ASSESSMENTS OF THE FISH COMMUNITY OF THE LOWER HUDSON-RARITAN ESTUARY COMPLEX

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ABSTRACT

The site selection process to implement a program for disposal of dredged material in existing or new subaqueous borrow pits in Lower New York Harbor requires preparation of a Federal Supplemental Environmental Impact Statement which will review and synthesize recent studies in this area. This Report utilizes an extensive fishery data base from recent ground trawl surveys (September 1984 to March 1986) in the Lower Bay Complex of the Hudson-Raritan Estuary, to describe the fishery resources, it goes on to evaluate borrow pit sites in terms of this resource.

The finfish community of the Lower Bay Complex, its species composition, abundance and biomass are described, including distributions through the area. Seasonal changes in the community composition are described. Resident, transient, and migratory species are identified. Utilization of the area by juvenile stages of species of interest is also described. Two important shellfish, lobsters and blueclaw crabs, are described separately in terms of abundance and distribution.

The data from the fishery analysis was used to develop criteria for identification within the Lower Bay Complex of areas which were of relatively low diversity and low use by the fish community. Criteria are given for the selection of five sites for potential disposal of dredged material. These five sites are allocated priorities according to their use by fishes and shellfish, and then discussed in terms of recently proposed disposal sites in the Lower Bay Complex.

REPORT ON THE FISH COMMUNITY OF LOWER NEW YORK HARBOR IN RELATION TO BORROW PIT SITES

INTRODUCTION

The New York District USCOE proposes to implement an operational program to dispose of dredged material in existing and/or new subaqueous borrow pits. Disposal in borrow pits is an option that is part of the Dredged Material Disposal Management Plan for the Port of New York and New Jersey. As part of the regulatory requirements needed for the authorization of the project, a Federal Supplemental Environmental Impact Statement (SEIS) is being prepared. The first objective of the work will be to review and synthesize the results of recent research studies related to subaqueous borrow pit disposal. These results will be integrated to produce an assessment of the site selection process for the implementation of the operational program for borrow pit disposal.

This is the first of two Reports which will be made using an extensive data base from recent ground trawl surveys by the Marine Sciences Research Center to describe the fishery resources of the Lower New York Harbor and to evaluate potential new pit sites. The trawl data was collected from September 1984 to March 1986. Separate analyses will be made for finfish (except anchovies) and for lobsters and blueclaw crabs which are important in the region.

REPORT OBJECTIVES

In the present Report the fishery resources of Lower Bay Complex (including Raritan Bay) will be described, using standard techniques to analyze the trawl survey data. The principal analyses will use data from stations which were trawled consistently throughout one year. These data will be supplemented with additional information from trawl stations to the south of the area, which were sampled over periods shorter than a year.

The trawl fishery data analysis used to describe the fish community of the Lower Bay-Raritan Bay area will address:

1. species composition and abundance of the finfish community and its general use of the subject area
2. overall distribution patterns
3. seasonal trends
4. resident populations
5. migratory/transient patterns
6. nursery/spawning usage
7. particular attention is given to two commercially important shellfish (lobsters and blueclaw crabs).

