay.

Thus, most of the more common species showed a warm-weather peak of abundance followed by a later seasonal decline. The remaining species observed in this study were either captured incidentally or in numbers too limited to accurately determine seasonal trends.

A similar analysis was conducted for differences in mean number of species among months, again using the December 1968 to November 1969 period. This also proved to be significant at $P \leq .05$ ($\chi_r^2 = 20.17$ with 11 df). Differences appeared to result both from increased numbers of species in warmer months and from a seasonal decline in cooler weather (Figure 10).

Further examination of the data reveals that the majority of the "incidental" species were also captured primarily in warmer months. For the most part, these fishes were also juveniles; the most numerous of these included the striped anchovy (Anchoa hepsetus), the scaled sardine (Harengula pensacolae), the Atlantic thread herring (Opisthonema oglinum), the rough silverside (Membras vagrans), the planehead filefish (Stephanolepis hispidus) and the striped burrfish (Chilomycterus schoepfi). Again, these observations agree with those of Roessler (1967) for the same area. A total of 23 "incidental" species were captured primarily in this period as opposed to seven during the remainder of the year, and of the latter group only one species, the speckled worm eel (Myrophis punctatus) occurred in any abundance. It therefore appears that the results of this test are also associated with juvenile recruitment and later mortality or offshore movement.

Thus, most of the fishes studied appear to conform to the cycle described by Gunter (1945) involving offshore spawning, migration by juveniles to estuarine areas of low salinity, and offshore movement with approaching maturity. It is therefore obvious that any study of seasonal changes in the population levels of estuarine fishes must

