Rev. Biol. Trop., 31(1): 75-101, 1983

Occurrence, distribution, abundance and diversity of fishes in the Gulf of Nicoya, Costa Rica

Charles E. Bartels and Kent S. Price
University of Delaware, College of Marine Studies, Lewes, Delaware 19958, U.S.A.
Myrna I. López and William A. Bussing
Universidad de Costa Rica, San Pedro, Costa Rica

(Received for publication December 13, 1982)

Abstract: Trawl samples of demersal fish populations within the Gulf of Nicoya, Costa Rica were conducted during February and July, 1979 and April, 1980 in an attempt to define basic abundance, diversity and distributional patterns. Seventeen day and three night samples produced 6,441 fishes of 107 species during the February cruise. Twenty day and two night samples produced 9,220 individuals of 131 species during the July cruise. Twenty day samples produced 14,151 individuals representing 125 species taken during the April cruise. A total of 214 species were collected during this study.

The Gulf of Nicoya may be divided into three zones on the basis of the physical characteristicsof the stations (water temperature, dissolved oxygen, salinity, depth and distance from the mouth of the Gulf). Few changes in the position of these zones occurred during the study period, indicating a relatively stablees-tuarine configuration from a biological perspective, under the influence of a wet and a dry season. No significant seasonal changes in the number, biomass, percent occurrence, diversity of partitioning by size class of fishes were observed.

Two major types of fish distributional patterns were observed. Several species were ubiquitous and were found throughout the Gulf in varying abundances. Other species were restricted to either the upper or lower Gulf. Dominant groups in the upper Gulf include the sciaenids, sea catfishes (Ariidae) and flatfishes (Soleidae, Cynoglossidae and *Syacium ovale*). These fishes tend to inhabit the warmer, shallower, less saline waters of the upper Gulf. Flounders (Bothidae), gobies (*Bollmannia* spp.), morays and congers (*Hildebrandia nitens, Priodonophus equatorialis* and *Muraenesox coniceps*) and several other species dominated the deeper, cooler, more saline lower Gulf.

While there have been several studies of various fishes or small groups of fish in the Gulf of Nicoya, these studies have not, for the most part, dealt with the overall distributional pattern of demersal fishes throughout the entire Gulf. Peterson (1956) studied the biology, taxonomy and ecology of anchovies and sardines in the Gulf. Brittan (1966) described a small collection of shore zone fishes, while Bussing (1969) listed the families of the marine fishes of Costa Rica. Erdman (1971) provided life history information for 55 species of marine fishes with special emphasis on sharks, rays and jacks. Leon (1973) studied the occurrence, and distribution of marine fishes in the upper and middle Gulf. He reported dominance of the upper Gulf by sciaenids in terms of biomass, number of species and number of individuals captured. Stevenson (1978) attempted to predict the maximum sustainable yield of selected fish species in the Gulf using the Beverton-Holt yield model.

The reader is referred to Voorhis *et al.*, (1982), Epifanio *et al.*, (1982), Maurer *et al.*, (1982) and Bartels (1981) for recent companion studies of the physical oceanography, chemical oceanography, megabenthic invertebrates, and fishes of the Gulf of Nicoya. The thesis bv Bartels (1981) contains much of the raw data analyzed in this study.

The purpose of this study is to describe the occurrence, distribution, abundance and diversity of demersal fishes in the Gulf of Nicoya and to attempt to define some of the factors responsible for these findings. This research was approached with four major objectives in mind. The first was to classify the Gulf into biologically functional zones on the basis of physical characteristics (water temperature, dissolved oxygen, depth, salinity, and the distance to the mouth of the Gulf) and the correlation of fish species occurrence with these physical parameters. The second objective was the identification of seasonal and zonal differences in dominance, diversity and occurrence. A third objective was to identify any day-night differences in species occurrence, diversity and dominance and the final objective was to identify anv juvenile-adult partitioning within the estuary.

The study was undertaken as part of a larger Sea Grant sponsored project designed to promote training, technological exchange and preliminary research between the University of Delaware and the University of Costa Rica. Hopefully, these efforts will help identify additional potential fisheries for the people of Costa Rica and provide a stronger basis for future management of fisheries resources. In particular, this study will provide basic information concerning the distribution of important fish species and possible key factors which lead to the observed patterns of their distribution.

MATERIAL AND METHODS

The Gulf of Nicoya is located on the west coast of Costa Rica between the Peninsula of Nicoya and the mainland (longitude 85°W and latitude 10°N; Fig. 1). The gulf is approximately 80 kilometers in length and 45 kilometers wide at its greatest width (near mouth). Mangrove swamps fringe most of the upper Gulf while steep, forested hills bound the lower Gulf. Fresh-water input is dependent on three main rivers. The Río Tempisque flows into the upper end (Fig. 1). This is the largest river entering the gulf and drains mostly agricultural land (Blutstein *et al.*, 1970). Two smaller rivers, the Río Barranca and Río Grande de Tárcoles, enter the middle to lower gulf along its east coast.

The west coast of Costa Rica is under the influence of seasonal rains. The wet season generally occurs from May through November (Leon, 1973). Due to the seasonality of precipitation in this area, there are significant variations in the discharges of the rivers and streams (Peterson, 1960) which contribute to changes in salinity and density distribution patterns (Voorhis *et al.*, 1982). The increased rainfall and subsequent runoff appear to contribute to increased nutrient and turbidity levels during the rainy season, particularly in the upper Gulf (Epifanio *et al.*, 1982).

The data used in this study were taken during three cruises in the Gulf of Nicoya. The first, February, 1979 consisted of 20 collections from 17 stations (3 stations were duplicated as night stations). The second cruise took place during July, 1979 and consisted of 22 collections at 20 stations (2 stations were duplicated as night stations). During April, 1980, a third cruise consisted of 20 day stations. The location of these stations (Fig. 1) was chosen to provide coverage of the majority of the Gulf. The addition of Stations 19, 20 and 21, in the July and April cruises, was made to enhance the coverage of the upper gulf.

Collections were made at each of the stations using a semi-balloon shrimp trawl (30 ft head rope and 37 ft foot rope at the mouth with 1 1/2 inch stretched mesh #9 thread body and 1 3/8 inch stretched mesh #18 thread bag). The net was towed at 1-2 knots with the prevailing current for a period of 30 minutes. A cable length of 5 or 6 to 1 (length to depth) was used to ensure that the trawl was fishing the bottom. If the net became fouled or failed to function properly the haul was repeated.

All fish captured were sorted to species whenever possible. Identifications were the responsability of López and Bussing, whereas Bartels and Price accounted for the ecological aspects of the study.

Identifications were completed using voucher specimens for the first cruise and were done on board ship during the second and third cruises. These fish were then measured (total length) to the nearest centimeter. Disk width was used instead of total length for all skates and rays. If there were greater than 50 individuals per species, a 50 individual subsample was measured. Subsample and total samples were weighed

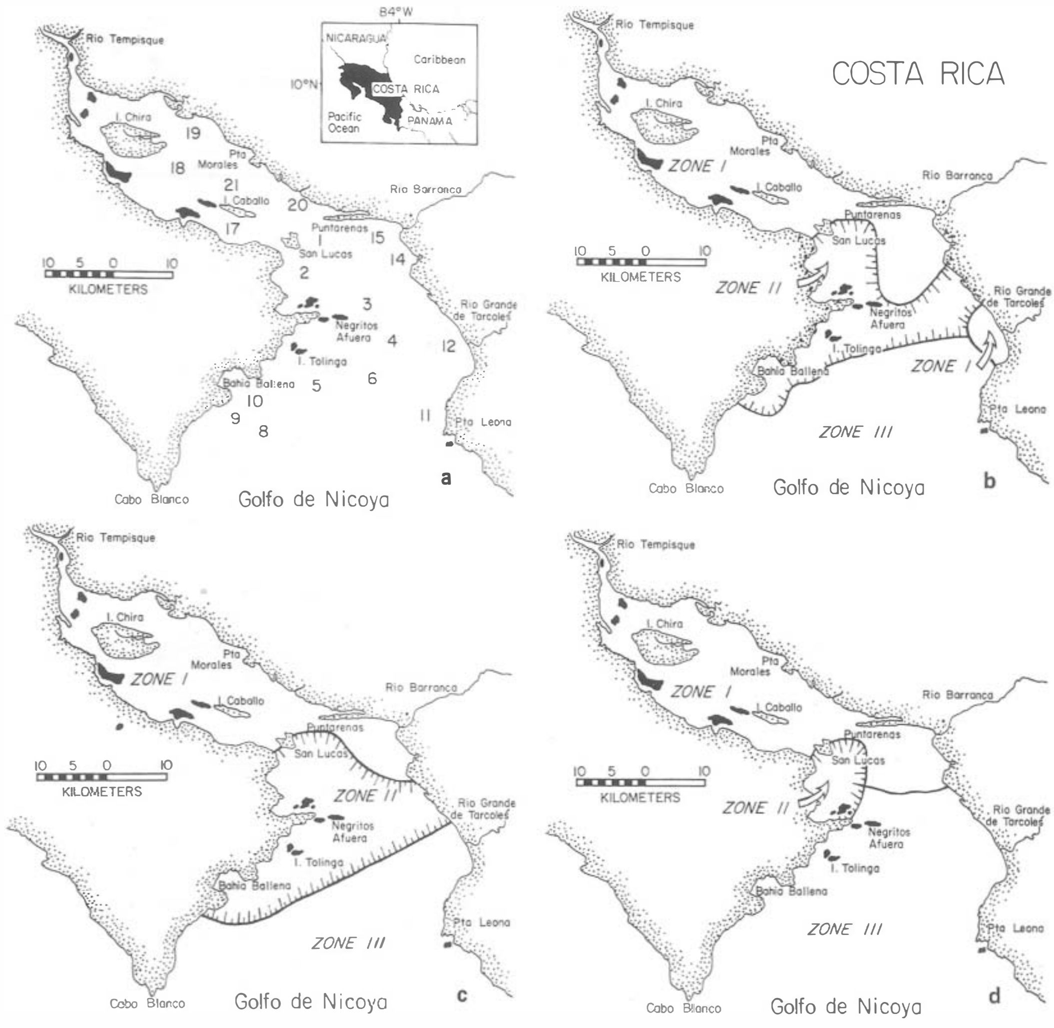

Fig. 1a. Gulf of Nicoya, Central America: Location of stations for fish survey, February and July 1979 and April 1980.

Fig. 1b. Gulf of Nicoya, Central America: Separation of the Gulf into zones by means of Ward's Euclidean Distance Cluster Analysis (February, 1979).

Fig. 1c. Gulf of Nicoya, Central America: Separation of the Gulf into zones by means of Ward's Euclidean Distance Cluster Analysis (July, 1979).

Fig. 1d. Gulf of Nicoya, Central America: Separation of the Gulf into zones by means of Ward's Euclidean Distance Cluster Analysis (April, 1980).

to the nearest 0.1 kilogram using a grocery scale. For those species with greater than 50 individuals, the number of individuals was calculated by extrapolating the number to weight ratio of the 50 individual subsample.