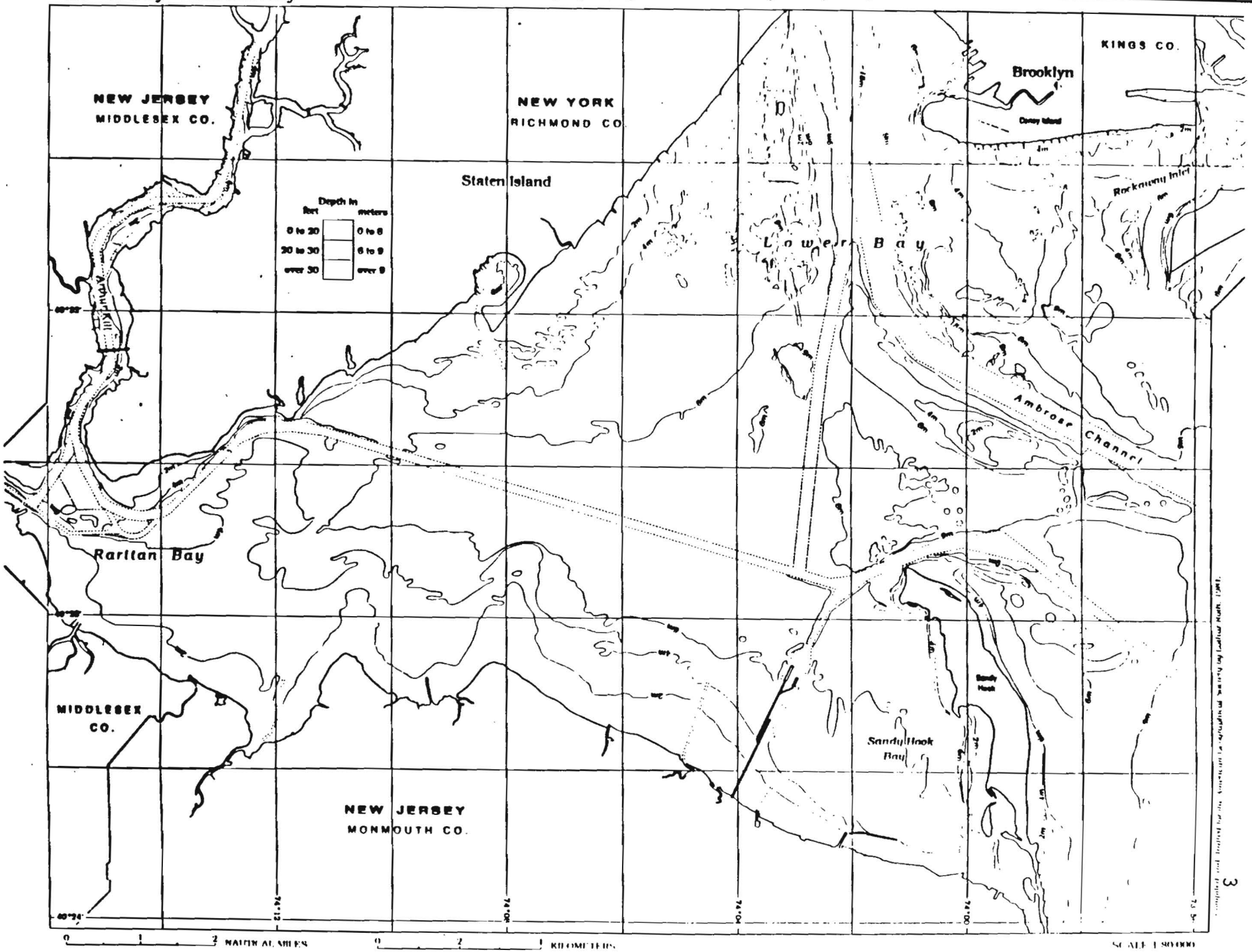
Data derived from the fishery analysis of the fish species and their distribution, diversity and abundance over the Lower New York Harbor have been inspected to identify five (5) areas of relatively low diversity and low use by the fish community, and also by lobsters and blueclaw crabs; the criteria for selection of the five sites are discussed. The fish population at each of the five sites is evaluated in terms of the average population densities of the community throughout the area surveyed.

GENERAL FEATURES OF LOWER BAY COMPLEX

The Lower Bay Complex of New York Harbor is estuarine consisting of the Lower, Raritan and Sandy Hook Bays at the mouths of the Hudson and Raritan Rivers. The waters of the Lower Bay Complex exchange and mix with the Upper Bay of New York Harbor through the Verranzo Narrows, and with the sea to the south through the relatively wide opening between Sandy Hook, N.J. and Rockaway Point, N.Y. (often referred to as the Sandy Hook-Rockaway Transect).

The Lower Bay Complex is shallow (5 to 20 m) and has an irregular bottom topography composed of numerous banks, shoals, ship channels and pits, Figure 1. The Ambrose Channel separates the Complex into eastern and western sections. The east side is dominated by the East Bank shoal lying between the Channel and Rockaway, which was a bottom type that is predominantly sandy with patches of shell. The western side of the Channel is bordered by the West Bank

Figure 1. Bottom topography of Lower Bay complex.



