

ABSTRACT The frequency and relative abundance of fish species found in the Rio Espiritu Santo River estuary was determined through a one-year sampling program. Thirty families, comprised of 60 species, were recorded from different locations in the estuary. The piperfish *Pseudophallus mindii* (eck and Hildebrand) and the blenny *Lupinoblennius dispar* Herre are new records for the literature fishes from Puerto Rico.

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DEDICATION TO MY MOTHER

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Appendix Table: List of scientific and common names of fish species in the Rio Espiritu Santo River estuary. Values of species diversity expressed in bit/individuals.

Introduction: An estuary has been defined as a semi-enclosed coastal body of water which has a free connection with seawater and within which seawater is measurably diluted with fresh water derived from land drainage (Pritchard, 1967). This mixing of fresh and salt water causes the salinity to vary in time and space. Salinity variations in time are caused by tidal fluctuations, which result in

marked salinity variations during a 24-hour period. Also, the salinity varies with the amount of freshwater runoff. The input of freshwater to the estuary helps to maintain the salinity gradient and without it, the entire estuary could become hypersaline. On the other hand, too much freshwater inflow may cause the entire estuary to become exceedingly fresh and destroy the salinity gradient. Thus the interaction of these two components, tidal fluctuations, and freshwater runoff, cause temporal and/or seasonal changes in the estuarine environment. The most important effect of these changes is the potential stress on individual organisms inhabiting the estuary. Although, all organisms possess, in some measure, the ability to adapt or adjust to changing environmental conditions; estuarine organisms must constantly face these drastic changes. To accommodate these changes, they...

In adapting to a changing environment, the animal has two alternatives. It can either migrate to suitable environments or it can remain in one place, having developed the physiological adaptation necessary for survival (Vernberg and Vernberg, 1976). The animals with the highest capacity for adjustment to changes in the environment are those that persist in abundance.

These changes, brought about mainly by the mixing of fresh and salt water, tend to produce a nutrient trap. This has been related to the high primary productivity of estuarine waters (Schelske and Odum, 1961; Maedrich and Hall, 1976). The large quantity of nutrients trapped and recirculated in the estuary provides suitable conditions for high primary productivity. This capacity for primary productivity is of utmost importance since biota in the estuary are either directly or indirectly dependent upon it for their sustenance. Even under highly productive conditions, food availability may be as important as salinity in controlling the number and distribution of animals in the estuary. Many of the temperate estuarine fish species are not permanent residents but spend only part of their life cycle in the estuary, causing seasonal variations in the fauna (McErlean et al., 1973; Frane, 1974; Livingston, 1976). Organisms may be moving to or from estuaries in search of spawning ground (Bechtel and Copeland, 1970; Cronin and Mansueti, 1971) or to better feeding ground (Diener et al., 1974; de Sylva, 1975). Such movement may also be a direct response to physical environmental gradients as well as a function of the species' evolutionary history.

The estuary provides a transitional area for those fishes whose life cycle includes both a marine and a freshwater phase. An interesting tropical example is the migratory species of goby, *Sicydium plumieri*, which changes its habitat preference with its life stage. *Sicydium plumieri* (Family: Gobiidae) lives as an adult in freshwater, but in its post-larval phase has been caught in the Miasco River estuary (Erdman).

1960). Another fish species which exhibits some estuarine tendency is the jack, *Caranx latus* (Fan, Carangidae), which feeds and matures in the sea. However, young individuals are frequently found inshore and around river mouths (Erdaan, 1972). In Puerto Rico, the estuaries (i.e., river mouths) and mangrove swamps have a major nursery function (Austin, 1971). Young fishes congregate in these areas and benefit from the availability of food and protection from predators. Thus, the increase in the number of individuals of a given species in a locality may be caused by an influx of young recruits (newborn) raised in that locality or a migration of young or older individuals. As a direct consequence of these considerations, the estuarine environment is necessary for the maintenance of coastal commercial and sport-related species of fish during all or parts of their life. Species diversity can be defined as the number of species in an area as a mathematical expression that deals with the relationship between species and the number of individuals (Withm, 1968). The

analysis of natural communities based on the distribution of organisms within species can reveal information about the community (Margalef, 1958), and many diversity indices have been proposed using this concept (Pielou, 1966). The diversity index based on Information Theory describes the average degree of uncertainty of occurrence of particular events; the greater the number of events, the greater the degree of uncertainty for predicting the occurrence of a particular event (Cox, 1976). Species diversity can be used as a tool to compare faunal diversities from area to area. Diversity indices have been used as a measure of environmental quality and as indicators of pollution, where lower diversity values are indicative of stress (Bechtel and Copeland, 1970; McErlean et al., 1973; Teai, 1973; Denocourt and Stambauch, 1974). The net result of pollution is to cause a redistribution of the number of individuals within species or in

In severe cases, the loss of species from an area may occur because pollution-intolerant organisms undergo a reduction in population density or merely leave the area. Meanwhile, pollution-tolerant organisms often increase in number, using up the available space necessary for survival. Physically, estuaries are influenced principally by variations in river flow and by tidal movement. The estuarine animals adapt to this environment in two ways: they evolve a high degree of plasticity and/or migrate at critical times in their life cycle to a more suitable area. It is known that migrations to various areas for spawning frequently help assure the survival of the larvae and the young of the year. Since migrations and spawning can affect the diversity of fish populations in the estuary, knowledge of the life history of the species involved is necessary to determine population fluctuations.

One must know the normal fluctuations of the fish populations in the estuary in order to detect natural alterations in the structures (migrations, newborns) of the populations, as well as those brought about by man-made changes (canal construction, dams, industry, and real estate development and/or pollution). Industrialization and real estate development have become major concerns in Puerto Rico's economy. Many municipalities have begun an unprecedented growth cycle with respect to industrial development and human population.

This investigation is an attempt to obtain reference data on relatively undisturbed fish populations in the Espiritu Santo River estuary, which is located contiguous to the municipality of Rio Grande. The objectives of this study were:

- a. To identify and describe the fish populations of the Rio Espiritu Santo River estuary.
- b. To determine the temporal and spatial distribution of the species in the estuary.
- c. To assess the relative abundance and species diversity of fish populations.
- d. To evaluate the effects of selected physical, chemical, and biological factors on fish distribution.

The study area is the estuary of the Rio Espiritu Santo.

The Espiritu Santo River is located in the Municipality of Rio Grande, in the northeastern sector of Puerto Rico. It is approximately 20 miles east of San Juan. The river proper and its tributaries originate in the Luquillo National Forest at elevations in excess of 900 meters. The main tributaries are Quebrada Sonadora, Quebrada Grande, and Quebrada Jimenez. The Rio Grande, to the west, eventually joins the Rio Espiritu Santo in the estuary (figure 1). The overall length of the Espiritu Santo River from its origin to the Atlantic Ocean is approximately 21 Km, and the drainage area above the estuary is approximately 25 sq km (Cuevas and Clements, 1975). The estuary extends landward approximately 7 Km, with Highway PR 3 marking the southern limit. The coastal plain

provides four additional freshwater inputs: Rio Grande, Calo Castaien, Quebrada Juan Gonzalez, and Caio San Luis. Calo Castaien receives the discharge from a secondary sewage treatment plant of the Municipality of Rio Grande, a daily input of about 0.8 million gallons per day. A fringing mangrove forest dominates both sides of the river from approximately 2 hours inland to its mouth (Cuevas and Clements, 1975). The width of the estuary varies between 12 and 55 meters while the depth ranges from 1 to 6 meters (Bhajan, pers. comm. 1977; Goldman, 1978 unpublished). The geological substrate consists mostly of swamp deposits, but also terrace alluvium deposits are found in the upper section of the estuary. The mean annual rainfall varies from over 4,000 mm (157 inches) at the higher elevations of the basin to about 1,650 mm (63 inches) in the coastal plain. Under normal flow conditions, the estuary is stratified with surface freshwater underlain by a salt-water wedge and the halocline found at a depth of approximately one meter (Goldman, 1978 unpublished). Under high flow conditions, such as those obtained after heavy rainfall in the watershed, there is less stratification.

Fresh water may completely dominate as much as the upper half of the estuary. The study area was divided into eight stations based upon preliminary field observations. The sampling stations established for this study were located throughout the estuary system and included a wide variety of habitats (Figure 2).

Station 1 was located upstream before the bridge on Highway PR #3, approximately 14.7 to 14.9 Km. from the river origin. This part of the river has a mean depth of 2 meters and a width of 22 meters at base flow conditions. The substrate is mainly gravel. Elevation is 8 meters. Adjacent land is dedicated to farming minor crops.

Figure 2. Rio Espirito Santo Estuary showing sampling stations.

Station 2 was located approximately 15.7 to 15.8 Km. from the river origin, below the confluence with the Rio Grande. This part has a mean depth of 3 meters and a width of 32 meters. The substrates consist of gravel, very fine sand, and clay. Adjacent lands are dedicated to farming.

Station 3 was located approximately 16.5 to 16.6 Km. from the origin. This part has a mean depth of 5 meters. It is approximately 38 meters wide, and the bordering land is dedicated to pasture.