The physical oceanographic data (water temperature, salinity, dissolved oxygen, depth and distance to the mouth of the Gulf) were recorded during the cruise by other researchers as another part of the International Cooperative Sea Grant Program (University of Delaware/University of Costa Rica) and are reported elsewhere (Voorhis *et al.*, 1982 and Epifanio *et al.*, 1982). Hydrographic data used in this analysis

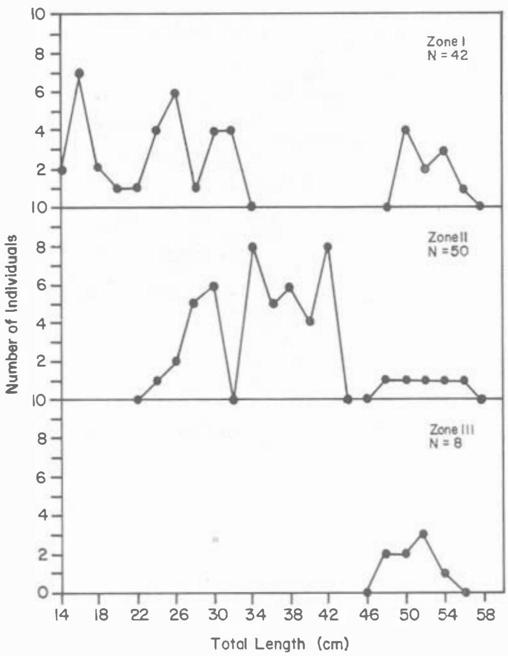

Fig. 2. Gulf of Nicoya, Central America: Length distribution of *Micropogonias altipinnis* by zone.

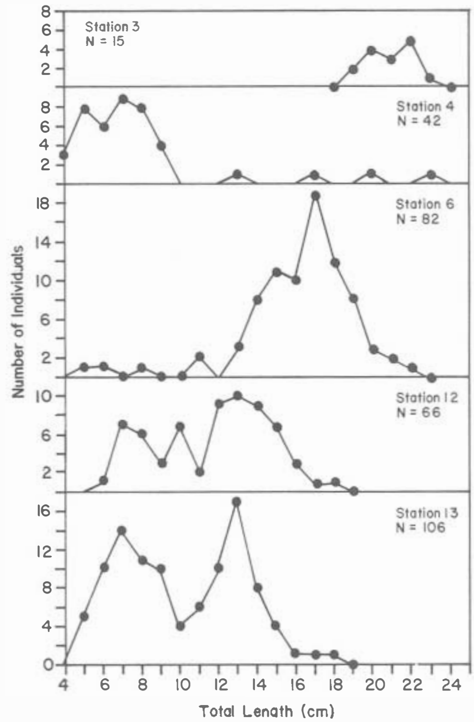

Fig. 3. Gulf of Nicoya, Central America: Length distribution of *Larimus pacificus* by zone.

were collected at each trawl station within a meter of the bottom, which best reflects the physical environment from which the fishes were collected.

Analysis of these data took several forms. The Gulf was divided into zones using cluster analysis (Ward's Method Euclidean Distance) of the physical data. The occurrence of fish species was correlated with these zones. This was done by means of percent of occurrence (# stations present/ # stations per zone) within each zone (Salzen, 1957). The relative importance (dominance) of fish species within each zone and the Gulf was calculated using the Biological Index Value (BIV)*. The BIV was calculated for both numbers of individuals and biomass. The percent of maximum BIV was used in order to allow comparisons among the various zones. The BIV takes into account the number or weight of individuals per species and the frequency of occurrence of that species (Subrahmanyam and Drake, 1975). For those stations at which both night and day samples were taken, day-night differences in species occurrence and abundances were described. Also, length frequency distributions of selected species were used to identify potential partitioning of the gulf by adults and juveniles. The species selected were those with a high number of individuals and a relatively large range of occurrence within the estuary or those species with potential commercial value. Determination of the stage of maturity of these fishes was obtained from the literature. Seasonal differences in length frequency distributions, in terms of their position in the estuary, were also determined.

Four diversity indices were calculated (Dahlberg and Odum, 1970). These indices were calculated for each cruise (sample period) and for each zone identified as part of this study. The Shannon-Weiner Index ($H' = \sum_{i=1} P_i \log_e P_i$ where P_i = the proportion of individuals in the *ith* species) was used to measure the "total" diversity of these areas. This index is influenced by

*BIV = species rank (wt. or #)/ # of species.

species richness and the equitability of species abundance (Dahlberg and Odum, 1970; Pielou, 1974). A species richness index ($D = [s - 1]/\log_e N$, where N = the number of individuals and s = the number of species) was also calculated (McErlean, *et al.,* 1973; Cain and Dean, 1976). This index reflects the changing number of species in relation to sample size. Lloyd and Ghelardi's (1964) equitability index ($E = s'/s$ where s= number of species and s' = number of species predicted by MacArthur's broken stick model) and Pielou's (1974) evenness index ($J = H'/H_{max} = H'/H \log_e s$ where H = Hmax when all species are equally abundant) reflect the evenness in the distribution of species abundance.

The species richness index and the two evenness indices were used to evaluate the causes for fluctuations in the Shannon-Weiner Index.

These diversity indices were used in an attempt to identify trends in fish distribution and the relative favorability of conditions for fish life at different locations throughout the Gulf. Analysis of variance was calculated to determine any significant differences in diversity among the seasons and zones (Dahlberg and Odum, 1970; Subrahmanyam and Drake, 1975). If seasonal or zonal statistical significance was found, Duncan's New Multiple Range Test was performed to determine the significantly different seasons or zones (Subrahmanyam and Drake, 1975).

Possible relationships among physical properties of the Gulf and the occurrence of fish species in those areas and among the fishes themselves were identified by using two measures of correlation. These were Spearman's Rho and Kendall's Tau (both non-parametric). These measures of correlation use rankings of the variables instead of absolute values and produce values between -1 and +1 which represent strongly negative and strongly positive correlation between variables, respectively (Conover, 1971). Correlation coefficients and their level of significance were calculated for species which are ranked highly in terms of number, biomass, percent occurrence and/or BIV. These species were correlated with the physical data as well as with each other. Numbers of individuals collected were used in this analysis. Correlation values obtained from this analysis should provide a starting point for identifying what factors are important in determining the distribution of fishes within the Gulf of Nicoya.

RESULTS AND DISCUSSION

Division of the Gulf into zones: the Gulf of Nicoya was divided into zones by cluster analysis (Ward's Euclidean Distance) of the "abiotic" data. The analysis was carried out using three combinations and/or treatments of the data. These were as follows: 1) use of all "abiotic" data (dissolved oxygen, water temperature, salinity, depth, distance to the ocean and fish biomass/station) in nonstandardized form, 2) all data in standardized form (to reduce the effect of the different units used to measure the various data), and 3) all data except fish biomass/station (standardized).

Final division of the Gulf was carried out using standardized data without fish biomass/station. Standardized data were chosen because of the reduction in the effect of data units on the clustering of stations. The use of biomass was dropped because it is not a physical characteristic of the water column. Since these zones were to be defined on the basis of their physical characteristics, fish biomass had no place in the clustering process.

Using these standardized data, the stations within the Gulf were divided into two to five clusters. It was decided to divide the Gulf into three zones because it produced the most reasonable and manageable division of the Gulf and the use of more than three zones produced occasional singular, isolated stations as zones. The three zones/cruise obtained fit reasonably well with the anticipated division of the Gulf by observation and from previous studies (Leon, 1973; Stevenson, 1979). The relative size and position of the zones fluctuates according to the hydrography of the bay at the time of the cruise.

Listed below are the stations found in each zone for the three cruises. This division will be used throughout this study whenever zones are mentioned (Figs. 2,3).

TABLE 1

Gulf of Nicoya, Central America. Scientific, common and local (Spanish) names of fishes collected during the three cruises (February and July 1979 and April 1980)*

Scientific Classification	Common Name	Local Name
CHONDRICHTHYES		
Carcharhinidae	Sharks	Tiburones
Mustelus sp.	Smoothhound	
Dasyatidae	Stingrays	
Dasyatis longus	Stingray	Raya
Rajidae	Skates	
Raja velezi		
R. equatorialis		Raya
R. sp.		Raya
Rhinobatidae	Guitarfishes	
Zapteryx exasperata	Banded guitarfishes	
Torpedinidae	Electric rays	
Narcine entemedor	Electric ray	
Urolophidae	Stingrays	Rayas de espina
Urolophus halleri	Round stingray	
Urotrygon aspidurus		
U. chilensis		
U. mundus		
U. serrula		
U. sp.		
OSTEICHTHYES		
Antennariidae	Frogfishes	
Antennarius avalonis	Roughjaw frogfish	Zanahoria
Apogonidae	Cardinalfishes	
Apogon dovii		*Cardenal*
Ariidae	Sea catfishes	Bagres, cuminates
Arius dasycephalys	Sea catfish	Cuminate
A. furthii		
A. jordani		
A. seemani		
A. steindachneri		
A. sp.		
A. sp. 2		
Netuma platypogon		Bagre
Sciadeichthys troschelii		Cuminate colorado
Batrachoididae	Toadfishes	
Batrachoides gilberti	Toadfish	Perro
B. pacificum		
B. sp.		
Porichthys nautopaedium	Midshipman	

Scientific classification	Common name	Local name
Bothidae	Left-eyed Flounders	Lenguados
Azevia panamensis		
Bothidae sp.		
Citharichthys gilberti		Lenguado
C. platophrys		
Cyclopsetta querna	Flounder	Lenguado
C. sp.		
Engyophrys sanctilaurentii		
Etropus crossotus	Fringed flounder	
Lioglossina tetraophthalmus		
Pseudorhombus dendritica		
Syacium latifrons	Flounder	
S. ovale	Flounder	
Flounder sp.		
Branchiostegidae	Tilefishes	
Caulolatilus sp.		
Carangidae	Jacks and pompanos	Jureles
Alectis ciliaris	African pompano	
Caranx vinctus	Jack	Platanillo
Chloroscombrus orqueta	Pacific bumper	Bonito ojón
Hemicaranx leucurus		
Selene brevoortii		Palometa
S. oerstedii		
S. peruviana	Pacific moonfish	Palometa
Centropomidae	Snooks	Robalos
Centropomus armatus	Snook	Robalo
C. nigrescens	Snook	Robalo
Clupeidae	Herrings	Sardinas
Ilisha furthii		
Neopisthopterus tropicus		
Opisthonema bulleri		Sardina
O. libertate	Thread herring	Gallera
O. sp.		
Ophisthopterus equatorialis		
Congridae	Conger eels	
Hildebrandia nitens		
Cynoglossidae	Tonguefishes	Lenguados
Symphurus atramentatus		
S. fasciolarius		
S. melanurus		
S. sp. 1		
S. sp. 2		
Engraulidae	Anchovies	Anchoas
Anchoa eigenmannia		
A. ischana		
A. lucida		Bocona
A. naso		
A. panamensis		