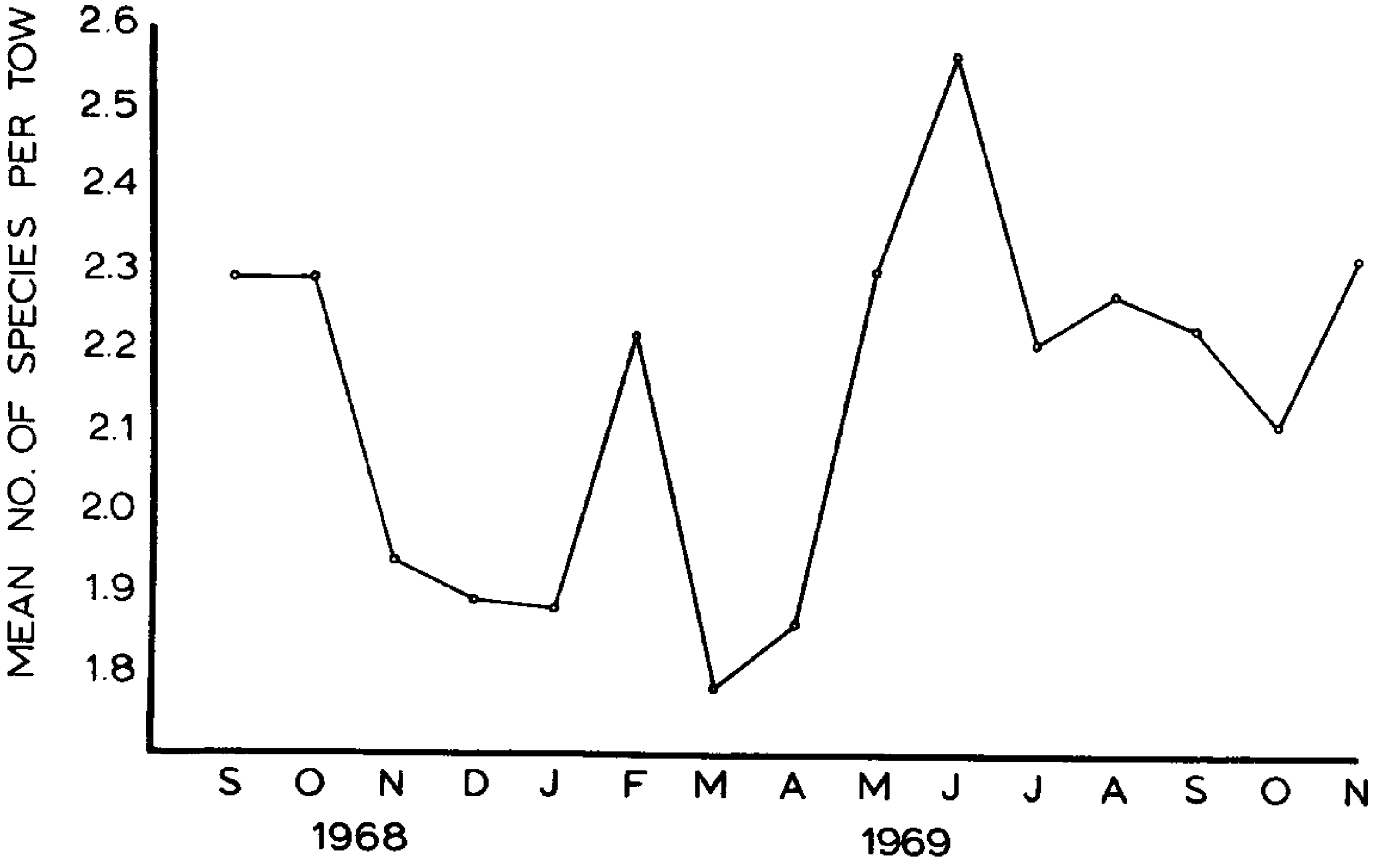

Figure 10. Mean number of species captured monthly in Whitewater Bay, September 1968 to November 1969.

consider factors influencing both spawning success and recruitment as well as inherent physiological mechanisms governing seasonal movements which may have little relation to changes in environmental variables measured on the study area. In this connection, it is uncertain to what extent seaward movements with increased size referred to under <u>Size Frequency Distributions</u> are influenced by innate behavior associated with the life cycle, although the physiological influence of salinity appears to be the predominating factor (Pearse and Gunter, 1957). Therefore, study of environmental variables on the nursery grounds can be expected to yield only tentative conclusions relative to population level changes in such areas.

The complexity of the problem is increased by the interaction of the environmental variables themselves. Low salinities undoubtedly enhance the value of estuarine areas as nursery grounds for juvenile fishes by excluding many marine predators; Gunter <u>et al</u>. (1964: 181) have stated that "...there is a great deal of evidence that salinity rather sharply limits the distribution of most marine organisms, especially as it varies downward." However, this factor is largely dependent upon temperature; Pannikar (1951, <u>in</u> Hedgpeth, 1957) has suggested that the increased richness of faunas in subtropical estuaries as opposed to those in higher latitudes may be correlated with an increased osmoregulatory capacity at higher temperatures. Seasonal movements seaward with cooler temperatures would also appear to result at least in part from temperature and salinity interactions as suggested by Pearse and Gunter (1957). The importance of these inter-relationships has been further noted by Kinne (1963) who stated that the biological effects of temperature and salinity are correlated in a very complex manner and that either variable may modify the effects of the other.

A number of other environmental variables could have affected the results observed. In addition to seasonal variations in temperature and salinity, Whitewater Bay is also subject to seasonal changes in local rainfall and influx of runoff from the Everglades to the north. The last three variables are obviously inter-related, although runoff, rather than local rainfall, appears to be the controlling influence in determining salinities in Whitewater Bay (Tabb, 1967). Both runoff and local rainfall are undoubtedly of importance in washing detrital material from mangrove swamps and marshes into the bay, where it is then incorporated into the food chains of juvenile fishes or may even be used directly.