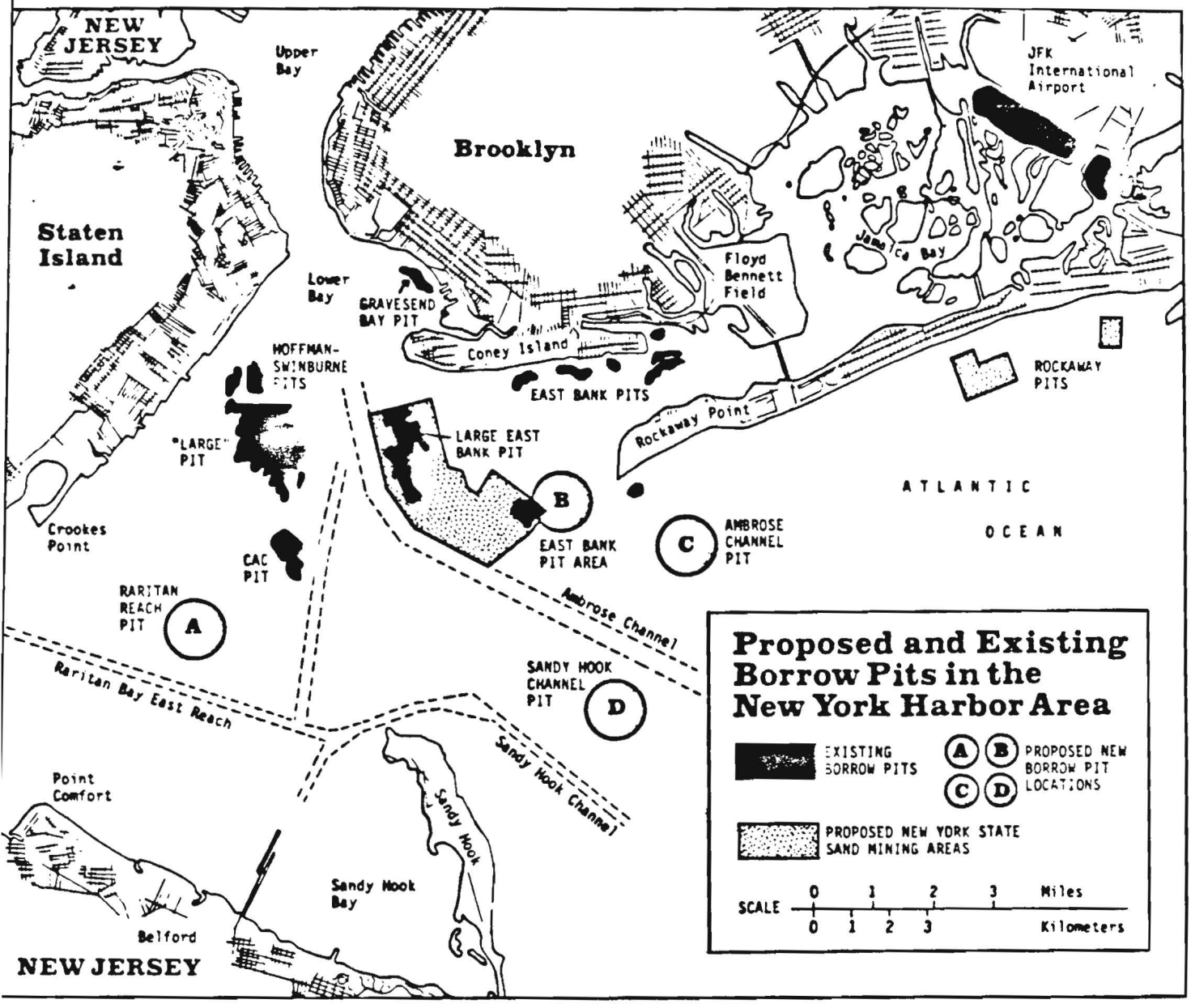
to the north and by Romer Shoal. To the south-west of Romer Shoal is another large bank, Flynn's Knoll. All of these banks are sandy, although some mud patches occur on Flynn's Knoll. Flynn's Knoll is bordered to the south by the Sandy Hook Channel and to the west by Chapel Hill Channel, which runs north-south. Raritan Bay covers the largest area of the Lower Bay Complex. It is shallow, with greatest depths about 8 m in the west-central areas, and is bounded to the north by Staten Island and to the south by Mommouth County, N.J. The bottom of Raritan Bay is largely soft and muddy in the areas deeper than 6 m and in the inner western shoals of the Bay, but off the northern and southern shores at depths shallower than about 5 m, sand and hard sand bottoms predominate with patches of shell. Sandy Hook Bay, sheltered by the Hook, has a soft mud bottom with sand bottoms close to shore.

BORROW PITS

The sites of the borrow pits in the Lower New York Harbor, together with potential new sites which have been proposed are shown in Figure 2 (from "PICG Update", January, 1986). The figure includes brief descriptions of the borrow pit sites.

TRAWL SURVEY STATIONS

A total of 16 bottom trawl surveys were made in the Lower Bay-Raritan Bay area. The first survey was principally a reconnaissance and the data have not been used here. On the next two surveys 31 stations were sampled in the eastern part of the Complex, but did not extend into inner Raritan Bay. The third survey was reduced to only 17 stations. From January 1985 until the end of the survey series, survey 5 through 16, all 38 stations shown in Figure 3 were sampled. These surveys (5-16) provided most of the data used in the assessments and site selections reported here, they are referred to in figures as the "annual" series. The codes used for the stations on surveys 5 through 16 are given in Figure 4; the station positions, and their codes for surveys 2 and 3 are given in Figures 5 and 6.



gure 2. Borrow Pit Sites (from "PICG Update", January 1986).

isting Pits

the existing borrow pits that e been surveyed, five sites ear to be the most promising an operational disposal program. estigations will be done on se sites; they are the CAC pit, "Large Pit", the Large East k Pit, the Gravesend Bay Pit the "Hoffman-Swinburne" pits ee Map, above). Of these five, CAC pit and the Large Pit have largest available volumes.