Scientific classification	Common name	Local name
A. spinifer		
A. starksi		
A. walkeri		
Anchovia macrolepidota		
Cetengraulis mysticetus	Anchoveta	Bocona
Lycengraulis poeyi		
Ephippidae	Spadefishes	
Chaetodipterus zonatus	Pacific spadefish	
Parapsettus panamensis		Catecismo
Gadidae	Cods	
Physiculus nematopus		
Gerreidae	Mojarras (Gerrids)	Palmitos
Diapterus aureolus		
D. peruvianus		Pargo blanco
D. sp.		
Eucinostomus argenteus		
E. gracilis	Pacific flagfin mojarra	Palmito
Gobiidae	Gobies	
Bollmannia chlamydes		
B. stigmatura		
Gobiodes peruvianus		
Gobionellus liolepis		
Microgobius erectus		
Grammistidae	Soapfishes	
Rypticus nigripinnis	Soapfish	Jaboncillo
Kyphosidae	Sea chubs	
Kyphosus elegans	Chub	Vieja
Lophiidae	Anglerfishes	
Lophiodes caulinaris		
L. setigerus		
Lutjanidae	Snappers	Pargos
Lutjanus colorado		Pargo colorado
L. guttatus		Pargo de la mancha
L. peru		
Hoplopagrus guentheri		Pargo roquero
Mullidae	Goatfishes	
Pseudopeneus grandisquamis	Bigscale goatfish	Salmonete
Muraenesocidae	Conger eels	
Muraenesox coniceps		Congrio
Hoplunnis pacificus		

Scientific classification	Common name	Local name
Muraenidae	Moray eels	Morenas
*Gymnothorax dovii**		Morena
Priodonophus equatorialis		
Ogcocephalidae	Batfishes	
Zalieutes elater		Pez diablo
Ophichthidae	Snake eels	
Myrichthys tigrinus		
Ophidiidae	Cuskeels	
Brotula clarkae		
Lepophidium pardale		Congrio moteado
L. prorates		Congrio plateado
Ophidion sp.		
Polynemidae	Threadfins	Bobo
Polydactylus approximans	Blue bobo	Bobo
P. opercularis	Yellow bobo	Bobo
Pomadasyidae (Haemulidae)	Grunts	Roncadores
Anisostremus dovii	Grunt	Cotón
A. pacifici		
Haemulopsis axillaris		
H. elongatus		
H. leuciscus		Lulo
H. nitidus		
H. sp.		
Orthopristis chalceus		Corcovado
Pomadasys macracanthus		
P. panamensis		Vieja
P. sp.		
Sciaenidae	Croakers and Drums	Corvinas
Bairdiella armata	Croaker	
B. sp.		
Cynoscion albus	Corbina (Corvina)	Corvina reina
C. phoxocephalus	Corbina (Corvina)	Corvina picuda
C. reticulatus	Corbina (Corvina)	Corvina rayada
C. squamipinnis	Corbina (Corvina)	Corvina aguada
C. stolzmanni	Corbina (Corvina)	Corvina coliamarilla
C. sp.	Corbina (Corvina)	
Elattarchus archidium		Gallinita
Isopisthus altipinnis		Ojona
Larimus acclivis		Ñata
L. argenteus		Nata
L. effulgens		Ñata
L. pacificus		Ñata
L. sp.,		
Menticirrhus nasus		Zorra
M. panamensis		Zorra
Micropogonias altipinnis		Corvina agria
Nebris occidentalis		Corvina guavina

* Probably *P. equatorialis* misidentified at time of capture.

Scientific classification	Common name	Local name
Ophioscion imiceps		Corvina china
O. sciera		Corvina china
O. typicus		
Paralonchurus dumerilii		Corvina cinchada
P. sp.		
Stellifer chrysoleuca		
S. ericymba		
S. furthii		
S. illecebrosus		
S. mancorensis		
S. oscitans		
S. zestocarus		
S. sp.		
Scorpaenidae	Scorpionfishes	
Scorpaena russula		
S. sp. 1		
S. sp. 2		
Serranidae	Sea basses, groupers	Meros
Cephalopholis acanthistius		
Diplectrum labarum		
D. macropoma		
D. pacificum		Menta
Epinephelus niveatus	Snowy grouper	Mero
Hemanthias peruanus	Splittail bass	Doncella
Paralabrax humeralis		Cabrilla
Pronotogrammus eos		
Soleidae	Soles	Lenguados
Achirus mazatlanus		
A. scutum		Lenguado redondo
A. sp.		
Trinectes fimbriatus		
T. fonsecensis		
T. sp.		
Sphyraenidae	Barracudas	
Sphyraena ensis	Sennet	Barracuda
Stromateidae	Butterfishes	Palometas
Peprilus medius		
P. snyderi		
P. sp.		Salema
Syngnathidae	Sea horses & Pipefishes	
Hippocampus ingens	Pacific sea horse	Caballito
Synodontidae	Lizardfishes	Garrobos
Synodus evermanni	Lizardfish	Picuda
S. scituliceps	Lizardfish	Picuda
Tetraodontidae	Puffers	Timboriles
Sphoeroides annulatus		Timboril
S. furthii		
S. kendalli		

Scientific classification	Common name	Local name
S. lobatus		Timboril
S. sechurae		
S. sp. 1		
S. sp. 2		
Trichiuridae	Cutlassfishes	
Trichiurus nitens	Pacific Cutlassfish	Cinta
Triglidae	Sea robins	Cabros
Prionotus albirostris		Cabro
P. gymnostethus		
P. horrens		Cabro
P. ruscarius		Cabro
P. stephanophrys	Lumptail sea robin	
P. sp. 1		
P. sp. 2		

Note:
Common and local names compiled from Erdman (1971), León (1973), a list of common and scientific names of fishes from The United States and Canada (1980), Fuentes and Araya (1979), Madrigal (1979) and Stevenson and Víquez (1978).

TABLE 2

Gulf of Nicoya, Central America: Top twenty species of fishes, ranked by percent occurrence (%OC) for each of the three cruises (February and July 1979 and April 1980)

Cruise I Species	%OC	Cruise II Species	%OC	Cruise III Species	%OC
Synodus scituliceps	70	*Symphurus* sp.	59	*Synodus scituliceps*	65
Prionotus horrens	55	*Sphoeroides furthii*	59	*Neopisthopterus tropicus*	60
Porichthys nautopaedium	50	*Prionotus horrens*	59	*Diplectrum pacificum*	60
Cyclopsetta querna	40	*Syacium ovale*	55	*Sphoeroides furthii*	60
Syacium ovale	35	*Neopisthopterus tropicus*	55	*Prionotus horrens*	60
Lepophidium prorates	35	*Synodus scituliceps*	55	*Porichthys nautopaedium*	55
Micropogonias altipinnis	35	*Diapterus aureolus*	45	*Symphurus* sp.	50
Diplectrum pacificum	35	*Porichthys nautopaedium*	41	*Stellifer illecebrosus*	45
Sphoeroides furthii	35	*Symphurus melanurus*	41	*Syacium ovale*	50
Selene peruvianus	30	*Stellifer zestocarus*	41	*Cyclopsetta* sp.	40
Symphurus sp.	30	*Diplectrum pacificum*	41	*Anchoa naso*	40
Priodonophus equatorialis	30	*Achirus scutum*	41	*Priodonophus equatorialis*	40
Zalieutes elater	30	*Cyclopsetta querna*	36	*Lepophidium prorates*	40
Brotula clarkae	25	*Eucinostomus gracilis*	32	*Diapterus aureolus*	35
Polydactylus approximans	25	*Muraenesox coniceps*	32	*Bollmannia chlamydes*	35
Engyophrys sanctilaurentii	20	*Polydactylus approximans*	32	*Anisostremus dovii*	35
Lioglossina tetraophthalmus	20	*Isopisthus remifer*	32	*Muraenesox coniceps*	35
Bollmannia chlamydes	20	*Stellifer oscitans*	32	*Cynoscion phoxocephalus*	35
Muraenesox coniceps	20	*Etropus crossotus*	27	*Stellifer zestocarus*	35
Raja velezi	20	*Anchoa naso*	27	*Achirus scutum*	35
Scorpaena russula	20	*Diapterus peruvianus*	27	*Peprilus medius*	35
Achirus scutum	20	*Bollmannia chlamydes*	27		
		Stellifer furthii	27		

Cruise	Zones	Stations
I	I	3, 12, 14, 15, 16, 17, 18
(Feb., 1979)	II	1, 2, 4, 9, 13
	III	5, 6, 8, 10, 11
II	I	14, 15, 16, 17, 18, 19, 20, 21
(July, 1979)	II	1, 2, 3, 4, 9, 10, 13
	III	5, 6, 8, 11, 12
III	I	14, 15, 16, 17, 18, 19, 20, 21
(April, 1980)	II	1, 2
	III	3, 4, 5, 6, 8, 9, 10, 11, 12, 13

Night stations were excluded from these zones and the analysis based on those zones. These stations were only completed during the February (8N, 9N, 10N) and July (8N and 10N) cruises. Due to differences in temperature and dissolved oxygen, these night stations tended to be split from the day stations at the same locations. For this reason and the inconsistency of the night sampling, the night stations will be discussed separately.

Species occurrence and abundance: A total of 29,812 fishes were collected during the three cruises: 6,441 fishes representing 107 species during the first cruise, the second cruise produced 9,220 fishes and 131 species, while 14,151 fishes representing 125 species were collected during the third cruise. A list of all species collected (214), by family is located in Table 1.

A top twenty species by percent occurrence (% OC), for each cruise, are given in Table 2. During the first cruise, only three species were collected in greater than or equal to 50% of the sampling stations. These were the lizard fish, *Synodus scituliceps* (70%); the sea robin, *Prionotus horrens* (55%); and the midshipmen, *Porichthys nautopaedium* (50%). Six species were collected at greater than or equal to 50% of the second cruise stations. These included the tongue fish, *Symphurus* sp. (59%); the puffer, *Sphoeroides furthii* (59%); the sea robin, *P. horrens* (59%); the flounder, *Syacium ovale* (55%); the herring, *Neopisthopterus tropicus* (55%); and the lizard fish, *S. scituliceps* (55%). Eight species were collected in greater than or equal to 50% of the stations during the third cruise. These were the lizard fish, *S. scituliceps* (65%); the sea robin, *P. horrens* (60%); the herring, *N. tropicus* (60%); the sea bass, *Diplectrum pacificum* (60%); the puffer, *S. furthii* (60%); the midshipmen, *P. nautopaedium* (55%); the flounder, *S. ovale* (50%); and the tongue fish, *Symphurus* sp. (50%).

The top twenty species by weight, for each cruise, are given in Table 3. The top five species collected during the first cruise were the drum, *Micropogonias altipinnis;* the catfish, *Arius* sp.; the croaker, *Stellifer oscitans;* the lizard fish, *S. scituliceps;* and the sea bass, *D. pacificum.* The top five species, by weight, collected during the second cruise consisted of the drum, *Ophioscion sciera;* the catfish, *Arius jordani;* the lizard fish, *S. scituliceps;* the Conger eel, *Muraenesox coniceps* and the catfish, *Arius steindachneri.* Top five species taken during the third cruise were the catfish, *A. steindachneri;* the ray, *Dasyatis longus;* the drum, *Paralonchurus dumerilii;* the croaker, *Stellifer zestocarus* and the drum, *M. altipinnis.* In each of these cruises, two families provided the greatest portion of the fish biomass collected. These were the Sciaenidae (drums and croakers) and the Ariidae (sea catfishes).