Station 4 was located approximately 17.3 to 17.4 Km. from the origin. It is approximately 40 meters wide with a depth of 4 meters. The substrate is mainly gravel. Bordering land vegetation consists of grass and mangroves. Quebrada Castañón, which transports secondary sewage plant effluents, drains into this area. The adjacent land area is largely undeveloped, overgrown tropical old-field or flood plain.

Station 5 was located approximately 18.0 to 18.1 km. from the river origin, at the confluence with Quebrada Juan Consilez. The bordering vegetation consists of mangroves, but open shore is found around the dock area. This area is approximately 6 meters deep. At base flow conditions, this part of the river is 35 meters wide.

Station 6 was located approximately 18.8 to

18.9 Km from the river origin, about 50 meters from the Quebrada Juan González confluence, this part is approximately 6 meters deep and 42 meters wide. The substrate primarily consists of silt, clay, and coarse sand. *Rhizophora mangle* borders both sides of this area.

Station 7: Station 7 was located approximately 19.6 to 19.7 Km. from the origin, above the Caño San Luis confluence. The mean depth of this area is 5 meters and its substrate primarily consists of silt, clay, and coarse sand. It is about 38 meters wide. The intertidal vegetation consists of a mangrove association.

Station 8: This station was located at the river mouth, and is approximately 20.4 to 20.5 Km. from the origin. The intertidal vegetation is typified by a mangrove association although many of the mangrove stands have been removed within the past 20 years. The substrate primarily consists of silt, clay, and sand with some gravel. The bottom line slope is smooth, but it becomes steeper at 4 meters from the shoreline. This area is approximately 50 meters wide at base flow conditions.

Methods and Materials: The fish populations study was done in conjunction with other estuarine studies of plankton, crustacea, molluscs, benthic organisms, sediment composition, and water quality. The sampling stations selected generally correspond to those of the other studies. Each station was sampled monthly for a period of one year to determine species present and to study the spatial and temporal distribution of the species. Each station was sampled with nylon monofilament, sinking, gill nets of 30.48 meters long and 1.83 meters wide. Four different mesh sizes, 1.27 cm, 2.54 cm, 5.08 cm, and 7.62 cm square mesh were used, since each mesh size is designed to catch fish of a specific size range. Collection efforts were standardized by sampling during the early morning hours between 7:00 and 11:00. At each sampling station, the nets were set by attaching the proximal line of the net to a stationary shore holder. These holders were placed on

Alternating shores. The nets were stretched at a 45-degree angle across the station, sloped toward the freshwater flow. The distal part of the net was held in position with floats (Floating Line) and with weights (bottom line) to keep the net vertical. The nets with 5.08 cm. and 7.62 cm. square mesh were placed on opposite shores, each at either extremity of the station. Nets of 1.27 cm. and 2.54 cm. square mesh were placed between the 5.08 cm. and 7.62 cm. square mesh net but on opposite shores from each other and on alternate shores from the smaller meshes. Each gill net was set for a period of one and a half hours and then retrieved. The fishes were removed as the net was hauled. Live specimens were transferred to a container of water for further processing. After all fishes were removed, they were identified, weighed and the total (TL) and standard lengths (SL) were recorded. Those specimens requiring verification of identification were preserved for analysis. Measurements were done first on healthy fish, after which each was tagged with lock-on spaghetti tags and released as part of a study of migrational patterns. This latter study is not reported here and it is part of the program of the Department of Natural Resources which kindly supplied the tags. The remaining fishes were measured and their stomachs were extracted and preserved in 10% formalin in the field. Stomach content samples were labeled with the location of capture and species information. In the case of large individuals, the examination of gonads was done in the field and these were extracted, labeled, and preserved in Gilson's fluid. Gonads from the small fishes were examined in the laboratory. While the gillnets were in place, a dip net was used to collect small fishes along the shore and under the intertidal vegetation. The specimens collected were immediately preserved in 10% formalin. Identification, measurements, and extraction of

stomach and gonads were done in the laboratory using a binocular dissecting microscope.
Additional

Information (creel-census) was obtained from fishermen who were fishing concurrently in the sampling area. Water samples were taken at each station and stored in polyethylene bottles after all nets were retrieved. In the laboratory, salinity was determined with a Bausch and Lomb temperature compensated refractometer. Salinity measures below detectable limits with the refractometer were determined by standard Hob titration with silver nitrate (AgNO_3). Water temperature was recorded in situ with a Keane's water sampling bottle equipped with a calibrated thermometer.

Feeding habits of fishes were determined by the analyses of the stomach contents from selected individuals. Stomach content analyses were done using either of two methods depending on the size of the fish's stomach. For small fishes, quantification of stomach contents was done using a binocular dissecting microscope and a petri dish fitted with a piece of coordinate graph paper. The percentage of the total volume of the various food items encountered was determined by grouping the components of a particular food item and counting the number of squares in the petri dish that the food item filled. The number of squares that the item filled was divided by the total number of squares covered by the entire stomach contents to obtain the fraction of the total stomach contents examined that each item constituted.

For large fishes, the quantification of stomach contents was done by immersing the individual food items in a graduated cylinder or in a calibrated glass tube filled with a known quantity of water to determine the volumetric displacement, after which the water displacement for all items together was calculated. The mean volume of a particular food item obtained by either method was determined by adding the fractions that the food item was found in each stomach, and then dividing by the number of fish with food in their stomachs.

Gonad condition was used to determine each species' reproductive condition. The following criteria

The following text was used to classify gonad condition:

1. Immature or inactive: The gonads are small and undeveloped ovaries.
2. Mature: The gonads are visible to the naked eye or enlarged. Gonads from small fishes showed small eggs attached to the ovarian wall and larger eggs in the middle portion of the ovary.
3. Ripe: The specimens are showing running milt or expelling ova with or without the application of light abdominal pressures, gonads from small fishes are greatly enlarged, or the ovary is filled with large eggs.

Species diversity was determined by Brillouin's formula as presented by Lloyd, Zar, and Karr (1968):

$eM (\log \sum_{j=1}^N n_j^{-1})$

Where N is the total number of individuals in the collection, n_j is the number of individuals in the j th species in the collection, and C is a factor to convert logarithm base 10 to the logarithm base desired. Logarithm to the base 2, or bit per individual, was used to compare within and between

samples, and the scale factor used was $C = 3.21928$.

Results and Discussion:

The mean and the range of salinity and temperature values for each station are shown in Table 1. Temperature in the estuary is influenced by both fresh and salt water input which causes temperature variations depending upon the station location. Salinity range was also dependent on station location, and approached seawater concentration at Station AR.

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At Station 8, the concentration of saltwater and freshwater varied. At Station 1, salinity concentration values varied with tidal position.

(Table 2). Low salinity values usually occurred when there was a large freshwater input from the mountains as a result of heavy rainfall. Fishes of the Espiritu Santo River estuary: A total of 1,306 specimens representing 60 species and 30 families were caught in 106 collections from eight localities in the Espiritu Santo River estuary. Out of these 106 collections, 96 were done in the morning between 0700 and 1100 hours (regular sampling), and 10 optional sampling at different times for selected localities. These optional samples were collected during the late afternoon and evening for station 5 on March 29, 1977, late afternoon for station 2 on May 29, 1977, and at dawn for station 7 on July 22, 1977. The listing of scientific and common names of the species identified is presented in Appendix Table A. Phylogenetic order of families used here basically follows that of Greenwood et al., (1966). Genera and species are listed in alphabetical order within each family. Species temporal and spatial distribution are shown in Table 3 and Table 4, respectively. These data will be discussed with respect to the information obtained relative to each species. Most species data included information on the number of individuals collected, followed by the size range of the standard length in millimeters. Data on stomach contents and reproductive conditions were also included.

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Each station's salinity (0/00) at the bottom and mean and range of both are shown in Table 2: SURFACE. High tide, low tide, high tide details are provided for each STATION.

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Table 4 shows the spatial distribution and number of individuals (n) of fish species in the Espiritu

Santo River estuary (Optional sampling not included). The data for each station is listed down, showing the count of various species like *Aetobatus narinari*, *Elops saurus*, *Megatoma atlantica*, *Angitia fostrat*, *Harengula humerali*, *Opisthonema oglinum*, *Rachos hepsetus*, *Anchovia clupeioides*, *Gerres cinereus*, *Strongylura marina*, *Poecilia vivipara*, and others.

Dostethus teneatus 2%, 2h 262310, *Pseudophallus sindit* 2, *Centropomus ensiferus* 306, 418, *Centropomus pectinatus*, *Centropomus undecimalis* 143, ob 5, *Rachicotus goodet*, *Totijonse apodus*, *Cot jaar rises*, *Tatienay tece* 121, *Diapteris otostomus* 3, *Diageerous rhawbens* m5 bo 3 3 3, *Hetairosroane teFPoy*, *Eigerte pluntert*, *Gerres cinereus*, *Fomsdazys crocro*, *Boiraiet ta ronchis*, *Eynoseton jana teensis*, *Larinus brevleeps*, *Siero en Furnes* 1, *cthostodiprerts Tater*, *Tilapia sossanbiea* 38, *os tonus*, *Pont Te woo*, *AagrT Sareea*, *RagrT cure* 7 3% 7 5, *Sphyraena barracuda* 1, *Sphyraena Suachanch* 16m 22.