The data of Appendix II also suggests that vegetation density may vary seasonally due to reproduction or natural mortality; in addition, low salinities may adversely affect _Udotea_ by causing partial or complete fragmentation of the thalli (Tabb _et_ _al_., 1962). Either of these factors could affect catch rates. In the present study, the latter condition was evidenced by discoloration of the tips of the thalli in the Clearwater Pass area during a brief period in summer, but its influence upon cover conditions appeared to be negligible. Consequently, salinity effects on vegetation were not considered in the following analysis.

In order to determine if direct relationships could be demonstrated between the above factors and catch rates, a multiple regression analysis was performed for seasonal catch data on Stations 5 and 6 using five independent variables: salinity, temperature, mean vegetation density (transformed to logarithms), local rainfall (in the month prior to sampling) and runoff into the estuary. Local precipitation data was obtained from U. S. Weather Bureau records for the Flamingo area, while runoff into the Bay was approximated using U. S. Geological Survey ground water level data at Well P-38 in the Whitewater Bay watershed 37 days prior to sampling. Tabb (1967) reported a lag period of this duration between this well and the Clearwater Pass area, in which Stations 5 and 6 were located.

Simple linear correlation analyses between these variables indicated that significant ($P \leq .01$) inverse relationships existed between runoff and salinity for both Stations 5 and 6 during the period of study; also, a strong positive correlation ($P \leq .01$) was found between temperature and algal density on Station 5, probably reflecting seasonal trends of increased reproduction and growth in summer. Thus, partial correlation or regression techniques were required to assess the relative importance of the factors considered. The actual procedure used involved a stepwise reduction of the variation in catch rates (Y) by successive addition of the independent variables in their order of importance, thus allowing successive estimates of the relative influence of each variable or any combination of variables in contributing to the total variation observed. The significance of each was determined by use of F-values obtained by dividing the sum of squares of the regression coefficient by the residual sum of squares with k and n-k-1 degrees of freedom, k being the number of independent variables and n being the number of observations. Results of these tests are given in Table 9.

In all cases, runoff and temperature were found to account for the greatest amount of the total variation in Y; salinity, vegetation changes,

Table 9. Results of stepwise regression tests of the influence of five environmental variables on catch rates for five species at Stations 5 and 6, February to November 1969.

Species	Variable	Slope	R	R^2	F value
Opsanus beta[1]	Runoff	-1.014	.38	.14	1.34
	Temperature	-0.169	.57	.33	1.70
	Vegetation	5.842	.66	.44	1.62
	Precipitation	-0.141	.69	.47	1.14
	Salinity	-0.161	.75	.57	1.08
Eucinostomus gula[2]	Runoff	14.824	.40	.16	1.53
	Temperature	0.279	.41	.17	0.71
	Precipitation	-0.363	.42	.18	0.43
	Vegetation	13.629	.43	.18	0.27
Orthopristis chrysopterus	Runoff	-6.312	.54	.29	3.34
	Temperature	0.852	.72	.52	3.83
	Precipitation	0.508	.74	.56	2.54
	Salinity	0.256	.75	.57	1.68
	Vegetation	5.323	.76	.58	1.08
Lagodon rhomboides	Runoff	-90.348	.67	.44	6.51*
	Temperature	2.190	.84	.72	9.01*
	Salinity	-3.632	.87	.77	6.82*
	Vegetation	79.355	.89	.80	5.05
	Precipitation	-0.775	.89	.80	3.30
Gobiosoma robustum	Temperature	-1.592	.76	.58	11.20**
	Runoff	-0.751	.88	.78	12.37**
	Vegetation	29.446	.94	.88	14.81**
	Salinity	-0.539	.95	.90	12.59**
	Precipitation	-0.214	.95	.91	8.84**

[1] All tests were made using Station 6 data except in the case of *Eucinostomus gula*, which was tested using data for Station 5.

[2] Salinity was deleted due to its low contribution to R^2.