The top twenty species, by number of individuals, are given in Table 4. The top five species taken during the first cruise were the midshipmen, *P. nautopaedium;* flounders, Flounder sp.; the croaker, *S. zestocarus;* the sea bass, *D. pacificum* and the anchovy, *Anchoa panamensis.* During the second cruise, the top five species consisted of four sciaenids (*Cynoscion squamipinnis, Isopisthus remifer, Stellifer furthii* and *S. zestocarus*) and the flounder, *S. ovale.* The top five species taken during the third cruise were the croaker, *S. zestocarus;* the midshipmen, *P. nautopaedium;* the catfish, *A. steindachneri*; the flounder, *Citharichthys platophrys* and the goby, *Bollmannia stigmatura.*

In order to obtain some indication of the overall contribution, and possibly importance, of the various species which were collected, we combined the rankings of the top twenty species by % OC, weight and number of individuals. The results of this procedure are listed in Table 5. The top five species collected during the first cruise were *P. nautopaedium, S. scituliceps, D. pacificum, Cyclopsetta querna* (flounder) and

S. zestocarus. The top five species taken during the second cruise were *S. scituliceps, S. ovale, A. steindachneri, I. remifer* and *C. squamipinnis.* During the third cruise, the top five species were *S. zestocarus, A. steindachneri, P. nautopaedium, Peprilus medius* (butterfish) and *S. scituliceps*. By combining the top twenty species for each cruise, a cumulative ranking was constructed for the cruise period. The top five species collected during this period were *S. scituliceps, P. nautopaedium, S. zestocarus, A. steindachneri* and *D. pacificum.*

Biological Index Values: Biological Index Values (BIV) were calculated using both numbers of individuals and biomass for each zone within each cruise. The BIV values (% of maximum) of the top twenty species, using numbers and biomass, for each zone of cruises I, II and III are given in Tables 10-12.

In zone I of the first cruise, *S. scituliceps* and *P. horrens* were ranked in the top five species using both numbers and biomass as a basis for the BIV. In zone II, three species were in the top five using both BIV values. These were *S. scituliceps, Symphurus* sp. and *C. querna*. *S. scituliceps* and *P. nautopaedium* were among the top five species, in both BIV categories, in zone III. *S. scituliceps, Symphurus* sp. and *C. querna* were ranked in the top five, in both BIV categories, when using the entire cruise as one zone.

In zone I of the second cruise, *S. zestocarus* and *S. oscitans* were ranked in the top five by number and biomass. *Sphoeroides furthii, S. ovale* and *Eucinostomus gracilis* (mojarra) were among the top five, in both BIV categories, within zone II. Among the top five species by BIV for both numbers and biomass in zone III were *S. scituliceps* and *B. chlamydes. Sphoeroides furthii* and *Symphurus* sp. were ranked in the top five species in both BIV categories, when the entire Gulf was used as a single zone.

In zone I of cruise III, *Cynoscion phoxocephalus* and *A. steindachneri* were ranked in the top five using both BIV values. In zone II, *S. zestocarus, M. altipinnis, Diapterus peruvianus, Cynoscion albus, Stellifer illecebrosus, Isopithus remifer* and *Diapterus aureolus* were included in the top five with ties for both BIV values. *P. nautopaedium, S. scituliceps, Priodonophus equatorialis* (Conger) and *Peprilus medius* were among the top five, of both BIV values, in zone III. For the entire cruise as a whole, only *S. scituliceps* and *Diplectrum pacificum* placed in the top five species using both numbers and biomass BIV values.

Partitioning of the Gulf by size classes: Six species were found to display some level of partitioning among size classes. These species were *Micropogonias altipinnis, Larimus pacificus, Cynoscion phoxocephalus, C. albus, Stellifer zestocarus* and *Synodus scituliceps.* These species were selected due to their importance in the local fishery or because of the wide range and relatively large number of individuals collected (i.e., *S. scituliceps*). Due to the small sample size, the results given below are provided to demonstrate possible trends in spatial distribution of the various size classes of these species and should only be used as an indicator of future areas of study.

Micropogonias altipinnis: Of the 100 fish collected, 23 over 46 cm in length were taken below Puntarenas (zones I, II and III during the three cruises). Of those fish measuring 34-46 cm (31 individuals), only one was collected, in zone I, above Puntarenas. The remaining 30 individuals were taken in zone II, below the Puntarenas peninsula. Of the 46 individuals measuring less than 34 cm, only 14 were from zone II. The remaining 32 fish were collected from zone I including 24 from above the peninsula. Figure 2 shows the distribution of the size classes among the three zones. Those fish from zone I that were greater than 46 cm were collected from stations 3 (cruise I) and 15 (cruise III). The only sample containing fish in all three size groups (<34, 34-46 and >46) was station 2 of the third cruise.

Larimus pacificus: Of those fish measured (309), only 32 were collected outside zone III. These were collected from station 13 (zone II) during the first cruise. The largest individuals were collected from stations 3 (cruise III) and 6 (cruises I and

TABLE 3

Gulf of Nicoya, Central America: Top twenty species of fishes ranked by biomass for each of the three cruises (February and July 1979 and April 1980)

Cruise I		Cruise II		Cruise III	
Species	Biomass (kg)	Species	Biomass (kg)	Species	Biomass (kg)
Micropogonias altipinnis	23.25	*Ophioscion sciera*	30.91	*Arius steindachneri*	95.95
Arius sp.	20.60	*Arius jordani*	22.57	*Dasyatis longus*	68.85
Stellifer oscitans	19.50	*Synodus scituliceps*	20.28	*Paralonchurus dumerilii*	56.90
Synodus scituliceps	15.00	*Muraenesox coniceps*	14.78	*Stellifer zestocarus*	46.75
Diplectrum pacificum	12.40	*Arius steindachneri*	13.34	*Micropogonias altipinnis*	44.60
Porichthys nautopaedium	12.10	*Stellifer furthii*	12.51	*Sciadeichthys troschelii*	37.40
Stellifer sp.	10.90	*Netuma platypogon*	9.97	*Ophioscion sciera*	28.50
Stellifer zestocarus	7.75	*Diplectrum pacificum*	9.92	*Muraenesox coniceps*	25.60
Cyclopsetta querna	6.90	*Syacium ovale*	9.60	*Urotrygon chilensis*	20.60
Flounder sp.	6.75	*Paralonchurus dumerilii*	9.07	*Porichthys nautopaedium*	19.30
Polydactylus approximans	5·80	*Achirus scutum*	8.25	*Stellifer furthii*	18.55
Prionotus horrens	5.76	*Stellifer zestocarus*	7.95	*Stellifer chrysoleuca*	16.35
Selene peruvianus	5.25	*Cyclopsetta querna*	7.92	*Peprilus medius*	15.85
Priodonophus equatorialis	5.05	*Stellifer oscitans*	6.85	*Synodus scituliceps*	15.55
Lepophidum prorates	4.25	*Ophioscion typicus*	6.60	*Menticirrhus nasus*	9.00
Larimus pacificus	4.25	*Isopisthus remifer*	6.03	*Eucinostomus argenteus*	7.50
Lioglossina tetraophthalmus	3.75	*Lepophidium prorates*	5.84	*Syacium ovale*	7.25
Mustelus sp.	3.50	*Symphurus* sp.	5.83	*Citharichthys platophrys*	6.95
Ophioscion sciera	3.20	*Stellifer chrysoleuca*	5.65	*Polydactylus approximans*	6.35
Scorpaena russula	2.57	*Micropogonias altipinnis*	5.16	*Cynoscion phoxocephalus*	6.80
Total all fishes:	224.54		331.19		680.26

III). These were the only stations containing relatively high numbers of individuals measuring 16-22 cm. Also, only 8 of the 97 specimens measured less than 14 cm in these zones. Relatively large numbers of fish (98) measuring less than 10 cm were only collected during the third cruise (stations 4, 12 and 13). Stations 13 (cruise I) and 12 (cruise II) contained mostly fish measuring 10-15 cm. Figure 3 provides a graphical demonstration of the size class distributions of *L. pacificus* at the various stations.

Cynoscion phoxocephalus: C. phoxocephalus were only captured during the third cruise. Only two individuals, of 211 total, were taken outside of zone I. These were taken at station 2 (zone II). Fish measuring greater than 15 cm were captured only at stations 2 (1 individual), 16 (14 individuals) and 18 (4 individuals). The majority of the catch at each station consisted of fish between 6 and 12 cm in length. There appeared to be a general scarcity of individuals in the 13-15 cm range.

Cynoscion albus: Of the 217 individuals measured, only 37 were captured outside zone I. These were taken at station 1 during the third cruise and ranged from 5 to 17 cm in length. There did not appear to be any dominant size group among them. Most of the fish lengths were spread relatively evenly between 7 and 14 to 15 cm.

Stellifer zestocarus: S. zestocarus were taken from all three zones. A total of 452 individuals were taken ranging from 3-19 cm. The samples taken during the third cruise contained fewer fish measuring less than 8 cm (2 individuals) than those fish taken during the first two cruises (80 individuals). The majority of the fish measured (328 individuals) were found to be between 10 to 13 cm in length.

TABLE 4

Gulf of Nicoya, Central America: Top twenty species of fishes ranked by number for each of the three cruises (February and July 1979 and April 1980)

Cruise I Species	#	Cruise II Species	#	Cruise III Species	#
Porichthys nautopaedium	1620	*Cynoscion squamipinnis*	915	*Stellifer zestocarus*	2146
Flounder sp.	886	*Isopisthus remifer*	799	*Porichthys nautopaedium*	1895
Stellifer zestocarus	560	*Stellifer furthii*	775	*Arius steindachneri*	1747
Diplectrum pacificum	486	*Syacium ovale*	528	*Citharichthys platophrys*	792
Anchoa panamensis	375	*Stellifer zestocarus*	524	*Bollmannia stigmatura*	749
Bollmannia stigmatura	300	*Arius steindachneri*	496	*Neopisthopterus tropicus*	460
Cyclopsetta querna	282	*Achirus scutum*	360	*Peprilus medius*	419
Synodus scituliceps	238	*Synodus scituliceps*	351	*Cynoscion phoxocephalus*	390
Stellifer oscitans	236	*Porichthys nautopaedium*	339	*Bollmannia chlamydes*	358
Scorpaena russula	207	*Selene oerstedii*	285	*Sphoeroides furthii*	347
Stellifer furthii	157	*Diapterus aureolus*	283	*Stellifer furthii*	295
Prionotus horrens	157	*Stellifer oscitans*	265	*Lepophidium prorates*	254
Cynoscion albus	133	*Sphoeroides furthii*	238	*Synodus scituliceps*	254
Symphurus sp.	131	*Citharichthys platophrys*	208	*Cynoscion albus*	253
Sphoeroides sp. 2	130	*Engyophrys sanctilaurentii*	187	*Sciadeichthys troschelii*	229
Sphoeroides furthii	128	*Eucinostomus gracilis*	178	*Urotrygon chilensis*	215
Larimus pacificus	114	*Neopisthopterus tropicus*	176	*Syacium ovale*	207
Lepophidium prorates	112	*Ophioscion typicus*	174	*Symphurus* sp.	196
Sphoeroides sp. 1	107	*Diplectrum pacificum*	173	*Achirus scutum*	190
Selene peruvianus	102	*Symphurus* sp.	158	*Prionotus horrens*	182
Total all fishes	6441		9220		14151

Synodus scituliceps: Ten stations contained at least 28 individuals of this species. Of these, only station 12 (zone I, first cruise) was outside zone III. A total of 390 individuals was measured from these stations. The fish lengths, from most of the stations, demonstrated a bimodal distribution with very few individuals of intermediate size. The first peak was generally located between 8 and 15 cm with the second peak between 18 and 28 cm. Stations 6 (first cruise) and 8 (second cruise) did not have the lower peak. Station 9 (third cruise) did not have a peak for larger individuals. Also, station 11 (second cruise) had only one broad peak located between 14 and 22 cm. Table 14 provides the length distribution for *S. scituliceps*.