Table 4, (Cont.) STATION species 4 2 03 4 5 6 7 28, *Scarus* sp. 1, *Polydactylus virginicus* 2, *Lucinoblennius dispar* 4, *Dormitator maculatus* yoy as 5 oat, *Eleotris sisonts* 2 30 17, *BO Gabionorus dormitor* 3508S 7 4, *Ogous tajacica* 2, *Bathygobius soporator*, *Gobionellus Beleovon* 1, *Gobionellus oceanicus*, *Gobiosona spes* 4a, *Trichiurus lepturus* 110, *Scomberomorus regalis* 1 2, *Citharichthys spilopterus* 1 1, *Achirus lineatus* 2, *Synodus plagiosa* 1, *Lagocephalus laevigatus* Bo 1, *Sphoeroides testudineus* 10. Totals 142207155 2311721529602. 23.

Species Accounts Class chondrichthyes order Laminiformes: None collected, but several small ones observed at station 4 and one larger individual was observed during dawn sampling on July 22, 1977. Fishermen reported sharks up to station 2. Order Rajiformes Family Myliobatidae *Aetobatus narinari* (Euphrasen): Four specimens were collected, three males in April and one female in May. The food of this eagle ray had been reported to consist of molluscs (Nichols, 1929; Cervigón, 1966; Randall, 1967) which are crushed by the dental plates and the soft parts are swallowed free from shell fragments. The stomach contents of four specimens from the Espiritu Santo River estuary were 100% molluscs. No reproductive information was available from these collections but embryos in terminal stages of development had been found from July to August (Erdman, 1976). Class Osteichthyes Family Elopidae *Elops saurus*.

Linnaeus 3:218-395 in SL Erdman (1972) reports that Ladyfish occur in both fresh and saltwater. In the Espiritu Santo River estuary, they are found from station 2 to 8 (river mouth), but also occur in channels connected to the estuary (from fishermen's personal communications). The Ladyfish reportedly feed on fish and crustaceans (Cervigón, 1966; Austin and Austin, 1971; Odum and Heald, 1972), as well as plant fragments and Pelecypods found in the stomachs of two out of three estuarine Ladyfish examined. No reproductive information was available from the specimens examined. The Ladyfish spawning occurs in the sea, and young leptocephali enter rivers in September (Erdman, 1972).

Family Megalopidae: *Megalops atlanticus* Valenciennes 9: 285-628 mm SL. Tarpons were not consistent throughout the year, but fishermen reported a tarpon of 110 pounds caught with hook and line. Three tarpon were caught during night fishing at station 2 on May 29, 1977. Stomach content analysis reveals tarpon feed on decapod larvae (26.932%), shrimps (16.402%), crabs (13.082%), and fish (33.60%). Tarpon spawning occurs in the sea, moving to open waters to spawn from late April to August (Erdman, 1960).

Family Anguillidae: *Anguilla rostrata* (Le Sueur) 35:62-195 mm TL. Freshwater eel became abundant in January, but the largest individual (195 mm TL) was collected in November at station 1. Freshwater eels were collected along the shore, mainly under the water hyacinth (*Eichhornia crassipes*) root system. The arrival in the estuary is readily evident but departure was not recorded, probably because larger individuals move along the deepest part of the estuary. Odum and Heald (1972) found that eels (50-200 mm) feed on amphipods and isopods in the North River estuary. Diptera larvae, Cladocera, Ostracods, and water hyacinth roots were also found in the stomachs of eels taken from the Espiritu Santo River estuary (Table 5). Freshwater eel reproduction takes place in the sea (Bohlke and Chaplin, 1968).

Family Clupeidae: *Marenella humeralis*.

"Cuvier 1134-152 mm SL. Only four individuals were caught during December at station 8. The stomach of the four caught contained 100% fish remains (one with anchovy). All specimens collected were female with small gonads. Erdaan (1976) states that females with ripe ova can be found from March to May.

Opisthonema oglinum (Le Sueur) 137-226 mm SL. The occurrence of these species in the estuary seems to be cyclic since a high number of individuals were caught during February, March, and April 1977 and in January 1978. Eleven specimens were caught during March when sampling at night and 55 specimens were taken during regular sampling for that month. The highest number of individuals was caught at station 2 during the dry season, with full stomachs containing decapod larvae. Other items encountered in the stomach of these specimens were algae, diatoms, small crustaceans, and fish larvae (Table 5). The thread herring reproduction takes place in March (Martin, 1974) although not all individuals collected in the Espiritu Santo were sexually mature.

Family Engraulidae *Anchoa hepsetus* (Linnaeus) 89-199 mm SL. This species was collected only once at station 7 during May. All specimens had stomachs full of unidentifiable fish remains and all were females. This species is preyed upon by *Sphyraena guachancho*.

Anchovia clupeioides (Swainson) 79-170 mm SL. A clupeioides (*Anchoa producta* Pocy) was caught quite frequently from February to July. A single catch at station 2 during July might be due to the presence of decapod larvae (66.50%) which were found among other stomach contents. The anchovy food items also included algae (5.52%), ostracods (6.39%), copepods (8.89%), and amphipods (12.70%). Specimens with enlarged gonads were found in May and July.

Cetengraulis edentulus (Gunther) 87-116 mm SL. This species was collected periodically in the estuary, at all stations. The whalebone anchovy was collected frequently but without a seasonal pattern. Its presence in the estuary seems to be regulated by salinity."

In June, several individuals were collected at station 2 and in November at station 1, but they were not present at these stations when salinity was low. This species is a filter feeder, feeding on minute planktonic organisms (Fisher, 1978). It feeds mainly on decapod larvae in the estuary. Gonzalez and Vitella (1976) found whalebone anchovy with developed ovas from April to June in Pifones Lagoon.

Family Poeciliidae: *Poecilia vivipara* (Bloch & Schneider) 7:11-30 cm SL. This species was collected only in November, after heavy rains (53.66 mm). It is likely that individuals of this species came from adjacent channels that drain into the estuary. One stomach examined revealed the remains of small crustaceans. Three of the seven caught were females with embryos (one contained 32 embryos). Martin (1974) mentioned that this family is a perennial breeder.

Family Syngnathidae: *Sostethus Lineatus* (Kaup) 114:14-155 cm SL. Gilmore (1977) described the opossum pipefish as a euryhaline fish that is commonly found in freshwater and estuarine areas. This species was collected all year at stations 1 through 5. It was less frequently encountered at station 6, and it was observed at this station in January, perhaps due to the presence of water hyacinth at the station. The water hyacinth transports this and other species such as *Eleotris Bisenis* to lower sections of the estuary. *S. Lineatus* was more common along the shore at the above-mentioned stations. It seems to avoid predation by a...

The text should be corrected as follows:

Showed ripe gonads. Other mature individuals were caught during June. *Gontrapomus pectinatus* Poey 2:104-148 um SL. This species occurred only in August, after heavy rains. Only one individual had food in its stomach and the items were 100% shrimp remains. Both individuals showed no evidence of sexual maturity and nothing is known about where and when this species may spawn (Fisher, 1978). *Gontrapomus umecimslis* (Bloch) 28:24-318 um SL. This snook occurred in the estuary as both juveniles and young adults from stations 1 through 6. Four individuals were caught during the night sampling at station 5. Stomach analyses of 16 stomachs revealed this species fed chiefly on shrimp (64.53%). Other food items encountered were fish remains (19.69%), vascular plant leaves (5.98%), crab (9.11%) and molluscs (0.69%). None of the species collected had mature gonads. Justin (1972), Exdoan (2976), Fisher (1978) reported that spawning takes place from April through September. One individual of 206 gms. and 295 um SL, was captured while it was swimming on the surface. Its viscera were full of a yellow liquid (probably derived from fats), its stomach was empty and a silvery plastic band was found attached to its gill, which no doubt interfered with the regular feeding of this fish.

Family Carangidae *Caranx hippos* (Linnaeus) 3:145-325 um SL. Crevalle jack were caught at stations 6 to 8. Cervigén (1966) cites them as coastal pelagic, but juveniles can be found in mangrove areas. This species is known to feed chiefly on fish, crabs, squid, shrimp and smaller invertebrates (Oius and Heald, 1972). Of three stomachs examined in this study, only two had food, 100% fish remains in both cases. Crevalle jack with ripe gonads were found by Munro et al. (1973) in July, 1970, Port Royal, Jamaica, but no individuals collected from the Espiritu Santo River estuary had developed gonads. *Caranx latus* Agassiz 15:58-163 am St. The horse eye jack was collected at most sites in the estuary and was the most common member of its family.