* Significant at $P \leq .05$

** Significant at $P \leq .01$

and local rainfall were found to contribute very little to reduction in total sum of squares. Runoff was usually the more important of the two although the relation was found to be inverse for *Opsanus beta*, *Orthopristis chrysopterus* and *Lagodon rhomboides*. As salinity appeared to contribute little to the variation explained by these equations and also appeared to be of minor importance in determining the areal distributions observed in this study, it is believed that these results are merely a reflection of increased recruitment during periods of low runoff, as a valid relation between runoff and catch rates should be a direct one as suggested above. Similarly, the importance of temperature can undoubtedly be explained in similar fashion, as species showing an inverse relationship (*Opsanus beta* and *Gobiosoma robustum*) were most common in this area during winter; peaks of abundance for the remaining species occurred in spring and summer. Thus, it is believed that the gross changes observed were primarily due to the overriding influences of the life cycles of these species and were not dependent to any appreciable extent upon the environmental factors measured, except possibly in fall when declining temperatures may have induced a seaward movement.

Roessler (1967) conducted a multiple correlation analysis of the effects of environmental variables on catch rates in Buttonwood Canal and concluded that rainfall (i.e., runoff) and season were most important. Thus, his results are in agreement with those of the present study. Waldinger (1968) used multiple correlation and regression techniques in a similar analysis involving three species of mojarras (Gerridae) and found runoff and temperature to be of importance. The total variation attributed to the environmental parameters used in Waldinger's study was low, however, ranging from 11 to 48 percent.

SUMMARY AND CONCLUSIONS

During the period from September 1968 to November 1969, a study of juvenile fish populations was conducted in Whitewater Bay, Florida. The objectives of this investigation were to study factors determining species distributions within the estuary and to assess the variation in the observed catch rates and the nature of the underlying data distributions.

A total of 68 species representing 36 families and 14 orders were collected during this study. The bulk of the catch was accounted for by two species, *Eucinostomus gula* and *Lagodon rhomboides*, which contributed 34.9 and 27.7 percent of the total respectively. The 12 most abundant fishes contributed 94.6 percent of the total catch; these represented the families Batrachoididae, Syngnathidae, Lutjanidae, Gerridae, Pomadasyidae, Sparidae, Sciaenidae, Gobiidae, Soleidae, and Cynoglossidae.

Data for 15 of the more common species were tested for agreement with the negative bionomial distribution. At low population densities, these usually approximated the Poisson series, but where contagion was evident the agreement was usually found to be good. Very infrequently, evidence was found that such data conformed to some other pattern; these cases were usually associated with bimodality, some degree of randomness, or skewness. The apparent tendency of species catch data to follow the negative bionomial has also been observed in earlier studies. However, the distribution of species per tow showed only partial agreement with the Poisson form of distribution, while the total data for all species did not conform to Fisher's logarithmic series in all cases tested; such results have not been observed by previous investigators.

Tests of two transformations applicable to contagiously distributed data revealed Anscombe's logarithmic transform employing the negative bionomial statistic k to be more effective than Taylor's procedure in stabilizing the variance and reducing skewness. This transformation was used in all subsequent parametric analysis of variance tests.

Catch data for 12 species were tested by factorial analysis of variance to determine the effects of nights (including tides), tow direction, and nets on the observed catch rates. Differences between nights, and some suggestion of interactions between nights and tow direction and nights and nets, appeared to exist for Eucinostomus gula and Gobiosoma robustum. For the study as a whole, however, the influence of the factors tested appeared to be negligible.

Friedman's two way analysis of variance was used for comparisons of catch rates among stations. For all fishes tested, significant differences ($P \leq .05$) were observed; these could usually be attributed primarily to differences in vegetation density. A similar test for differences in mean number of species captured among stations was also significant ($P \leq .01$) and appeared to result both from vegetation differences and from increased richness of the fauna in higher salinity areas.

Earlier investigators have shown that the distribution of juvenile fishes in estuaries may be affected by salinity-induced movements to more optimum areas with increased size. To determine if such movements could have influenced the areal differences observed in the present study, size frequency distributions were prepared for six of the more common species; these were examined for monthly differences among stations. A definite trend of increasing size proceeding towards higher salinity areas was observed for three of these fishes, indicating a seaward movement which appeared to be of importance in determining the late summer and early fall distributions of *Eucinostomus gula* and *Lagodon rhomboides*. For the study as a whole, however, the influence of this factor appears to have been minor compared with that of vegetation.