Correlation analysis: The abundances of six species were found to be significantly (> .05) correlated to one or more of the physical properties of the Gulf (salinity, dissolved oxygen, water temperature, depth and distance to the ocean) during the first cruise (Table 17). Kendall's and Spearman's correlations both yielded similar results with the exception of the correlation between *Antennarius avalonis* and the distance to the ocean. This correlation was not significant to the .05 level using Kendall's Tau (.055) although it was significant using Spearman's Rho (.034). Throughout these analyses, Spearman's Rho was consistently higher than Kendall's Tau.

The occurrence of *A. avalonis* was negatively correlated with high dissolved oxygen levels (DO), temperature and large distances from the ocean and was positively correlated with increasing depth. *Achirus scutum* distributions were negatively correlated with increasing depth and salinity while being positively correlated with increasing temperature and distance from the ocean. *Stellifer oscitans* and *S. zestocarus* distributions were positively correlated to increasing distance from the ocean. The occurrence of *Priodonophus equatorialis* was positively correlated to

TABLE 5

Gulf of Nicoya, Central America: Top twenty species per cruise as measured by their total combined rank (number, biomass and %occurrence).

Cruise I		Cruise II		Cruise III		Cumulative	
Rank	Species	Rank	Species	Rank	Species	Rank	Species
1	*Porichthys nautopaedium*	1	*Synodus scituliceps*	1	*Stellifer zestocarus*	1	*Synodus scituliceps*
2	*Synodus scituliceps*	2	*Syacium ovale*		*Arius steindachneri*	2	*Porichthys nautopaedium*
3	*Diplectrum pacificum*	3	*Arius steindachneri*	2	*Porichthys nautopaedium*	3	*Stellifer zestocarus*
4	*Cyclopsetta querna*	4	*Isopisthus remifer*	3	*Peprilus medius*		*Arius steindachneri*
	Stellifer zestocarus	5	*Cynoscion squamipinnis*	4	*Synodus scituliceps*	4	*Diplectrum pacificum*
5	*Stellifer oscitans*	6	*Ophioscion sciera*	5	*Neopisthopterus tropicus*	5	*Stellifer furthii*
	Flounder sp.	7	*Arius jordani*		*Sciadeichthys troschelii*	6	*Stellifer oscitans*
6	*Prionotus horrens*		*Diplectrum pacificum*	6	*Citharichthys platophrys*		*Syacium ovale*
7	*Arius* sp.	8	*Stellifer furthii*		*Stellifer furthii*	7	*Micropogonias altipinnis*
8	*Anchoa panamensis*	9	*Porichthys nautopaedium*	7	*Dasyatis longus*		*Ophioscion sciera*
	Bollmannia chlamydes		*Stellifer oscitans*	8	*Paralonchurus dumerilii*		*Peprilus medius*
9	*Bollmannia stigmatura*	10	*Sphoeroides furthii*	9	*Sphoeroides furthii*	8	*Isopisthus remifer*
10	*Scorpaena russula*		*Diapterus aureolus*		*Urotrygon chilensis*		*Muraenesox coniceps*
11	*Selene peruvianus*	11	*Achirus scutum*	10	*Bollmannia stigmatura*		*Sphoeroides furthii*
	Polydactylus approximans		*Netuma platypogon*		*Micropogonias altipinnis*	9	*Cyclopsetta querna*
12	*Lepophidium prorates*	12	*Stellifer zestocarus*	11	*Cynoscion phoxocephalus*		*Cynoscion squamipinnis*
	Symphurus sp.	13	*Symphurus* sp.	12	*Muraenesox coniceps*		*Neopisthopterus tropicus*
	Priodonophus equatorialis	14	*Cyclopsetta querna*		*Ophioscion sciera*		*Sciadeichthys troschelii*
	Stellifer furthii		*Selene oerstedii*	13	*Bollmannia chlamydes*	10	*Bollmannia stigmatura*
			Paralonchurus dumerilli	14	*Syacium ovale*		*Citharichthys platophrys*

increasing salinity. The occurrence of *Brotula clarkae* was negatively correlated with increasing DO levels. Table 18 contains the correlation coefficients and their level of significance for the first cruise species-species correlations.

The abundances of four species were found to be significantly correlated(.05) to one or more of the physical properties of the Gulf during the July cruise (Table 19). The occurrence of *Synodus scituliceps* was negatively correlated to high DO, temperature and large distances to the ocean and demonstrated a significant positive correlation with increasing depth and salinity. The occurrence of *Arius steindachneri* was negatively correlated to increasing depth and positively correlated with the distance to the ocean. The distribution of *A. scutum* demonstrated a negative correlation with increasing depth and a positive correlation with the distance to the ocean. The occurrence of *Arius jordani* was positively correlated to the distance from the ocean. Table 20 contains the correlation coefficients and their significance levels ($\leqslant .05$) for the second cruise species-species correlations.

The abundances of nine species were significantly correlated (.05) to one or more of the physical properties of the Gulf during the third cruise (Table 21). The occurrence of *A. scutum, Symphurus* sp., *Arius steindachneri* and *Cynoscion phoxocephalus* were negatively correlated to increased temperature and distance from the ocean. The occurrence of *Trinectes* sp. was positively correlated to increasing temperature and distance from the ocean. The distribution of *Cynoscion albus* demonstrated a positive correlation with the distance to the ocean. *S. scituliceps* and *Symphurus atramentatus* distributions were negatively correlated to increasing temperature and distance to the ocean. *S. scituliceps* and *Symphurus atramentatus* distributions were negatively correlated to increasing temperature and distance to the ocean.

Table 22 contains the correlation coefficients and their significant values for the third cruise species-species correlations. Forty-eight species pairs were significantly correlated (.05). Of these correlations, six were only significant using Spearman's correlation. Six of the forty-eight pairs were negatively correlated.

Leon's (1973) study extended only to a line between the Río Grande de Tárcoles and Negritos Afuera and included approximately nine, predominantly near-shore, stations below zone I of this study. Only three of these stations were part of zone III of this study (only for cruise III). Leon found a large decrease in the frequency of occurrence of the catfishes

TABLE 6

Gulf of Nicoya, Central America: Top twenty fish species in terms of BIV (number and biomass) for Cruise I (February 1979).

Species	% Maximum BIV (Number)	% Species	% Maximum BIV (Biomass)
Prionotus horrens	62.150	*Synodus scituliceps*	44.840
Synodus scituliceps	61.710	*Cyclopsetta querna*	33.127
Cyclopsetta querna	39.637	*Symphurus* sp.	32.301
Porichthys nautopaedium	39.555	*Micropogonias altipinnis*	28.793
Symphurus sp.	39.445	*Selene peruvianus*	26.987
Sphoeroides furthii	37.658	*Prionotus horrens*	26.574
Selene peruvianus	33.645	*Polydactylus approximans*	22.601
Micropogonias altipinnis	32.875	*Porichthys nautopaedium*	17.441
Diplectrum pacificum	27.900	*Diapterus peruvianus*	16.718
Lioglossina tetraophalmus	27.460	*Syacium ovale*	15.893
Polydactylus approximans	27.295	*Diplectrum pacificum*	15.015
Syacium ovale	22.677	*Stellifer zestocarus*	11.662
Lepophidium prorates	22.430	*Stellifer* sp.	11.662
Zalieutes elater	22.402	*Stellifer oscitans*	11.662
Achirus scutum	21.853	Flounder sp.	11.558
Antennarius avalonis	21.495	*Lepophidium prorates*	11.507
Priodonophus equatorialis	21.385	*Larimus pacificus*	11.352
Muraenesox coniceps	21.193	*Priodonophus equatorialis*	11.352
Bollmannia chlamydes	17.097	*Achirus scutum*	11.249
Flounder sp.	17.042	*Lioglossina tetraophthalmus*	11.042
		Isopisthus altipinnis	11.042

TABLE 7

Gulf of Nicoya, Central America: Top twenty fish species in terms of BIV (number and biomass) for cruise II (July 1979)

Species	% Maximum BIV (Number)	Species	% Maximum BIV (Biomass)
Sphoeroides furthii	61.622	*Symphurus* sp.	45.588
Prionotus horrens	55.782	*Synodus scituliceps*	42.892
Neopisthopterus tropicus	55.706	*Sphoeroides furthii*	40.368
Symphurus sp.	55.515	*Stellifer zestocarus*	36.985
Syacium ovale	47.137	*Muraenesox coniceps*	34.191
Synodus scituliceps	46.870	*Syacium ovale*	32.206
Diapterus aureolus	46.775	*Stellifer oscitans*	31.103
Stellifer zestocarus	43.302	*Prionotus horrens*	30.564
Achirus scutum	41.126	*Arius jordani*	28.554
Porichthys nautopaedium	37.023	*Stellifer furthii*	28.529
Isopisthus remifer	34.237	*Paralonchurus dumerilii*	28.431
Diplectrum pacificum	32.786	*Isopisthus remifer*	28.284
Symphurus melanurus	32.500	*Polydactylus approximans*	27.696
Stellifer oscitans	32.500	*Achirus scutum*	26.985
Polydactylus approximans	31.164	*Diapterus aureolus*	24.265
Muraenesox coniceps	30.420	*Diapterus peruvianus*	23.309
Eucinostomus gracilis	28.740	*Porichthys nautopaedium*	23.260
Stellifer furthii	28.492	*Symphurus melanurus*	22.132
Arius jordani	27.901	*Ophioscion sciera*	19.363
Paralonchurus dumerilii	27.786	*Eucinostomus gracilis*	19.314

TABLE 8

Gulf of Nicoya, Central America: Top twenty fish species in terms of BIV (number and biomass) for cruise III (April 1980)

Species	% Maximum BIV (Number)	Species	% Maximum BIV (Biomass)
Synodus scituliceps	60.800	*Synodus scituliceps*	51.989
Neopisthopterus tropicus	56.140	*Syacium ovale*	45.739
Sphoeroides furthii	55.480	*Porichthys nautopaedium*	43.239
Prionotus horrens	55.020	*Diplectrum pacificum*	40.824
Diplectrum pacificum	53.700	*Symphurus* sp.	39.574
Porichthys nautopaedium	53.34	*Prionophus equatorialis*	36.960
Syacium ovale	47.520	*Stellifer illecebrosus*	35.795
Symphurus sp.	45.960	*Prionotus horrens*	35.284
Stellifer illecebrosus	41.700	*Muraenesox coniceps*	33.608
Anchoa naso	36.880	*Peprilus medius*	32.756
Lepophidium prorates	36.200	*Cynoscion phoxocephalus*	31.222
Diapterus aureolus	36.160	*Paralonchurus dumerilii*	29.233
Priodonophus equatorialis	36.000	*Micropogonias altipinnis*	28.381
Cyclopsetta sp.	35.660	*Arius steindachneri*	27.699
Cynoscion phoxocephalus	33.640	*Lepophidium prorates*	27.670
Stellifer zestocarus	32.980	*Stellifer zestocarus*	26.705
Peprilus medius	32.960	*Neopisthopterus tropicus*	26.080
Bollmannia chlamydes	32.880	*Sciadeichthys troschelii*	23.920
Achirus scutum	32.620	*Polydactylus approximans*	23.267
Muraenesox coniceps	30.520	*Menticirrhus nasus*	22.926

and a general decrease in dominance by any single group in this lower gulf area. The present study found that although the sciaenids were the most dominant group, they were collected at fewer stations than in Leon's (1973) study. The down-bay decline in catfish abundance was similar to that described by Leon (1973). *Syacium ovale* and *Prionotus horrens* were common inhabitants of this area in both studies. However, two species collected at greater than 50% of Leon's stations (*Lycengraulis poeyi* [anchovy] and *Vomer declivifrons* [carangid]) were rare (collected at 2 of 27 stations) or absent, respectively, from our collections. Also, *N. tropicus*, *Symphurus* sp. and *Sphoeroides furthii* were collected at greater than 50% of the stations within this area by us while only *Symphurus* sp. and *S. furthii* were taken at greater than 20% but less than 49% by Leon. The differences between these studies, for the mid-Gulf area, may be due to the differences in sampling patterns and gear size. Leon's mid-Gulf stations were clustered around four main areas, near our stations 1, 14, 12 and ten kilometers west of 3, and do not cover much of the deeper water located in the center of the Gulf. Sampling, in the present study, was intended to cover both near-shore and deep-water areas. The trawls in Leon's study were twice as wide at the mouth (20 meters) had larger mesh (5 cm) and were towed twice as long (one hour) as the trawls in this study.