Family. Stomach analyses revealed that it fed on shrimps (such as *Xipho* 5p.) and fish. The stomach analysis of one individual revealed anchovy remains. The anchovy had fed on small neritid snails. No individual collected had developed gonads, but there are literature reports that reproduction takes place from February through August (Munro et al. 1973; Erdman, 1976). *Es rocosbrus chrysurus* (Linnaeus) 12:104-156. St. Cervigén (1966) described the species as a

coastal pelagic, but small individuals can be found in areas surrounded by mangroves. The species were collected from March to July. Two individuals were collected at station 3 during high tide in March and one was collected during night sampling at station 5. This species is said to feed on planktonic crustaceans (Cervigén, 1966). Specimens from the Espiritu Santo River estuary had empty stomachs. Martin (1971) found fish remains in specimens collected from Jobos Bay, Puerto Rico. No reproductive data for this species was available from this study, but Fisher (1978) reported spawning probably occurred in spring and summer for the Caribbean area. *Selene voner* (Linnaeus) 2:69-160 mm. SL. Lockdown were collected in April and May at stations 7 and 8. This species is said to feed chiefly on small crabs, shrimps, fish, and worms (Fisher, 1978). Specimens collected during this study had empty stomachs. Munro et al. (1973) reported one ripe running male at Port Royal reef Jamaica in April 1971. Martin (1972) reported enlarged ovaries in a 21 cm female. No reproductive data were available from this study. *Tectonotus goodei* (Bloch) 2:198-206 mm. This species can be qualified as a sporadic visitor in the estuary. Randall (1967) reported that this species is common in shallow to moderate deep water around reefs, feeding on sea life invertebrates. One stomach examined revealed mangrove oysters and vascular plant tissues, which probably was ingested along with mangrove root oysters. Specimens collected showed no evidence of sexual maturity. Family.

Lutjanidae *Lutjanus apodus* (Walbaum) 3:129-154 mm SL. This snapper is typical of shallow coastal waters (Randall, 1967). The three specimens collected from the Espiritu Santo River estuary were caught with hook and line using shrimp as bait. This species is said to feed on crabs, fish, shrimps, and octopuses (Randall, 1967; Cervigon, 1966).

However, juveniles feed on amphipods and copepods (Austin and Austin, 1972). Austin (1971) suggests that spawning takes place between February and April. *Lutjanus griseus* (Linnaeus) 1:112 mm SL. Only one gray snapper was captured by hook and line during the same sample period that *L. apodus* were taken. Its stomach contained only shrimps used as bait. Randall (1967) stated that juvenile specimens in seagrass beds feed on small crustaceans, while large individuals feed on shrimps, crabs, and fish. Sexually mature specimens were reported as occurring May through September (Erdman, 1976).

Lutjanus jocu (Bloch and Schneider) 4:103-263 mm SL. Four individuals of this species were collected during this study, but more were seen between mangrove roots when the water was clear. Two stomachs examined revealed shrimp and crab remains (*Callinectes* sp). There was no evidence of sexual maturity in the specimens collected.

Family Gerreidae *Diapterus olisthostomus* (Goode and Bean) 3:90-113 mm SL. Specimens of Irish pompano were collected at station 3 in August and October and all had empty stomachs. Austin and Austin (1971) found 100% plant material in six specimens collected from mangroves in western Puerto Rico. No reproductive data were available from specimens collected but Martin (1972) found a male with enlarged testes in September in Jobos Bay, PR.

Diapterus rhombeus Cuvier 43:51-142 mm SL. The rhomboid mojarra was found to be more prevalent during periods of low flow. Only one individual was collected during night sampling at station 5 in March. Stomach analysis revealed algae and plant material (23.43%), worm fragments (9.71%), small crustaceans (40.66%), and oysters.

(21.432%), and unidentified material (14.57%). No reproductive data were available from specimens collected, but spawning had been reported as occurring during June and July (Austin, 1971). *Eucinostomus lefroyi* (Goode) 2271-76 cm SL. One specimen of this species was collected in July at station 3 where bottom salinity was 36.2 ppt. Another was collected during the average sampling at station 7 in July. The stomachs of the two specimens examined revealed they fed on pelecypods (44.52%), small crustaceans (50.002%), and other unidentified material (5.502%). No information on spawning period was available from this study. *Eucinostomus gula* (Bleeker) 67-74 cm SL. Erdman (1972) cites this species as a freshwater mojarra. Two specimens were collected, one at station 4 in July and the other at station 2 in October. Both stomachs examined were empty. No evidence of sexual maturity was available from specimens collected. *Eugerres plumieri* (Cuvier) 23-960-280 cm SL. The striped mojarra occurred in all localities sampled in the estuary, but it seemed to prefer fresh to brackish waters. When the water was clear, it was possible to see striped mojarra feeding on the mangrove root oyster communities, where fishermen caught them with harpoons. Large quantities of oysters were found in stomach analysis (they ingested everything that is found in the oyster community). Ripe or near-ripe gonads were found from March to May. One female (800 gms., 280 cm SL) was caught at station 5 during night sampling in May and showed full ripe ova. *Gerres cinereus* (Walbaum) 58-134 mm SL. The yellowfin mojarra was found in the upper areas of the estuary during low flow conditions. One individual was caught during the night sampling in March. Randall (1967) and Austin and Austin (1971) reported that the yellowfin mojarra feeds on crabs, pelecypods, and gastropods as main food items. Five stomachs examined during this study revealed the following food items: amphipods (43.462%), pelecypods (45.072%), polychaetes (6.252%), and insect larvae.

The text should read:

Seine 4 to B. Austin (1971) mentions that this species prefers high salinity and open waters. One individual was caught at station 4 when bottom salinity was 30.4 ppt. Another one (644 gms., 326 mm SL) marked with a tag on May 31, 1977 at station 8 was recaptured by one fisherman on June 22, 1977 in the Punta Miquillo beach area. This suggests that this species, which was first captured in the estuary in April, was leaving the estuary in July, after which only two specimens were caught. Of nine stomachs examined, five contained the following items: shrimp (72.992), crab (9.382), fish remains (6.902) and plant materials (7.292). The spawning period probably occurs from June to November (Martin, 1972; Erdman, 1976).

Family Ehippidae *Chaetodipterus faber* (Brossonet) 1:206 mm SL. This species was collected only once at station 6 during high tide. The specimen collected had an empty stomach and immature gonads. This species feeds on a great variety of food items such as sponges, antharians, worms, and algae (Randall, 1967; Martin, 1972). Reproductive activity occurs from May to October (Erdman, 1976).

Family Cichlidae *Tilapia mossambica* (Peter) 17:212-342 mm SL. The tilapia was imported to the island in 1958 from Alabama for fish culture purposes (Erdman, 1972), and subsequently spread to open waters. González and Vilella (1976) reported that the tilapia occurred in the Piones lagoon. Various mature males and a spent female (222 mm SL) were caught, but young individuals were not collected. Probably this species came into the estuary from adjacent channels that drain into

the estuary. Tilapia are bottom feeders. Stomach analysis reveals large quantities of diatoms, filamentous algae, and detritus. Erdman (1976) reported this species as a year-round spawner.

Family Mugilidae *Agonostomus monticola* (Bancroft) 15:32-234 mm SL. The mountain mullet develops eggs in summer and the eggs or young larvae are washed to the sea (Erdman, 1972). The first specimen collected was in June, a ripe female of 234 mm.

"SL, a small one (52 mm SL) was collected at station 2 in August. Erdan (personal communication, 1977) informed that this specimen had recently returned from the sea. The mountain mullet becomes abundant in September after the heavy rains when they try to return to upper areas. This suggests that they were probably displaced from their preferred areas to lower areas by the large amount of freshwater runoff, or they were returning to their habitat after reproduction. Males from 83-96 mm SL caught in September showed running gametes and a female of 216 mm SL was spent. The mountain mullet feeds on shrimps (93.33%), adult insects (50.00%) and on plant material (seeds, 16.67%).

Mugil curema Valenciennes 103:98-280 mm SL. The white mullet is more abundant than the data suggests. Schools of white mullet have been seen moving along the estuary. The white mullet have a muscular stomach that grinds the food items obtained from the benthic layer. These food items consist primarily of benthic diatoms, blue-green and filamentous algae, plant detritus and inorganic sediment particles. The stomachs and viscera of mullet taken from the estuary exhibited large quantities of empty diatom frustules and algae, which gives a greenish appearance to the intestines. However, in April, various individuals collected at station 8 showed different stomach contents, not only in food items but also in intestinal color. From March to May, nearly ripe females were captured. Fisher (1978) stated that spawning occurs in the sea, Erdan (1976) reported spawning occurring in September. These facts explain the low number of *M. curema* collected during these months (Table 3).

Mugil liza Valenciennes 2:358-473 mm SL. *Liza* were found in the mangrove areas, but fishers reported that they are more common in the adjacent channels such as Quebrada Juan Gonzalez. Just as *M. curema*, *Liza* also feeds on algae and other organic matter. *Liza* spawning occurs in January (Erdan, 1976).

Family Sphyraenidae 12 mm SL *Sphyraena barracuda* (Walbaum): Only one individual was found."