Tests for seasonal changes in catch rates using Friedman's two-way analysis of variance were usually significant ($P \leq .05$). The differences observed appeared to result from population increases due to recruitment and later declines due to seasonal movement, mortality or other factors. There appeared to be little if any relation between seasonal catch rates and changes in environmental factors measured on the study area.

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APPENDICES

Appendix I. Average bottom salinities, temperatures, and dissolved oxygen concentrations recorded for eight sampling stations, Whitewater Bay, September 1968 to November 1969.

Salinity $^{o}/oo$

Month	Station no. 1	2	3	4	5	6	7	8	$\bar{x}$
September 68	5.3	6.5	4.9	4.5	8.1	6.1	14.9	18.5	8.6
October	4.5	4.1	3.3	3.7	4.9	4.1	11.7	14.9	6.4
November	2.9	3.7	3.3	3.7	5.7	5.7	13.7	16.1	6.9
December	4.9	4.9	5.3	4.5	10.5	8.9	19.3	18.9	9.7
January 69	6.7	6.7	7.7	6.5	13.1	13.7	18.9	18.9	11.5
February	9.7	9.7	10.1	9.3	19.7	20.1	26.1	27.7	16.5
March	12.9	12.9	14.9	14.9	24.1	23.7	29.3	30.9	20.5
April	14.3	14.3	14.5	14.3	22.3	22.1	27.3	27.5	19.6
May	16.7	16.5	16.1	15.7	19.3	19.7	24.0	24.7	19.1
June	8.3	9.5	10.1	9.5	10.2	9.5	12.8	14.7	10.6
July	3.4	3.3	2.9	2.6	4.4	3.9	12.1	14.2	5.9
August	5.0	4.9	3.2	3.1	7.3	6.9	16.5	18.5	8.2
September	5.7	6.2	4.5	4.2	6.6	6.4	13.7	15.4	7.9
October	3.3	3.1	3.5	3.1	4.5	5.0	14.8	16.4	6.7
November	3.2	3.2	3.0	2.6	6.0	5.2	12.8	14.9	6.4
$\bar{x}$	7.1	7.3	7.2	6.8	11.1	10.8	17.9	19.5	11.0

Appendix I.--(Continued)

Temperature °C

Month	Station no. 1	2	3	4	5	6	7	8	$\bar{x}$
September 68	27.6	27.7	27.3	27.2	28.7	28.3	28.5	28.7	28.0
October	26.6	26.5	26.6	26.4	26.6	27.0	27.0	26.9	26.7
November	21.3	21.4	21.7	21.7	19.8	20.4	24.9	24.7	22.0
December	16.8	16.4	16.9	15.9	16.4	16.1	18.0	18.3	16.9
January 69	18.2	18.0	18.3	17.6	18.8	18.4	18.6	18.5	18.3
February	20.8	20.6	20.6	20.4	19.3	19.4	19.8	19.6	20.1
March	21.5	21.5	21.0	20.6	21.6	21.5	21.4	21.0	21.3
April	26.6	26.1	26.9	26.3	27.1	26.6	27.3	26.9	26.7
May	27.6	27.3	28.7	27.9	28.6	28.2	28.3	28.4	28.1
June	29.6	28.7	28.6	28.5	29.3	29.2	29.3	29.4	29.0
July	32.1	32.1	31.8	31.8	31.4	31.3	31.4	31.9	31.7
August	31.1	30.5	30.4	30.6	29.9	29.9	30.3	30.1	30.4
September	30.0	29.8	29.8	29.6	29.2	29.1	29.9	29.6	29.6
October	27.5	27.1	27.8	27.3	28.0	27.5	28.3	28.0	27.7
November	20.8	20.6	20.8	20.8	22.3	21.9	22.2	22.2	21.5
$\bar{x}$	25.1	25.0	25.1	24.9	25.1	25.0	25.7	25.6	25.2