Some seasonal (cruise versus cruise) differences were observed. More species per station were collected at more stations during the third cruise than during the first (9 of 14) or second cruises (11 of 20). Third cruise stations also provided the highest biomass per station when compared with the first (13 of 14) and second cruises (16 of 20). These results were probably due to the increase in the number and weight of catfish caught in the upper Gulf and the increase in biomass contributed by sciaenids (especially *Micropogonias altipinnis* and *Stellifer zestocarus*) in the mid-Gulf, during the third cruise. Any seasonal (wet season versus dry season) causes for these results

TABLE 9

*Gulf of Nicoya, Central America: Distribution of lizard fish (*Synodus scituliceps*) lengths (cm) for all stations with greater than 25 individuals collected (1979-1980)*

Cruise	Station Number	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	>32
		Length in cm																										
I	5	2	8	2	1	1	1	1	1						4		3	2	4	2	4	3	1					
	6									3	1		1	5	2	7	6	8	8	4	4		1					
	12		1							4	9	1	5	2	5	2		2	1	1				1				
II	6								2	2	6	2	1	1	5	7	5	4	2	1								
	8											1	2	1	3	5	2	4	8	2	3		3	1	1			
	11							1	4	3	6	5	6	7	5	3	3	1	2	2		1						1
III	3		3	3	2					1				3	5		4	4	4	6	6	3	2	1				
	9			1	1	5	4	6	8	1		1	1															
	11			1	1		2		5	2		1		3	4	2	3	2	5	5	1	4	3	1			1	
	12		2		1			5	1	2	1	3	2	1	3	3	4	2		1		1		1				

TABLE 10

Gulf of Nicoya, Central America: Correlation coefficients and level of significance for Kendall's and Spearman's rank-order correlation of species vs physical parameters for cruise I (February 1979)

Species	Physical Parameter	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Antennarius avalonis	Dissolved Oxygen	-0.4709	0.022	-0.5937	0.012
Bollmannia chlamydes	Dissolved Oxygen	-0.4594	0.025	-0.5516	0.022
Achirus scutum	Depth	-0.5202	0.012	-0.6304	0.007
Antennarius avalonis	Depth	0.4548	0.028	0.5881	0.013
Achirus scutum	Temperature	0.4589	0.025	0.5454	0.024
Antennarius avalonis	Temperature	-0.4860	0.018	-0.6312	0.007
Achirus scutum	Salinity	-0.5065	0.026	-0.5716	0.017
Priodonophus equatorialis	Salinity	0.5109	0.025	0.5518	0.022
Achirus scutum	Dist. to Ocean	0.5306	0.011	0.6573	0.004
Antennarius avalonis	Dist. to Ocean	-0.4044	0.055	-0.5148	0.034
Stellifer oscitans	Dist. to Ocean	0.4355	0.043	0.4953	0.043
Stellifer zestocarus	Dist. to Ocean	0.4355	0.043	0.5218	0.032

are highly doubtful. During the first cruise, three species (*D. aureolus, A. naso* and *N. tropicus*) which were found in large numbers in the other cruises were rarely collected. Meanwhile, *Cynoscion phoxocephalus* was only taken during the third cruise. There was no apparent reason for these results. Also, the catfishes surpassed the sciaenids in number in the upper Gulf, during Cruise III. In fact, sciaenid abundance levels were generally down throughout their range (except *S. illecebrosus* and *S. zestocarus*) during this cruise. Reasons for this observation are unclear due to the limited time period of this study.

During the three University of Delaware/University of Costa Rica research cruises in the Gulf of Nicoya, Costa Rica, 29,812 fishes representing 214 species were collected. The sciaenids (drums and croakers) and sea catfishes (Ariidae) were most important in terms of biomass. *Stellifer zestocarus* (croaker), *Porichthys nautopaedium* (midshipmen), several flounders and catfishes contributed the greatest numbers of individuals. The top five species ranked by their combined biomass, numerical abundance and percent occurrence were *Synodus scituliceps* (lizard fish), *P. nautopaedium, S. zestocarus, Arius steindachneri* (catfish) and *Diplectrum*

TABLE 11

Gulf of Nicoya, Central America: Correlation coefficients and significance levels (≤0.05) for Kendall's and Spearman's rank-order correlation of species vs species for cruise I (February 1979)

Species	Species	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Achirus scutum	*Diplectrum pacificum*	0.5252	0.028	0.5485	0.023
A. scutum	*Stellifer zestocarus*	0.6839	0.004	0.7055	0.002
A. scutum	*Synodus scituliceps*	-0.4213	0.045	-0.4887	0.047
Anchoa panamensis	*Scorpaena russula*	1.000	0.001	1.000	0.001
Antennarius avalonis	*Priodonophus equatorialis*	-	-	0.4967	0.043
A. avalonis	*Prionotus horrens*	0.5298	0.028	0.5491	0.022
Arius sp.	*Diplectrum pacificum*	0.6286	0.011	0.6378	0.006
Bollmannia stigmatura	*Sphoeroides* sp.	1.000	0.001	1.000	0.001
Diplectrum pacificum	*Stellifer furthii*	0.7184	0.004	0.7289	0.001
D. pacificum	*Stellifer zestocarus*	0.7184	0.004	0.7289	0.001
Flounder sp.	*Stellifer furthii*	0.6286	0.011	0.6378	0.006
Flounder sp.	*Stellifer oscitans*	0.6286	0.011	0.6378	0.006
Priodonophus equatorialis	*Synodus scituliceps*	0.5950	0.005	0.6816	0.003
Selene peruvianus	*Stellifer oscitans*	0.7184	0.004	0.7289	0.001
S. peruvianus	*Stellifer zestocarus*	0.6286	0.011	0.6378	0.006
Stellifer furthii	*S. zestocarus*	0.4839	0.046	0.5000	0.041
Stellifer oscitans	*Symphurus* sp.	0.4194	0.025	0.5438	0.024

TABLE 12

Gulf of Nicoya, Central America: Correlation coefficients and level of significance for Kendall's and Spearman's rank-order correlation of species vs. physical parameters for cruise II (July 1979)

Species	Physical Parameter	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Synodus scituliceps	Dissolved Oxygen	-0.4692	0.007	-0.6344	0.003
Arius steindachneri	Depth	-0.4569	0.015	-0.5404	0.014
Achirus scutum	Depth	-0.4111	0.022	-0.5492	0.012
Synodus scituliceps	Depth	0.4901	0.005	0.6192	0.004
Synodus scituliceps	Temperature	-0.4204	0.021	-0.5219	0.018
Synodus scituliceps	Salinity	0.4711	0.012	0.5837	0.007
Achirus scutum	Dist. to Ocean	0.5944	0.7379	0.001	
Arius jordani	Dist. to Ocean	0.5193	0.006	0.6175	0.004
Arius steindachneri	Dist. to Ocean	0.5873	0.002	0.6819	0.001
Synodus scituliceps	Dist. to Ocean	-0.6110	0.001	-0.7166	0.001

pacificum (sea bass). In terms of Biological Index Value (BIV), *S. scituliceps, P. nautopaedium, D. pacificum, Syacium ovale* (flounder), *Prionotus horrens* (sea robin) and *Symphurus* sp. (tonguefish) were the most important species collected in the Gulf

The Gulf of Nicoya was divided into three zones, for each cruise, on the basis of physical data taken at each station

TABLE 13

Gulf of Nicoya, Central America: Correlation coefficients and level of significance (≤ 0.05) for Kendall's and Spearman's rank-order correlation of species vs species for cruise II (July 1979)

Species	Species	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Achirus scutum	*Arius jordani*	0.6266	0.002	0.7204	0.001
A. scutum	*Arius steindachneri*	0.5326	0.009	0.5752	0.008
A. scutum	*Syacium ovale*	-0.4223	0.026	-0.5114	0.021
A. scutum	*Synodus scituliceps*	-0.5388	0.005	-0.6512	0.002
Arius jordani	*Prionotus horrens*	0.4403	0.042	0.4663	0.038
A. jordani	*Synodus scituliceps*	-0.5051	0.010	-0.5949	0.006
Arius steindachneri	*Polydactylus approximans*	0.5210	0.018	0.5407	0.014
A. steindachneri	*Prionotus horrens*	0.4661	0.035	0.4837	0.031
A. steindachneri	*Syacium ovale*	-0.2984	0.045	-0.4599	0.041
A. steindachneri	*Symphurus* sp.	0.4063	0.037	0.4787	0.033
A. steindachneri	*Synodus scituliceps*	-0.3984	0.045	-0.4599	0.041
Diapterus aureolus	*Paralonchurus dumerilii*	1.000	0.001	1.000	0.001
Diplectrum pacificum	*Isopisthus remifer*	1.000	0.001	1.000	0.001
Neopisthopterus tropicus	*Cynoscion squamipinnis*	1.000	0.001	1.000	0.001
Netuma platypogon	*Stellifer oscitans*	1.000	0.001	1.000	0.001
Ophioscion sciera	*Porichthys nautopaedium*	1.000	0.001	1.000	0.001
O. sciera	*Sphoeroides furthii*	1.000	0.001	1.000	0.001
Porichthys nautopaedium	*Sphoeroides furthii*	1.000	0.001	1.000	0.001
Syacium ovale	*Synodus scituliceps*	0.4722	0.011	0.5752	0.008
Polydactylus approximans	*Symphurus melanurus*		-	0.4435	0.050

(water temperature, depth, salinity, dissolved oxygen and distance from the mouth of the Gulf). Little change in the position of these zones, during the study period, was observed. The distribution of fish species within the zones remained relatively constant. No significant seasonal changes in number, biomass, percent occurrence, diversity or partitioning by size class of fishes were observed.

Night stations had generally higher biomass and more species than those same stations during daylight. Five species were collected predominantly at night. These were *Brotula clarkae* (goby), *Lepophidium prorates* (cuskeel), *Raja velezi* (skate), *Scorpaena russula* (scorpion-fish) and *Hildebrandia nitens* (moray eel).