The species is described by Dawson (1970). Family Eleotridae *imitator maculatus* (Bloch) 115:10-120 mm SL. This species became abundant in August when 65 individuals were caught and many more were seen. All individuals caught during that sample showed running gametes. During the spawning time this species behaves carelessly, becoming easy prey to larger fishes. One *Centropomus* was observed feeding on them but yet they did not seek protection. The reproductive ritual consists of the female and male getting close to each other on a mangrove root or on a water hyacinth mat and then releasing the gametes. The male showed reproductive colors such as bright yellow and red in different parts of the body such as the dorsal spines. Females retain their regular colors. There was a high incidence of liver parasites among individuals examined. Individuals of this species can be used as aquarium pets. *Eleotris pisonis* (Gmelin) 145:13-132 mm SL. The spinycheek sleeper is an euryhaline species inhabiting fresh and brackish water (Bohlke and

Chaplin, 1968). Most individuals were collected among river shore vegetation or under the water hyacinth roots. It was abundant from stations 1 to 4, but less common at stations 5 and 6. Its presence in the latter stations was due mainly to the movement of water hyacinth into the stations. The spinycheek is a voracious species (Table 5). The larger ones feed on small fishes, shrimps, molluscs, such as *Nerita* sp., and the small individuals (13-20 mm SL) on insect larvae such as Diptera, Cladocera and Amphipods. Mature individuals were collected from July to December and many small ones were found at stations 6 and 7 during December and January. 92:14-362 mm SL. This species was collected from stations 1 to 5, but it was more abundant at stations 1 and 2. Small individuals were collected among shore vegetation, but larger ones were collected in deeper waters. The bigmouth sleeper feeds mainly on shrimps and the juveniles on diptera larvae, small crustaceans and on smaller fishes.

Erdman (1972) mentioned that females with developing eggs can be found from March through June, but ripe females were caught up to September. During November, small ones (14-19 mm SL) were collected. Family Gobiidae *Awaous tajasica* (Lichtenstein) 2:201-210 mm SL. The river goby was collected only at station 1 after periods of heavy rains during August and October. One stomach examined reveals shellfish (89.00%), vascular plant leaves (8.002) and unidentified material (3.00%). No evidence of sexual maturity was available from specimens examined. Post-larvae are found in September (Erdman, 1976).

3468 mm SL *Bathygobius soporator* (Valenciennes) 2. The frillfin goby was collected mainly among oyster communities associated with the mangrove roots, but also was found along the shore at station 5. They feed on amphipods, isopods, small fishes, such as blennies and to a lesser degree on filamentous algae and other food items (Table 5). A ripe female (68 mm SL) was collected in August.

Gobionellus boleosoma (Jordan and Gilbert) 8-39 mm SL. The darter goby had been found among shoreline vegetation at station 5 and under water hyacinths at stations 4 and 7. Stomach analyses revealed algae, diatoms, and vascular plant remains. Males with breeding colors were found in November. Similar results are reported by Erdman (1977).

Gobionellus oceanicus (Pallas) 1:136 mm SL. This species was collected only once at station 1 when bottom salinity was 26.6 ppt. Stomach analysis revealed that it fed on filamentous green algae. No information on reproductive activities was available for this species.

Gobi jona spes (Ginsburg) 27:11-22 mm SL. This goby occurred in the same habitat as *L. dispar*. *G. spes* feeds on amphipods and isopods which were abundant in the mangrove oyster communities. Various mature females were found in October.

Family Trichiuridae *Leichiurus lepturus* Linnaeus 12:403-787 mm SL. This species occurred in the lower part of the estuary. Of twelve stomachs examined, only three were empty. The food

The items consisted mainly of fish remains (88.86%), but shrimp remains (11.12%) were also found. A male caught during the night sampling at station 5 had nearly ripe gonads and eight of nine specimens captured in July at station 7 showed ripe gonads. Family Scombridae, *Scomberomorus regalis* (Bloch), ranged from 226-526 mm SL. This species was collected in the

lower part of the estuary and occurred only in February, June, and July. The cero feed on fish. In June and July, post specimens examined contained anchovy which in turn had fed on decapod larvae. Two mature females were caught in February. Erdman (1976) mentions that this species has an extended spawning period. All fishes collected showed isopods attached to the gills.

Family Bothidae, *Chascanopsetta lugubris* Alcock, ranged from 103-106 mm SL. The bay whiff were caught first at station 6 in March. Later, a single individual was collected at station 3 in July when bottom salinity was 36.2 ppt. One stomach examined contained plant material (13.16%), shrimp remains (23.69%), crab fragments (34.21%) and fish (28.95%). Austin and Austin (1971) found 100% fish in one specimen. No information on reproductive condition was available from specimens collected.

Family Soleidae, *Achirus lineatus* (Linnaeus) ranged from 111-113 mm SL. The Lined sole was collected only at station 5 in April and May. One individual was caught while a blue crab, *Callinectes* sp., fed on it. One stomach examined was empty. Odum and Heald (1972) found amphipods, mysids, diptera larvae, worms and foraminifera in specimens from the North River estuary in Florida. No reproductive data was available for the specimens collected, but Erdman (1976) reports reproduction occurring in July.

Family Cynoglossidae, *Symphurus plagiusa* (Linnaeus) was 109 mm SL. This specimen was collected in February 1977. The contribution of this species to the ichthyofauna of the Espiritu Santo River estuary cannot be established because of its low frequency of occurrence in the samples. Austin (1971) stated that this species lives in muddy bottoms.

High salinities. The tongue fish has been described as a nocturnal feeder, feeding mainly on polychaetes and crustaceans. Family Tetraodontidae *Lagocephalus laevigatus* (Linnaeus) 5:121-150 mm SL. The smooth puffer was collected in the lower part of the estuary. Three stomachs examined contained Pelecypods (96.672) and vascular plant wood (3.332). The wood was probably taken incidentally along with pelecypods from the mangrove roots oyster community. Two ripe females (149 and 150 mm SL) were caught in May at station 5.

Sphacroides testudineus (Linnaeus) 10:32-59 mm SL. This species was abundant in open shallow waters near the shore at station 8, but many more were observed hidden under mangrove roots. Austin and Austin (1971) found crustaceans and gastropods in two specimens examined, but other food items were found in stomachs examined from the estuary. Erdman (1956) suggests spawning occurs in February.

Trophic levels. The quantitative data for the stomach contents of various species collected in the Rio Espiritu Santo River estuary were discussed individually in the previous section and are summarized in Table 5. Food items in the stomachs examined indicate whether a given fish species is a consumer of (1) primary level (2) secondary level, or (3) tertiary level. Some species were found to participate in more than one trophic level and their diet appears to depend on several factors. Some of these factors are fish size or age, habitat and/or seasonal abundance of prey (de Sylva, 1975).

The primary consumers are organisms which feed on plant material and/or detritus and they can

obtain additional nourishment from microorganisms ingested during the feeding activities. Also, inorganic materials such as sand grains can be ingested by these consumers. Some primary consumers obtained during the sampling were *Mugil curema*, *Tilapia mossambica* and others. Some species were found to be partially primary consumers such as *Sphaeroides* sp. According to stomach contents analyses, most species.

The corrected text:

Collected feed belongs to the group of secondary consumers. These organisms feed on insects, crustaceans, molluscs, and also on herbivorous fish.

Table 5: Stomach contents of some fishes examined.

These carnivorous species may feed on only one prey item or can include a more variable diet. Although many secondary consumers examined may not be commercially important species, they do play an important role in the transference of energy to the tertiary consumers. Tertiary consumers were found to be mostly migratory species, utilizing the estuary at different times, thus reducing interspecific competition at this level.

There are two basic types of estuarine food webs (Odum and Heald, 1975); one based on vascular plant detritus, and the other on phytoplankton. The results of the stomach content analyses indicated that both types of food webs are present in the Rio Espiritu Santo River estuary.

The number of species obtained in each sampling period is given in Table 6. The graphic representation of these results is shown in Figure 3. This is a three-dimensional representation in which the axes are station number, time, and number of species in the X, Y, and Z directions, respectively. The effect of presenting collection data in this manner is to allow a visual presentation of both spatial and temporal variations in the number of species collected during one year period.

The stations sampled in the estuary show striking variations in the number of species, and in the number of individuals collected at different dates. Spawning, recruitment of juveniles, feeding migrations and/or displacement caused by abiotic conditions greatly influence the spatial and temporal distribution of ichthyofauna observed in the Espiritu Santo River estuary during the year of sampling. Variations in the number

Table 6: Number of species per station per month.

Station: February, March, May

Note: The text "alah] | adolddaasdaddadda 4" and "wo3 8 5 4s March 3 ' Cr jorit ' 8 6 2 8 4 2 7 May 2 8 5 2 nm on wm o3 sone 2 5 es 5 8 1" appear to be either encoded information or errors in the original text and cannot be corrected without further context.

Mangrove and intertidal marsh grass, where the different requirements for food and space of many different species can be satisfied. The lowest number of species was observed at station 1, where 19 species were collected. Although station 1 showed a higher number of individuals than station 7, 26 species were taken at the latter. Some species caught at station 1 were represented by a large number of individuals. Fish species collected were recorded in terms of their frequency of occurrence in the samples for each station, and classified into various categories with regard to their occurrence. The following relative terms were used to express population status:

Abundant: The species were collected in nine (9) to twelve (12) samples for that station. Juveniles and adults were captured.