Appendix I.--(Continued)

Dissolved Oxygen ppm

Month	Station no. 1	2	3	4	5	6	7	8	$\bar{x}$
September 68	6.5	6.0	6.5	6.5	7.0	7.5	5.5	5.5	6.3
October	6.5	6.5	6.0	6.0	6.5	6.0	5.5	5.0	6.0
November	8.0	8.0	8.0	8.5	7.5	8.0	7.5	8.0	7.9
December	8.5	8.5	8.5	9.0	9.0	9.0	7.5	7.0	8.4
January 69	8.5	8.5	8.0	6.5	9.0	8.5	8.0	8.0	8.1
February	7.0	7.0	7.0	6.5	6.5	6.5	6.0	6.0	6.6
March	8.5	8.0	8.0	8.5	9.0	7.5	7.0	7.5	7.0
April	7.0	7.0	6.5	7.5	9.0	6.0	6.5	6.0	6.9
May	6.5	7.0	6.5	6.5	7.0	6.5	6.5	6.0	6.6
June	6.5	6.5	6.0	6.5	7.5	6.5	6.0	6.0	6.4
July	5.0	6.0	6.0	5.5	5.5	5.5	5.0	5.0	5.4
August	6.0	5.5	5.5	5.5	5.5	5.0	5.0	5.0	5.4
September	6.5	5.5	6.5	6.0	7.0	5.0	6.0	5.0	5.9
October	7.0	7.5	7.0	7.0	7.0	7.0	6.5	6.0	6.9
November	8.0	8.0	8.5	8.0	8.0	6.5	7.0	6.5	7.6
$\bar{x}$	7.1	7.0	7.0	6.9	7.4	6.7	6.4	6.2	6.8

Apendix II. Mean stem counts of <u>Udotea</u> <u>conglutinata</u> and <u>Diplanthera</u> <u>wrightii</u> occurring in 1/50 square meter bottom samples taken on Stations 2-8, Whitewater Bay, February to November 1969.

Month	Station no.						
	2[1]	3	4	5	6	7	8[1]
February	0.0[2]	11.0	17.4	73.7	81.3	0.8	0.0
March	1.1	8.7	6.3	91.7	68.9	2.1	0.5
April	0.0	14.2	8.4	108.3	70.2	1.8	0.0
May	1.3	4.5	10.9	177.4	61.0	12.7	0.1
June	0.0	6.7	10.0	140.3	70.8	12.0	0.1
July	0.5	6.8	8.1	139.8	74.9	11.4	0.1
August	0.8	3.6	4.8	150.0	94.5	8.3	0.1
September	2.0	2.7	8.4	139.1	91.6	7.9	0.0
October	0.7	2.8	9.5	113.2	46.0	3.8	0.2
November	0.1	2.1	5.8	113.1	65.3	4.6	0.0

[1] Includes only <u>Diplanthera</u> counts; other data includes only <u>Udotea</u> counts.

[2] Each mean is based on 10 monthly samples.

Appendix III. **Summarized catch data for each species by station, September 1968 to November 1969.**