Two major types of distributional patterns were observed. Several species were found throughout the Gulf in varying abundances. These included *S. scituliceps, S. ovale, P. horrens, Symphurus* sp. and the herring, *Neopisthopterus tropicus.* Other species were restricted to either the upper (warm, shallow) or lower (cool, deep) portions of the Gulf with some mixing in the mid-Gulf area. Dominant groups and species in the upper Gulf include sciaenids, sea catfishes, flatfish (soles, tonguefish and *S. ovale*), *Sphoeroides furthii* (puffer), *P. horrens* and *N. tropicus.* The lower Gulf displayed less dominance by only a few groups than the upper Gulf. Flounders (*S. ovale, Cyclopsetta* sp. and *C. querna*), gobies (*Bollmannia chlamydes* and *B. stigmatura*), morays (*H. nitens, Priodonophus equatorialis* and *Muraenesox coniceps*), *Symphurus* sp., *S. scituliceps, P. nautopaedium, Diapterus aureolus* (mojarra), *Antenarius avalonis* (frogfish), *D. pacificum* and *Larimus pacificus* (drum) were collected primarily in the lower Gulf.

TABLE 14

Gulf of Nicoya, Central America: Correlation coefficients and level of significance for Kendall's and Spearman's rank-order correlation of species vs. physical parameters for cruise III (April 1980).

Species	Physical Parameter	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Achirus scutum	Depth	-0.5883	0.001	-0.7489	0.001
Arius steindachneri	"	-0.5736	0.002	-0.6730	0.001
Cynoscion phoxocephalus	"	-0.3922	0.031	-0.5365	0.015
Symphurus sp.	"	-0.4153	0.019	-0.5123	0.021
Trinectes sp.	"	-0.3618	0.052	-0.4749	0.034
Achirus scutum	Temperature	0.5742	0.002	0.7078	0.001
Arius steindachneri	"	0.6185	0.001	0.6860	0.001
Cynoscion phoxocephalus	"	0.4652	0.013	0.6051	0.005
Symphurus atramentatus	"	-0.5538	0.004	-0.6476	0.002
Symphurus sp.	"	0.4117	0.024	0.5168	0.020
Synodus scituliceps	"	-0.5000	0.005	-0.6122	0.004
Trinectes sp.	"	0.4923	0.010	0.5846	0.007
Achirus scutum	Dist. to Ocean	0.6392	0.001	0.8048	0.001
Anisostremus dovii	"	0.3869	0.040	0.4652	0.039
Arius steindachneri	"	0.6346	0.001	0.7803	0.001
Cynoscion albus	"	0.5544	0.003	0.6447	0.002
Cynoscion phoxocephalus	"	0.6534	0.001	0.8012	0.001
Symphurus atramentatus	"	-0.5085	0.007	-0.6173	0.004
Symphurus sp.	"	0.6160	0.001	0.7351	0.001
Synodus scituliceps	"	-0.4479	0.010	-0.5728	0.008
Trinectes sp.	"	0.6033	0.001	0.6935	0.001

TABLE 15

Gulf of Nicoya, Central America: Correlation coefficients and level of significance (≤0.05) for Kendall's and Spearman's rank-order correlation of species vs species for cruise III (April 1980)

Species	Species	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Achirus scutum	*Anisostremus dovii*	0.5966	0.003	0.6473	0.002
A. scutum	*Antennarius avalonis*	-0.4115	0.045	-0.4595	0.042
A. scutum	*Arius steindachneri*	0.8072	0.001	0.9213	0.001
A. scutum	*Cynoscion albus*	0.5022	0.013	0.6192	0.004
A. scutum	*Cynoscion phoxocephalus*	0.7143	0.001	0.8551	0.001
A. scutum	*Porichthys nautopaedium*	-	-	0.4435	0.050
A. scutum	*Symphurus* sp.	0.5136	0.008	0.6189	0.004
A. scutum	*Stellifer mancorensis*	-	-	0.4435	0.050
A. scutum	*Synodus scituliceps*	-0.4022	0.031	-0.4727	0.035
A. scutum	*Trinectes* sp.	0.5637	0.005	0.6540	0.002
A. scutum	*Urotrygon chilensis*	-	-	0.4435	0.050
Anchoa naso	*Diapterus aureolus*	0.4344	0.027	0.4890	0.029
Anchoa walkeri	*Cynoscion albus*	0.4815	0.026	0.5254	0.017
A. walkeri	*Elattarchus archidium*	0.6412	0.005	0.6491	0.002
A. walkeri	*Ophioscion sciera*	0.6412	0.005	0.6491	0.002
A. walkeri	*Porichthys nautopaedium*	0.7166	0.002	0.7255	0.001
A. walkeri	*Stellifer mancorensis*	0.7166	0.002	0.7255	0.001
A. walkeri	*Trinectes* sp.	0.4815	0.026	0.4969	0.026
A. walkeri	*Urotrygon chilensis*	0.7166	0.002	0.7255	0.001

Species	Species	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Anisostremus dovii	*Arius steindachneri*	0.5369	0.009	0.6030	0.005
A. dovii	*Antennarius avalonis*	-0.4230	0.044	0.4619	0.040
A. dovii	*Urotrygon chilensis*	-	-	0.4458	0.049
A. dovii	*Cynoscion albus*	0.4635	0.025	0.5303	0.016
A. dovii	*Stellifer mancorensis*	-	-	0.4458	0.049
A. dovii	*Cynoscion phoxocephalus*	0.6792	0.001	0.7659	0.001
A. dovii	*Porichthys nautopaedium*	-	-	0.4458	0.049
Antennarius avalonis	*Cyclopsetta* sp.	0.4506	0.028	0.5156	0.020
A. avalonis	*Cynoscion phoxocephalus*	-0.4115	0.045	-0.4595	0.042
A. avalonis	*Paralonchurus dumerilii*	0.4520	0.041	0.4687	0.037
A. avalonis	*Syacium ovale*	0.4580	0.021	0.5267	0.017
A. avalonis	*Synodus scituliceps*	0.4413	0.022	0.5005	0.025
Arius steindachneri	*Cynoscion albus*	0.4797	0.020	0.5446	0.013
A. steindachneri	*Cynoscion phoxocephalus*	0.7123	0.001	0.8843	0.001
A. steindachneri	*Stellifer illecebrosus*	0.4381	0.042	0.4660	0.038
A. steindachneri	*Symphurus* sp.	0.5631	0.004	0.6543	0.002
A. steindachneri	*Synodus scituliceps*	-0.4355	0.021	-0.5228	0.018
A. steindachneri	*Trinectes* sp.	0.6105	0.003	0.7212	0.001
Bollmannia chlamydes	*Diapterus peruvianus*	1.000	0.001	1.000	0.001
B. chlamydes	*Symphurus atramentatus*	0.4756	0.030	0.4971	0.026
B. stigmatura	*Sciadeichthys troschelii*	1.000	0.001	1.000	0.001
Brotula clarkae	*Sphoeroides furthii*	0.5307	0.018	0.5440	0.013
B. clarkae	*Peprilus medius*	0.5307	0.018	0.5440	0.013
B. clarkae	*Paralonchurus dumerilii*	0.4683	0.036	0.4800	0.032
Citharichthys platophrys	*Haemulopsis nitidus*	1.000	0.001	1.000	0.001
C. platophrys	*Larimus pacificus*	1.000	0.001	1.000	0.001
C. platophrys	*Neopisthopterus tropicus*	1.000	0.001	1.000	0.001
C. platophrys	*Priodonophus equatorialis*	1.000	0.001	1.000	0.001
Cynoscion albus	*Cynoscion phoxocephalus*	0.5432	0.007	0.5774	0.008
C. albus	*Diapterus aureolus*	-	-	-0.4466	0.048
C. albus	*Symphurus* sp.	0.5986	0.002	0.6647	0.001
C. albus	*Elattarchus archidium*	-	-	0.4445	0.050
C. albus	*Synodus scituliceps*	-0.4365	0.022	-0.5477	0.012
C. albus	*Ophioscion sciera*	-	-	0.4445	0.050
C. albus	*Trinectes* sp.	0.6235	0.003	0.6961	0.001
Cynoscion phoxocephalus	*Symphurus* sp.	0.5294	0.006	0.6181	0.004
C. phoxocephalus	*Synodus scituliceps*	-0.4022	0.031	-0.5016	0.024
C. phoxocephalus	*Trinectes* sp.	0.4612	0.023	0.5218	0.018
Diapterus aureolus	*Syacium ovale*	-	-	0.4699	0.037
D. aureolus	*Trinectes* sp.	-	-	-0.4466	0.048
Diapterus peruvianus	*Symphurus atramentatus*	0.4756	0.030	0.4971	0.026
Diplectrum pacificum	*Symphurus atramentatus*	0.4513	0.022	0.5329	0.016
Elattarchus archidium	*Ophioscion sciera*	1.000	0.001	1.000	0.001
Haemulopsis nitidus	*Neopisthopterus tropicus*	1.000	0.001	1.000	0.001
H. nitidus	*Larimus pacificus*	1.000	0.001	1.000	0.001
H. nitidus	*Priodonophus equatorialis*	1.000	0.001	1.000	0.001
Larimus pacificus	*Neopisthopterus tropicus*	1.000	0.001	1.000	0.001
L. pacificus	*Priodonophus equatorialis*	1.000	0.001	1.000	0.001
Lepophidium prorates	*Symphurus atramentatus*	-	-	0.4447	0.049

Species	Species	Kendall's Tau Coef.	Kendall's Tau Signif.	Spearman's Rho Coef.	Spearman's Rho Signif.
Menticirrhus nasus	*Stellifer furthii*	1.000	0.001	1.000	0.001
Micropogonias altipinnis	*Polydactylus approximans*	1.000	0.001	1.000	0.001
M. altipinnis	*Trichiurus nitens*	1.000	0.001	1.000	0.001
Neopisthopterus tropicus	*Priodonophus equatorialis*	1.000	0.001	1.000	0.001
Peprilus medius	*Sphoeroides furthii*	1.000	0.001	1.000	0.001
Polydactylus approximans	*Trichiurus nitens*	1.000	0.001	1.000	0.001
Porichthys nautopaedium	*Stellifer mancorensis*	1.000	0.001	1.000	0.001
P. nautopaedium	*Urotrygon chilensis*	1.000	0.001	1.000	0.001
Stellifer chrysoleuca	*Prionotus horrens*	1.000	0.001	1.000	0.001
Stellifer mancorensis	*U. chilensis*	1.000	0.001	1.000	0.001
Syacium ovale	*Cyclopsetta* sp.	0.4527	0.018	0.5907	0.006
S. ovale	*Synodus scituliceps*	0.4901	0.007	0.5831	0.007
Symphurus atramentatus	*Symphurus* sp.	-0.4562	0.021	-0.5287	0.017
S. atramentatus	*Synodus scituliceps*	0.3799	0.048	-	-
Symphurus sp.	*Trinectes* sp.	0.5442	0.006	0.6066	0.005
Synodus scituliceps	*Trinectes* sp.	-0.4365	0.022	-0.5477	0.012

TABLE 16

Gulf of Nicoya, Central America: Physical data summary for Cruise I (February 1979)