Common: The species were collected in five (5) to eight (8) samples for that station.

Occasional: The species were collected in one (1) to four (4) samples for that station. Occurrence of the species is usually due to migration into the station.

This symbol was assigned to those species represented by only one individual. The low frequency in the samples (annual occurrence of 1.04) gives more realistic categorical evaluation. These data are summarized in Table 7.

The fish populations collected from the Espiritu Santo River estuary consist mainly of occasional visitors (Table 7). Most of these occasional visitors into the estuary were migratory species and dominated the samples in which they occurred. A high number of these species showed ripe or near ripe gonads, supporting the hypothesized function of the estuary as a spawning ground. Species occurring only once in the whole year of sampling were probably found present at this level due to the sampling and/or the environmental conditions existent at that station at a particular time. Sampling technique could explain the low frequency of occurrence for species like *S. plagivsa*, *L. laevigatus* and *A. rol* (adults) since gill nets had low efficiency in capturing these.

Fishes (Martin, 1972). Variations in salinity or the amount of freshwater at a particular time in a station will determine the presence of a species. Another aspect which should be considered as influencing the observed distribution is location preference. A high number of individuals caught in one locality established the preference of that species for that locality in the estuary. The high mobility exhibited by most fishes enables them to move to more suitable areas in a short time. The existing estuarine conditions may well dictate which species may inhabit.

Table 7. Occurrence and relative abundance rank of fish species in different localities of the Espiritu Santo River estuary based on frequency (= 12). (A= abundant, C = common, = occasional, += species represented by only one individual)

Species | Stations | Percentage of annual occurrence

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8

As marinor | - | - | - | - | 3.2

saurus | - | - | - | + | 2.08

Ap rostrata | = | - | - | - | 6.25

humeratis | - | - | - | - | 3.12

edentuus | - | - | - | - | 43.54

linatus | - | A | A | C | 37.50

indi | - | - | - | - | 48.75

pocinatus | - | - | - | - | 15.62

chrysurus | - | - | - | - | 6.25

voner | - | - | - | + | 2.08

Table 7 (Cont.)

Species | Stations | Percentage of annual occurrence

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8

soodei | - | - | - | - | 2.08

apodus | - | - | - | - | 1.04

griseus | + | - | - | - | 1.04

leproyi | - | - | - | - | 1.08

melanopterus | - | - | - | - | 2.08

eres | - | - | - | - | 6.25

ronchus | - | - | - | - | 18.75

Jamaicensis | - | - | - | - | 0.32

furniert | - | - | - | - | 9.38

mossambica | - | - | - | - | 13.54

curena | - | - | - | - | 35.41

barracuda | + | - | - | - | 1.08

guachancho | - | - | - | - | 1.08

Table 7 (Cont.)

Species | Stations | Percentage of annual occurrence

1 | 2 | 3 | 4 | 5 | 6 | 7 | 8

Searus sp. | - | - | - | - | 0.08

Virginicus | - | - | - | - | 0.08

625 Ls dispar ' 0 0 © 8.33 D. maculatus | 0 0 0 0 0 0 0 + 14.58 pisonis a a) * 37.50 G dormitor = ©
6 0 0 * 29.17 tajesiea ho + 2.08 soporator oc 0 0 * 13.54 boleosona oo ° + 6.25 cceanicus | + "1.08
spe, ' oo + 6.25 eptures oo "3a Se regalis ' 00 0! 5.20 ©. spilopterus ! ° ° + 2,08 Ay Vineatus ° +
2.08 S. plagives + 1,08 L, Jnevigatus —* oo 0 kay 8. testudineus cot 625 ST

In this particular area, the fishes can move from one place to another without showing a particular preference for a specific area. The number of individuals during the year of sampling varied widely (Figure 4). The number of fishes caught per sampling date ranged from zero to 84 individuals, with the highest number of individuals per sample being caught at station 4. This occurred during August when *Dormitator maculatus* became abundant.

The estuary is subject to seasonal influxes of many species. Some of the species observed used the estuary for spawning, spending a short time period in the estuary, while others species such as *Anguilla rostrata* used the estuary as juveniles but mature elsewhere. The number of individuals of resident species also varied depending on their spawning and migrations within the estuary. The recruitment of juveniles of *Gobionorus dormitor*, *Dormitator maculatus*, and *Eleotris pisonis* resulted in a larger catch of individuals of these species.

For each month, the data for all stations were combined to determine the total number of individuals (Figure 5). The number of individuals fluctuates every three months but more sampling would be required to determine if this cycle of fluctuation is a natural phenomenon or an artifact of this particular study. If the effect is general, one possible explanation may be associated with the increase and decrease of zooplankton throughout the year (Canals, personal communication). Stomach content analysis data could possibly be related to these fluctuations since food availability (especially decapod larvae and juveniles).

Particular distribution of individuals as a species. The factors influencing the species diversity are: (1) the number of individuals, (2) the number of species, and (3) the distribution of individuals among the species. Both, number of species and number of individuals, formerly presented as

separate entities, do not account for how the number of individuals are allocated into species categories. This latter consideration can be gauged by means of the Brillouin's species diversity formula (Lloyd et. al., 1968). The species diversity index used in this study summarizes the distribution of the individuals among the species for each sampling date at a particular station. All individuals obtained using different sampling gear in the various different habitats within stations are included in the analysis. Comparative studies of habitats should take this difference in sampling methodology into account to avoid misapplication or misinterpretation of the conclusions derived. Thus, the effect of pollution on species diversity, for example, can be misestimated unless the methodology used in sampling is identical at each station. Species diversity information is summarized in Figure 6, a three-dimensional graphic presentation in which date, station-number and species diversity are plotted in the conventional Cartesian coordinates X, Y, and Z respectively. The graph is based upon numerical values given in Appendix Table 2. The February catch consisted of 117 individuals representing 22 species. The highest species diversity occurred at station 3, where 70% of the species collected were marine species. Species diversity for March ranged from 1.9264 (station 3) to 0.6856 (station 5) while the range for April was 2.0935 (station 2) to 0.4010 (station 7). The maximum species diversity for May was obtained at station 7 (SD 2.7778 bit/individuals) and the minimum at station 4 where only two individuals were caught. The June species diversity ranged from 2.0280 (at station 5) to zero at station 6.

When only one specimen of *7. lepturus* was collected, while in July the maximum species diversity was 2.4227 (at station 2) and the minimum was 0.5000 at stations 4 and 8. The maximum species diversity in July was attributable to observations of *M. atlanti* (2), *A. elupeoides* (10), *O. Linestus* (3), *C. ensiferus* (3), *C. undecimalis* (0), *D. zhombeus* (1), *G. cinereus* (2), *B. rhonchus* (3), *M. curema* (1), *E. pisonis* (1) and *G. dormitor* (2). The August catch consisted of 136 individuals representing 22 species, with the maximum species diversity occurring at station 6 (1.8533 bit/individuals). The September maximum species diversity occurred at station 1 (1.6759 bit/individuals) and decreased to station 5 where three *B. soporator* were collected along the shore. The number of fish collected in October was considerably less than previous sampling periods, with only 50 individuals representing 18 species caught. The maximum species diversity was obtained at station 1 (21.6130 bit/individuals) when surface and bottom salinities were 12 ppm and 64 ppm respectively. During November, a total of 147 individuals representing 25 species were collected, with a maximum diversity of 2.6373 bit/individuals at station 4. At station 7 only one *B. rhonchus* was collected. December species diversity ranged from 1.9656 (station 4) to 0.5000 at stations 5 and 6. The January maximum species diversity occurred at station 5, with an index of 1.9028 bit/individuals. The minimum species diversity was at station 4, where *O. oglinum* comprised 84.62% of the catch. Station 1 showed a gradual increase in species diversity from February to April. Marine species such as *M. curema*, *Q. oplinum* became abundant during this period. From May to June, the diversity was reduced to a minimum at station 1, while stations 5 and 6 reached their maximum values. Diversity indices increased from September to November in station 1. The migrations of *A. monticola*, and the presence of *B. rhonchus*, *C. latus* and *A. tajasica* contributed to this increase.

Species diversity for Station 2 ranged from 1.0859 to 2.4227 bit/individuals. During the February to March sampling period, *M. curema* and *O. oglinum* constituted 84.91% of the catch. The sample for April and May had the same number of species and individuals, but the diversity index differed due to the frequency distribution of the individuals among species. In May, two species accounted for 62.50% of the catch. From April to June, the species diversity decreased, but rose abruptly in July when it reached its maximum value. Stomach contents of the different species collected indicated a large number of decapod larvae at this time. During the August to September sampling period, the

diversity decreased, but from October to January the index fluctuated from 1.5773 to 1.7556 bit individuals.