Species	Station no. 1	2	3	4	5	6	7	8
Elops saurus	1	0	0	0	0	0	0	0
Bascanichthys scuticaris	0	0	0	0	0	0	0	1
Myrophis punctatus	5	3	1	4	4	2	3	2
Ophichthus gomesii	0	0	0	0	0	0	1	1
Harengula pensacolae	5	0	1	0	1	0	5	9
Opisthonema oglinum	4	1	2	0	3	2	4	6
Anchoa hepsetus	0	5	2	0	10	2	6	4
A. mitchilli	87	190	113	53	47	12	136	44
Anchoa sp.	1	0	0	1	2	0	7	7
Synodus foetens	1	0	4	1	39	51	259	63
Arius felis	0	0	0	0	23	41	2	3
Opsanus beta	9	5	178	81	374	364	127	60
Porichthys porosissimus	0	0	0	0	0	0	3	2
Gobiesox strumosus	0	0	1	0	5	1	1	0
Ophidion holbrooki	0	0	0	0	0	0	0	1
Ogilbia cayorum	0	0	0	0	0	0	1	1
Ogilbia sp.	0	0	0	0	0	0	0	1
Strongylura notata	0	0	1	0	0	0	0	0
S. timucu	1	0	0	0	4	1	1	2
Hyporhamphus unifasciatus	0	0	0	0	0	1	0	7
Floridichthys carpio	0	0	3	1	0	0	1	0
Lucania parva	1	0	8	3	52	5	28	1
Rivulus marmoratus	0	0	1	0	0	0	0	0
Gambusia affinis	0	0	1	0	2	0	0	0
Membras vagrans	4	4	4	2	2	2	2	14
Menidia beryllina	1	1	2	0	0	0	0	0
Hippocampus erectus	0	0	0	0	0	0	1	0
H. zosterae	0	0	0	0	0	0	12	0
Syngnathus floridae	1	0	0	0	0	0	18	0
S. louisianae	0	2	1	1	0	2	63	9
S. scovelli	9	53	55	36	18	87	841	41
Prionotus scitulus	0	1	0	0	0	0	21	38
P. tribulus	0	0	1	1	4	2	8	16
Diplectrum formosum	0	0	0	0	0	0	1	1
Astrapogon alutus	0	0	0	0	0	0	0	1
Oligoplites saurus	0	0	0	2	1	0	1	4
Selene vomer	0	0	0	0	0	0	3	0
Lutjanus griseus	7	1	3	0	70	75	8	0
L. synagris	0	0	4	0	82	105	534	36
Eucinostomus argenteus	13	1	10	1	2	1	45	3
E. gula	161	62	1847	1573	4458	1498	11659	365
H. sciurus	0	0	0	0	5	2	125	5
Orthopristis chrysopterus	2	1	34	89	663	1119	430	59
Archosargus probatocephalus	1	0	10	4	271	236	8	4

Appendix III.--(Continued)

Species	Station no. 1	2	3	4	5	6	7	8
Lagodon rhomboides	41	12	488	731	4184	9689	1920	102
Bairdiella batabana	0	0	0	0	1	0	0	0
B. chrysura	4	3	189	24	479	264	201	22
Cynoscion nebulosus	2	3	18	22	19	1	68	1
Sciaenops ocellata	1	0	0	0	0	0	0	0
Chaetodipterus faber	0	0	0	0	0	1	0	1
Mugil cephalus	0	0	0	0	1	0	0	0
Sphyraena barracuda	0	0	0	0	5	0	7	0
Sparisoma radians	0	0	0	0	0	2	0	0
Chasmodes saburrae	0	0	3	11	9	59	12	1
Bathygobius soporator	0	0	1	0	19	21	6	13
Gobionellus smaragdus	0	0	0	0	0	0	37	32
Gobiosoma robustum	17	17	340	339	898	1099	639	394
Lophogobius cyprinoides	0	2	102	18	922	85	7	4
Microgobius gulosus	950	858	655	393	25	9	566	420
M. thalassinus	0	0	0	0	0	0	5	9
Etropus crossotus	0	0	0	0	0	0	0	1
Paralichthys albigutta	0	0	2	0	3	5	25	14
Achirus lineatus	10	9	89	46	84	142	858	222
Trinectes maculatus	44	36	3	4	1	3	12	7
Symphurus plagiusa	9	9	9	31	132	169	875	1625
Stephanolepis hispidus	0	0	0	0	1	4	30	3
Sphoeroides nephelus	0	0	1	11	12	58	43	45
Chilomycterus schoepfi	0	0	0	1	1	4	3	4