	STATION NUMBER																			
	1	2	3	4	5	6	8	8N	9	9N	10	10N	11	12	13	14	15	16	17	18
Total Weight (kg)	30.8	14.1	14.2	8.4	16.8	28.3	8.5	9.5	3.4	16.8	4.3	8.9	4.4	6.5	12.8	14.5	6.4	14.4	3.9	29.7
Total number of species	13	14	11	8	11	13	16	14	10	15	12	13	12	14	19	23	19	18	13	17
Distance from Ocean (km)	42	41	37	30	20	20	15	15	15	15	15	15	15	20	30	37	41	43	50	62
Dissolved Oxygen Level	2.8	5.2	5.0	1.6	1.4	2.0	2.0	1.4	4.0	1.8	1.2	1.4	1.4	5.6	3.2	3.8	4.0	4.8	6.2	3.9
Depth (m)	50	50	30	40	50	45	55	50	40	48	55	50	48	30	28	16	8	25	8	15
Temperature (C)	23	26	24	25	18	19	18	17	22	18	17	17	17	28	23	25	26	26	27	27
Salinity (°/oo)	34	34	34	35	35	35	34	34	35	35	34	35	34	33	35	33	34	34	33	33

TABLE 17

Gulf of Nicoya, Central America: Physical data summary for Cruise II (July 1979)

STATION NUMBER	1	2	3	4	5	6	8	8N	9	10	10N	11	12	13*	14	15	16	17	18	19*	20	21*
Total Weight (kg)	22.6	3.7	9.6	9.7	4.5	14.6	10.3	13.1	6.0	6.9	19.1	22.1	10.4	27.1	1.7	19.4	21.9	9.1	9.1	98.5	9.4	89.8
Total number of species	22	15	17	24	3	19	16	20	10	19	21	22	24	27	12	39	27	26	21	22	25	29
Distance from Ocean (km)	42	41	37	30	20	20	15	15	15	15	15	15	20	30	37	41	43	50	62	62	45	53
Dissolved Oxygen Level	4.5	5.7	4.6	4.1	2.0	2.7	2.1	2.1	5.6	5.1	3.0	2.8	2.6	6.2	5.2	5.1	5.0	6.2	4.4	5.8	4.8	5.6
Depth (m)	50	20	25	40	60	55	65	60	35	45	47	60	45	28	17	16	20	8	15	8	18	18
Temperature (C)	26	27	26	24	16	19	18	14	26	24	14	17	19	27	24	23	24	24	23	24	23	23
Salinity (o/oo)	34	33	34	34	36	36	37	37	34	36	37	36	36	33	35	35	34	34	35	33	36	34

*** Only two thirds of fish counted.**

TABLE 18

Gulf of Nicoya, Central America: Physical data summary for Cruise II (April 1980)

STATION NUMBER	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Total Weight (Kg)	50.5	28.4	22.8	14.7	18.8	24.7	11.3	5.1	27.3	14.1	6.2	29.5	5.4	31.0	67.3	84.1	41.2	84.3	70.2	93.9
Total number of species	12	10	26	20	20	24	16	20	27	23	19	25	17	17	33	26	27	25	31	27
Distance from Ocean (km)	42	41	37	30	20	20	15	15	15	15	20	30	37	41	43	50	62	62	45	53
Dissolved Oxygen Level	Not available																			
Depth (m)	50	50	30	40	50	45	55	40	55	48	30	28	16	8	25	7.5	15	8	18	18
Temperature (C)	22	21	21	21	17.5	20	18	18	18	17	18	21	28	27	27	28	27	28	27	25
Salinity (o/oo)	32	33	33	32	33	32	33	33	30	30	31	29	28	39	30	31	28	28	32	32

Diversity remained relatively constant over the study period. Shannon-Wiener (H') index values ranged from 0.671 to 3.163 for zones and between 3.186 and 3.622 for the cruises. High species richness accounted for the relatively high H' compared to temperate estuarine areas.

Information presented in this report should be used as a starting point for more in-depth life history studies of the important commercial and ecological species common to the Gulf of Nicoya. These studies, along with careful monitoring of water quality, would assist scientists and managers in making proper fisheries management and water resource decisions in the future.

ACKNOWLEDGMENTS

This study was supported by funds from the Sea Grant International Cooperative Assistance Program, the University of Costa Rica, and the Organization for American States, and represents portions of a thesis submitted to the faculty of the School of Graduate Studies of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science in Marine Studies. Thanks are due Dr. Franklin C. Daiber, Dr. Charles E. Epifanio and Dr. Vic Lotrich of the University of Delaware who provided critical evaluations of a preliminary draft of this paper and to John R. Casedevall who provided advice and assistance in statistical analysis of the data. Measurements were taken from the University of Delaware's R/V *Skimmer* and we are grateful to Donald Evans, Rolando Hoffmeister, Timothy Pfeiffer, and Thomas White who served as officers and crew of the vessel. Additionally we thank the students from the University of Costa Rica and the University of Delaware who assisted in collection and analysis of data. We extend special thanks to Dr. Manuel M. Murillo who coordinated relations between the two universities.

RESUMEN

Durante los meses de febrero y julio de 1979 y abril de 1980 se realizó muestreos de arrastre en el Golfo de Nicoya, Costa Rica con el objeto de definir los patrones básicos de abundancia, diversidad y distribución de los peces bentónicos. La jornada de febrero comprendió diecisiete muestreos diurnos y tres nocturnos y un total de 6441 individuos de 107 especies. En el mes de julio se efectuó veinte colectas diurnas y dos nocturnas dando un total de 9220 individuos de 131 especies. Finalmente, la jornada de abril comprendió veinte colectas diurnas con un total de 14.151 individuos de 125 especies. El total de especies colectadas en este estudio fue de 214.

El Golfo de Nicoya puede dividirse en tres zonas con base en parámetros físicos considerados en cada sitio de recolección (temperatura del agua, oxígeno disuelto, salinidad, profundidad y distancia desde la boca del Golfo). Se determinó pocos cambios en la posición de estas zonas durante el lapso de este estudio, lo que indica una configuración estuarina relativamente estable desde el punto de vista biológico, bajo condiciones de estaciones seca y lluviosa. No se observó cambios significativos estacionales con respecto al número, biomasa, porcentaje de especies ni en la separación por grupos con base en la talla.

Se observó dos tipos principales de patrones de distribución de los peces. Varias especies presentan una distribución muy amplia y éstas se encontraron en todas las estaciones. Otras especies presentaron una distribución restringida, ya sea a la parte superior o inferior del Golfo.

En la parte superior los grupos dominantes son los sciánidos, bagres (Ariidae) y los lenguados (Soleidae, Cynoglossidae y *Syacium ovale*). Estos peces muestran preferencia por las aguas más tibias, someras y de menor salinidad de la parte superior del Golfo. Los lenguados (Bothidae), gobios (*Bollmannia* spp.), morenas y cóngridos (*Hildebrandia nitens, Priodonophus equatorialis* y *Muraenesox coniceps*) y varias otras especies dominan en aguas más frías y de mayor salinidad de la parte inferior del Golfo.

LITERATURE CITED

Bartels, C.E. 1981. Occurrence, distribution, abundance, and diversity of fishes in the Gulf of Nicoya, Costa Rica. University of Delaware. M.S. Thesis, 120 p.

Blutstein, H.I., L.C. Anderson, E.C. Betters, J.H. Dombrowski, & C. Townsend. 1970. Area handbook for Costa Rica. U.S. Gov. Printing Office 323 p.

Brittan, M. 1966. A small collection of the shore fishes from the west coast of Costa Rica. Ichthyologia, 37:121-134.

Bussing, W.A. 1969. Familias de peces marinos costarricenses y de aguas contiguas. Ser. Cienc. Nat. No.6, San José, Costa Rica. 39 p.

Cain, R.L., & J.M. Dean. 1976. Annual occurrence, abundance and diversity of fish in a South Carolina intertidal creek. Mar. Biol., 36:369-379.

Conover, W.J. 1971. Practical non-parametric statistics. Wiley. New York. 461 p.

Dahlberg, N., & E.P. Odum. 1970. Annual cycles of species occurrence, abundance and diversity in Georgia estuarine fish populations. Amer. Midl. Nat., 83:382-392.

Epifanio, C.E., D. Maurer, & A.I. Dittel. 1982. Seasonal changes in nutrients and dissolved oxygen in the Gulf of Nicoya, a tropical estuary on the Pacific coast of Central America. Hydrobiologica (in press).

Erdman, D.S. 1971. Notes on fishes from the Gulf of Nicoya, Costa Rica. Rev. Biol. Trop., 19:59-71.

Fuertes, J. R. & H. Araya. 1979. Campaña de prospección pesquera en la plataforma continental del Pacífico de Costa Rica (noviembre 1977, enero 1978). Inf. Técn. Int. Inv. Pesq., Barcelona 69: 1-31.

Leon, P.E. 1973. Ecología de la ictiofauna del Golfo de Nicoya, Costa Rica, un estuario tropical. Rev. Biol. Trop., 21:5-30.

Lloyd, M., & R.J. Ghelardi. 1964. A table for calculating the "equitability" component of species diversity. J. Anim. Ecol., 33:217-225.

Madrigal, E. 1979. Algunos peces de importancia comercial del litoral pacífico costarricense. Public. Biol. Marina Pesquera, Min. Agric. y Ganadería de Costa Rica No.3, 27 p. (mimeogr.).

Maurer, D., C.E. Epifanio, J.A. Vargas, A.I. Dittel, M.M. Murillo, H.K. Dean, & S.R. Howe. 1982. Megabenthic invertebrates of a tropical estuary: Gulf of Nicoya, Costa Rica. Hydrobiologia (in press).

McErlean, A.J., S.G. O'Connor, J.A. Mihursky, & C.I. Gibson. 1973. Abundance, diversity and seasonal patterns of estuarine fish populations. Est. and Coastal Mar.Sci., 1:19-36.

Peterson, C.L. 1956. Observations on the taxonomy, biology and ecology of the engraulid and clupeid fishes in the Gulf of Nicoya, Costa Rica. Bull. Inter-Amer. Trop. Tuna Comm., 1:139-280.

Peterson, C.L. 1960. La oceanografía física del Golfo de Nicoya, Costa Rica, un estuario tropical. Bull. Inter-Amer. Tropical Tuna Comm., 4:139-214.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. J. Theoret. Biol., 13:131-144.

Salzen, E. 1957. A trawling survey off the Gold Coast. J. du Conseil. 23:72-82.

Stevenson, D.K. 1978. Management of fisheries resources in the Gulf of Nicoya, Costa Rica: Methods and preliminary results. Rev. Biol. Trop., 26 (Suppl. 1): 107-123.

Stevenson, D.K. 1979. Use of length frequency data to estimate growth and mortality rates for species exploited by tropical small-scale fisheries in Puerto Rico and Costa Rica, p.137-153. *In* S.B. Saila & P. Roedel (eds.). Stock assessment for tropical small-scale fisheries, University of Rhode Island, Kingston, R.I.

Stevenson, D., & F. Víquez. 1978. Evaluación preliminar sobre ciertas especies de corvina, robalo, pargo y macarela en el Golfo de Nicoya. Dir. Gral. Rec. Pesqueros y Vida Silvestre, Minist. Agric. y Ganadería de Costa Rica 27 p. (mimeogr.).

Subrahmanyam, C., & S. Drake. 1975. Studies on the animal communities in two north Florida salt marshes, Part I. Bull. Mar. Sci., 25: 445-465.

Voorhis, A.D., C.E. Epifanio, D. Maurer, A.I. Dittel, & J. A. Vargas. 1982. The estuarine character of the Gulf of Nicoya, Costa Rica. Hydrobiologia, (in press).