The peak value of species diversity at Station 3 occurred in February when 70% of the species collected were marine species. The decrease noted in the diversity for March is due not only to the decrease in the number of species, but also to an increase in the number of *O. oglinum*, which constituted 48.15% of the catch. Significantly, the reproductive period of this species has been established as occurring in March (Martin, 1974). A decline in diversity continued during the following months with the exception of June and October, in which several species collected were represented by only one individual. In November, *D. paculatus* constituted 73.68% of the catch.

Species diversity for Station 4 ranged from 0.5000 to 2.6373 bit/individuals. Low diversity values were obtained from February to July. During these months, this area was covered by water hyacinth, which in turn was washed away by heavy rains in the upper watershed during the month of August. After this, the number of species increased from 2 to 6, accounting for an increase in the species diversity from 0.5000 to 1.0939 bit/individuals. A higher value was expected due to the gain in species number, but the large number of *D. saculatus*, which constituted

76.19% of the catch tended to maintain a lower index. The maximum species diversity for this station occurred in November, when eleven species containing 34 individuals were collected. The reduction in the number of species and the recruitment of *E. pisonis* juveniles are responsible for the lower diversity in December and January. Species diversity for station 5 ranged from zero (all individuals collected belonging to one species) to 2.4828 bit/individual. Indices for February and March were 1.5620 and 0.6856 respectively, and an increase in April was noted when eleven individuals representing eight species were collected. Most species collected in April were marine species such as *A. narinari*, *O. optimum*, *C. 2*, *virginicus* and *A. Lineatus*. Species diversity increased in May due to the additional species collected such as *C. jansicensis*, *L. breviceps*. A decline in species diversity was noted during June when many species collected previously were not found in catches from that period. In August most species collected were Gobiidae. The same situation persisted in September when only three saporator were collected. The species collected in October were *C. edentulus* (4), *C. ensiferus* (1), *A. unde* (0), *G. datus* (2), *L. Jgcus* (1), while in December only two species, *O. optimum* and *E. pisonis* were caught. In January, most species were collected among shore vegetation and under water hyacinth, 24 specimens of *A. zostrata* were collected in one sample. Species diversity for station 6 fluctuated from 1.1510 to 1.4713 bit/individuals from February to April. Some species collected were *G. hippos*, *S. regalis*, *B. ronchus*, *E. faber* and *C. spilopterus*. In May the diversity index reached its maximum value when eleven species were collected. Five of these 11 species were represented by only one individual. Stomach contents of *C. undecimalis*, *M. furnieri*, *B. ronchus* and *P. virginicus* revealed decapod and fish remains. In June only one *S. Aepturus* was caught at station 6 and it was a gravid female. Significantly,

During July, nine individuals collected showed ripe gonads. Species diversity gradually increased from July to August. Three species, *B. saporator*, *G. spes*, and *L. dispar* were common in the mangrove oyster communities during August to October. These three species constituted 89.76% of the catch for that period. The species *Gobiososa spes* and *Lypinoblennius dispar* seemed to be highly dependent on the oyster communities since it was observed that in December, when oyster communities became scarce, the number of *G. spes* was reduced and no *L. dispar* was collected.

Also, a mat of water hyacinth moved into this station from higher stream flow in the watershed at this time and the hyacinth root system appears to have conveyed species such as *E. pisonis* and *O. lineatus*, which were previously uncommon at station 6. *Opisthonema oglinum* constituted 76.00% of the catch for the first three months of sampling at station 7. The maximum diversity for this station occurred in May. This increase in species diversity was due to the presence of many species that evidenced spawning conditions such as *A. hepsetus*, *C. nesis*, *L. breviceps*, *T. lepturus*.

Species *A. hepsetus* appeared for the first time in the collections and it may have been even more abundant than the collection data showed since *S. guachancho* stomach consists of anchovy remains. The content analysis revealed large quantities Carangidae collected included *C. latus*, *C. cheysurus*, *S. vomer* and *T. goodel*. Most species collected in May were limited to this period and the loss of these species from the other sampling dates caused a reduction in the number of species and consequently a reduction in diversity. Also, the increase in numerical abundance of *T. lepturus* related to reproduction activities resulted in a lower index.

In August, fishing in this station was totally unsuccessful. Indeed, only scyphozoans (Jellyfish) were captured in the nets. The diversity value for station 8 was more variable temporally, with peaks occurring in April (maximum diversity), June.

The months in the text should be spelled as "August" and "December". "*Mugil curena*" comprised 70.58% of the February collection, but the number of *M. curena* decreased in subsequent samples. Three *S. regalis* collected in June had stomachs full of fish remains and the gonads were inactive. Other species collected were *C. hippos*, *P. virginicus*, *O. oplinun*, *D. rhosbeus*, and *M. eur*.

In July, *C. chrysurus* constituted 75.00% of the catch. One *Scarus* species was collected in October, but a blue-crab (*Callinectes* sp.) fed on it. The blue-crab eliminated much of the catch and it is not known if there had been more than one *Scarus* sp. present. In December, *Harengula humeralis* appeared in the sample for the first time. Hue and *P. virginicus* stomachs were full of fish remains. *O. oplinun* constituted 84.62% of the January catch at station 8.

The numerical abundance of this species probably was due to migration into the estuary. The shore fish populations consisted of *S. testudineus* which can be found along open shore or hidden in the mangrove root. One characteristic of the Rio Espiritu Santo River estuary fish populations is that many species are not permanent residents but only spend part of their life cycle in the estuary.

For most samples, fluctuations in species diversity were indicative of the changing composition of the ichthyofauna of the estuary, but in some collections, the fluctuations of the diversity index resulted in the same or nearly the same values. This would suggest that the collections are equivalent. However, the determination of the species diversity for a collection does not take into account the nature of the individuals. One individual of a marine species can be substituted by one individual of a freshwater species as a result of abiotic or biotic factors, thus species diversity may be seasonally compensating.

Since all stations were affected by migration, it was necessary to determine the annual species diversity for the station to eliminate the seasonal compensation. Species diversity indices were calculated for each of the eight stations by

The text is corrected as follows:

Each station is considered as one sample. Pooled samples contain all species found at a station during the year and the results are presented in Table 8. The species index gradually increased from station 1 to station 3. At station 4, the minimum value for the index was obtained while station 5 showed the highest value. The differences in depth, salinity and water quality may act as barriers to upstream migration of the fish and additional investigation is required to determine if any of these factors contribute to station-to-station differences in diversity. The heavy growth of water hyacinth (generally indicative of organic enrichment) at station 4 during the first months of sampling can contribute to the difference in species diversity. Thus, although stations 4 and 5 are close together, the bloom of water hyacinth present at station 4 did not extend to station 5. While salinity increased from stations 6 to 8, the number of species decreased resulting in lower diversity values, although fish collected were, in general, larger.

Community Similarity Indices were characterized using calculated community Similarity indices. The species composition of individual stations were compared using a modified coefficient of community, or an index of similarity (Bray and Curtis, 1957) which takes into consideration the relative abundance of the individuals among the species. The Similarity index is defined as $2u/(a+b)$, where a is the sum of all values for the first station, b is the same as a but for the station with which comparison is sought, and u is the sum of the lower of the two quantitative values for those species shared by the station compared (Bray and Curtis, 1957). The index is 1 when sample stations have identical populations.

Table 8: Pooled Species Diversity by Station Number

Number Species Diversity

Station Species (bit/individual)

1 22 3.2147

2 23 3.2966

3 24 3.3797

4 23 2.9733

5 33 4.3410

6 28 3.7919

7 26 3.5384

8 21 3.2864

The value is 0 when they are totally dissimilar. The numerical measure of fauna similarity within stations derived from the Bray and Curtis index is given in Table 9 and depicted graphically in Figure 7. Station 1 gives the best indication of the similarity between this location (upper part) and other stations closer to the sea (Figure 7). There is a gradual decrease of species shared by stations as habitats change due to salinity and/or bordering vegetation type. The similarity between stations compared with station 1 is inversely proportional to their distance from one another. Station 2 showed the greatest similarity with station 3 with a Community Similarity index of 0.661 (Table 9). The faunal similarity of station 2 with other stations decreases from station 3 through station 7 and then increases at station 8, an unexpected result. A detailed examination of the data shows that this similarity between station 2 and station 8 was due to the relatively high number of individuals of species *Mugil curema* and *Opisthonema oglinum* found at both stations. However, if faunal similarity is recalculated without taking these two species into consideration, the similarity between stations decreases gradually (Table 9).

Table 9: Matrix of the Bray & Curtis (1957) index of similarity. (See text for explanation)

1	2	3	4	5	6	7	8
158	245	294	60	403.95	0.26	0.117	
2	661.512	459.362	301.422	/(.160)*			
3	5	488	376.361	.422/(.155)*			
4	5	1	.328	202	181		
5	1550-350	.280					
6	271.280						
7	408	1					

Station 3 has more similarity with neighboring stations than with stations further away. Bordering vegetation common to the station allows the presence of species such as *Eleotris pisonis* and *Oostethus lineatus*. Unexpected similarity between stations 3 and 8 was due to the high number of individuals of *M. curema* and *O. oglinum*, as was the case at station 2. Recomputed data shows less similarity (Table 9).

Station 5 showed more...

The text has more similarity with Station 3 than with Station 1. This similarity cannot be explained in terms of bordering vegetation, but the occurrence of species such as *Aetobatus narinari* (Spotted Eagle Ray) at Station 3 would appear to depend upon the salinity gradient found at particular times. Station 6 showed less similarity with Station 7 than expected, and a high similarity with Station 5. Differences between Stations 6 and 7 may be due to salinity differences found during high and low

tides (Table 2), and the proximity of Station 7 to the sea may be decisive in explaining why the index for Stations 6 and 7 is not higher. As expected, Station 8 shows a great dissimilarity with Station 1, but more similarity than expected with Stations 2 and 3. Station 8 is located at the river mouth where marine species enter the estuary. The number of marine species shared with other localities contributed to their similarity, although there was a very pronounced difference in salinity and bordering vegetation. The community similarity was characterized using Jaccard Coefficients (Srover and Zar, 1977). This index is defined by the equation: $C_{xy} = C / (S_x + S_y - C)$; where S_x and S_y are the number of species in each community under comparison, respectively and C_x is the number of species common to both stations. This index is predicated on the presence or absence of species at the stations under comparison and not on the distribution of individuals among the species as with the Bray and Curtis index of similarity. These data are presented in Table 10. When comparing stations based only on the presence and absence of species without taking into consideration their relative abundance, rare species contribute heavily to the similarity, since their contribution to similarity is the same as the contribution of numerically important species. On the other hand, when numerical abundance is considered, the effect of rare species is reduced. Both community similarity indices have shown that the areas into which the estuary was

"Arbitrarily divided during station designation, differences in species composition, food availability, and salinity contribute heavily to these differences.

Table 10. Matrix of the Jaccard coefficient of community (see text for explanation)

	1	2	3	4	5	6	7
1	s615	519	.367	.368	.343	.284	
2	4-800	500	.400	.342	.225		
3	S17	447	.389	.263			
4	410	.282	.333				
5	2566	405					
6	2385						
7	-250/(.206)#	+294)	(250)	2333			
	cet	429	am				

Summary and Conclusions

A twelve-month survey was carried out to collect, identify, and describe the ichthyofauna components of the Rio Espiritu Santo River estuary. Comparative analyses were conducted between the type and number of fish collected on a spatial and temporal basis. Sixty species were encountered at eight localities in the estuary. Only a few species were captured throughout the year, but their presence was restricted to the upper zone of the estuary. These species were *Oosthetus Lint*, *Eleotris pisonis*, and *Gobiomorus dormitor*. Most species collected were occasional visitors to the estuary, since they were only captured during a maximum of 4 sampling periods at any given station. The migration of most of the species was found to be in response not only to abiotic factors, but also to species-specific reproductive cycles. Trophic relations appeared to greatly influence the movement of these species in the estuary.

Migratory patterns were related to the reproductive cycle in which the spawning migrations of the

adults and the recruitment of juveniles resulted in variations in species composition and in the number of components of each sample. Stomach content analyses revealed that the majority of fish could be considered as secondary consumers feeding on insects, crustaceans, molluscs, and other fish. The secondary consumers feed on only one prey item or can include a more variable diet depending on several factors such as prey abundance. Future studies should examine the relationship between food abundance changes along the estuary and the pattern of prey."

Utilization by fish.

The fluctuations in species diversity values of collections were due to the temporal and spatial separation of the fish populations. These spatial and temporal separations combined with trophic variability allowed more species to utilize the estuary than if they were in constant direct competition. However, over a long period of time, species diversity may be high. The similarity indices show that each sampling location in the estuary supports different fish populations. The temporal change in environmental conditions at each locality and the biological characteristic of the species operate in such a way as to permit the best utilization of the estuarine resources. Any modification of the estuarine environment could affect the fish populations and their trophic relationship. This is especially true of the coastal commercial and sport-related fish species.

Censuses of fish populations as performed in this study presented various difficulties. The chief limitation to obtaining substantial data on fish populations was in gear selectivity (Martin, 1972). The fish are too mobile and too clever to be captured in most sampling gear and they may avoid the nets by moving to areas which lie outside the sampling stations. Also, all habitats cannot be sampled with specific gear. For this reason, any generalizations predicated on censuses of fish populations as performed in this study will always be relative.

Despite the weaknesses in the collection procedures, the results presented here illustrate the continuously changing nature of the ichthyofauna components in the Espiritu Santo River estuary during an annual cycle.

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APPENDIX

Appendix Table I, List of scientific and common names of fish species in the Espiritu Santo River estuary.

Scientific Name | English Name | Spanish Name

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Myliobatidae | Spotted Eagle Ray | Chucho, Mariposa

Aetobatus narinari | Ladyfish | Piojo, Sacabi

Megalopidae Megalops atlanticus | Tarpon | Sabalo

Anguillidae Anguilla rostrata | American Eel | Anguila

Harengula humeralis | Redear Herring | Sachelo
Opisthonema oglinum | Thread Herring | Arenque
 Engraulidae *Anchoa hepsetus* | Striped Anchovy | Bocua
Anchoviella lepidentostole | Bocua Anchovy | Bocua
Cetengraulis edentulus | Whalebone Anchovy | Bocua
Strongylura timucu | Atlantic Needlefish | Agujea
 Poeciliidae *Poecilia vivipara* | Top Minnow | Guppy
 Syngnathidae *Oostethus lineatus* | Opossum Pipefish | Trompetero
Pseudophallus mindii | Short Nose Pipefish | ?
Centropomus ensiferus | Swordfin Snook | Robalo Machuelo
Centropomus pectinatus | Tarpon Snook | Robalo Sachelo
Centropomus undecimalis | Snook | Robalo Machuelo
Caranx hippos | Crevalle Jack | Jurel
Selene setapinnis | Horse Eye Jack | Jurel Ojón
Chloroscombrus chrysurus | Bumper | Casabe
Lactophrys quadricornis | Boxfish | Jorobado
Tetraodon cutcutia | Pufferfish | Patoneta

Appendix Table 1. (cont.)

Scientific Name	English Name	Spanish Name
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<i>Lutjanus apodus</i>	Schoolmaster Snapper	?
<i>Lutjanus griseus</i>	Gray Snapper	?
<i>Lutjanus jocu</i>	Dog Snapper	?
Gerreidae <i>Diapterus olisthostomus</i>	Mojarra	?
<i>Diapterus rhombeus</i>	Silver Mojarra	?
<i>Eucinostomus gula</i>	Silver Jenny	?
<i>Eucinostomus harengulus</i>	Herring Silverside	?
<i>Gerres cinereus</i>	Yellowfin Mojarra	?
Haemulidae <i>Pomadasys crocro</i>	Burro Grunt	?
Sciaenidae <i>Cynoscion arenarius</i>	Sand Seatrout	?
<i>Cynoscion nebulosus</i>	Spotted Seatrout	?
<i>Menticirrhus americanus</i>	Southern Kingfish	?
<i>Pogonias cromis</i>	Black Drum	?
Ephippidae <i>Chaetodipterus faber</i>	Atlantic Spadefish	?
<i>Tilapia mozambica</i>	Mozambique Tilapia	?
Mugilidae <i>Agonostomus monticola</i>	Mountain Mullet	?
<i>Mugil curema</i>	White Mullet	?

Corrected Text:

Meet the Sphyraenidae 'Sphyraena barracuda Sphyraena guachancho Scaridae Scarus sp.
 Polynemidae Polydactylus virginicus Blenniid Lupinoblennius dispar Schoolmaster snapper Gray
 snapper Dog snapper Irish pompano Rhomboid mojarra Mottled mojarra Blackfin mojarra Striped
 mojarra Yellowfin mojarra Freshwater grunt. Ground drummer Mongolar drummer Drummer,
 Creaker Spadefish Tapia mountain millet White mullet Liza mullet barracuda 'guachanche

Threadfin blenny -85- Pargo amarillo Pargo prieto Pargo colorado Mojarra Morarreta Mundi
Espuela, Mojarra Miniana viejo dentin, Dientén coving Cabexén Paguala Ritapia dajao Javea Lita
picua picuilla loro, cotorro barb

Appendix Table I. (cont.) Eleotridae *Gobionorus dorsitor* Gobiidae *Bathygobius soporator*
Gobionellus oceanicus *Gobiosoma* sp. Trichiuridae *Trichiurus lepturus* Scombridae
Scomberomorus regalis Bothidae *Citharichthys spilopterus* Soleidae *Achirus lineatus*,
Cynoglossidae *Symphurus plagiusa* Tetraodontidae *Lagocephalus laevigatus* *Sphoeroides*
testudineus Fat sleeper Spinycheek sleeper Bigmouth sleeper River goby Frillfin goby Darter goby
Hightail goby Cutlassfish Cero mackerel Bay whiting Lined sole Blackcheek tonguefish Smooth
puffer Checkered puffer 86 Moroneillo Morn Sage Moroneillo Sable, Machete Sierra Lenguado
Lenguado tambor, Ratón tamborin

The remaining text appears to be random and nonsensical, and I'm unable to correct it. It could be
a coding error or a language I'm unfamiliar with.

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context or a clearer text?