The Large Pit is located north of the CAC pit and south of the Hoffman-Swinburne pits. It is large but it is not as deep as some of the other pits. If this pit is selected, it may have to undergo some physical modification.

The CAC or West Bank borrow pit was originally selected as the best location for the demonstration project; the objectives of the project were achieved through other research efforts. It is located close to the Chapel Hill Channel and it is relatively large and deep.

The Gravesend Bay pit is relatively small and shallow, as are the Hoffman Swinburne pits. The Large East Bank Pit is part of the proposed Office of General Services sand mining area; it covers a large area and is adjacent to Ambrose Channel. In addition to these five, there are small pits near Coney Island and in Rockaway. The Jamaica Bay pits may be the largest and deepest of all existing pits, but they are adjacent to Gateway National Recreation Area and may not be available for use as a disposal site.

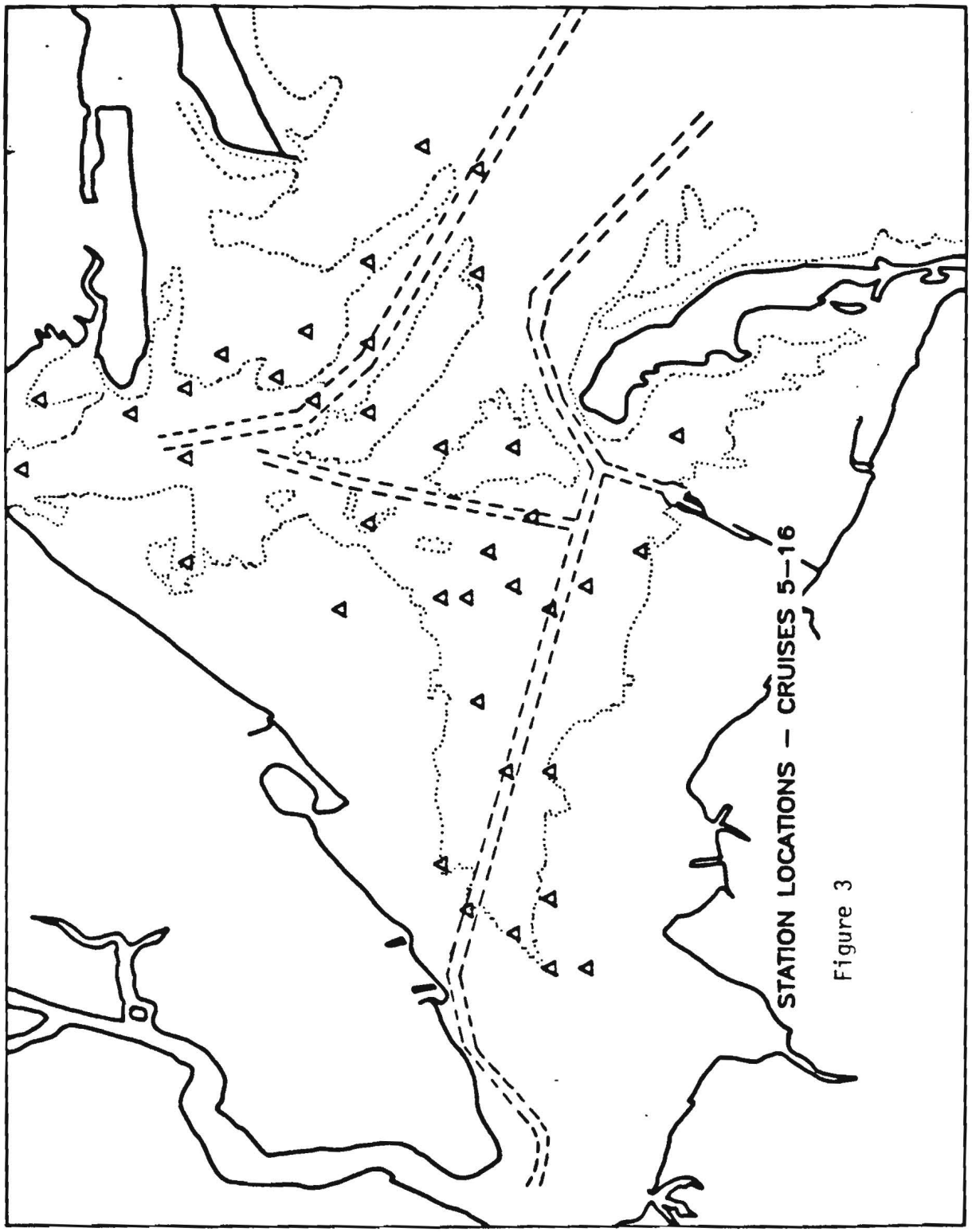
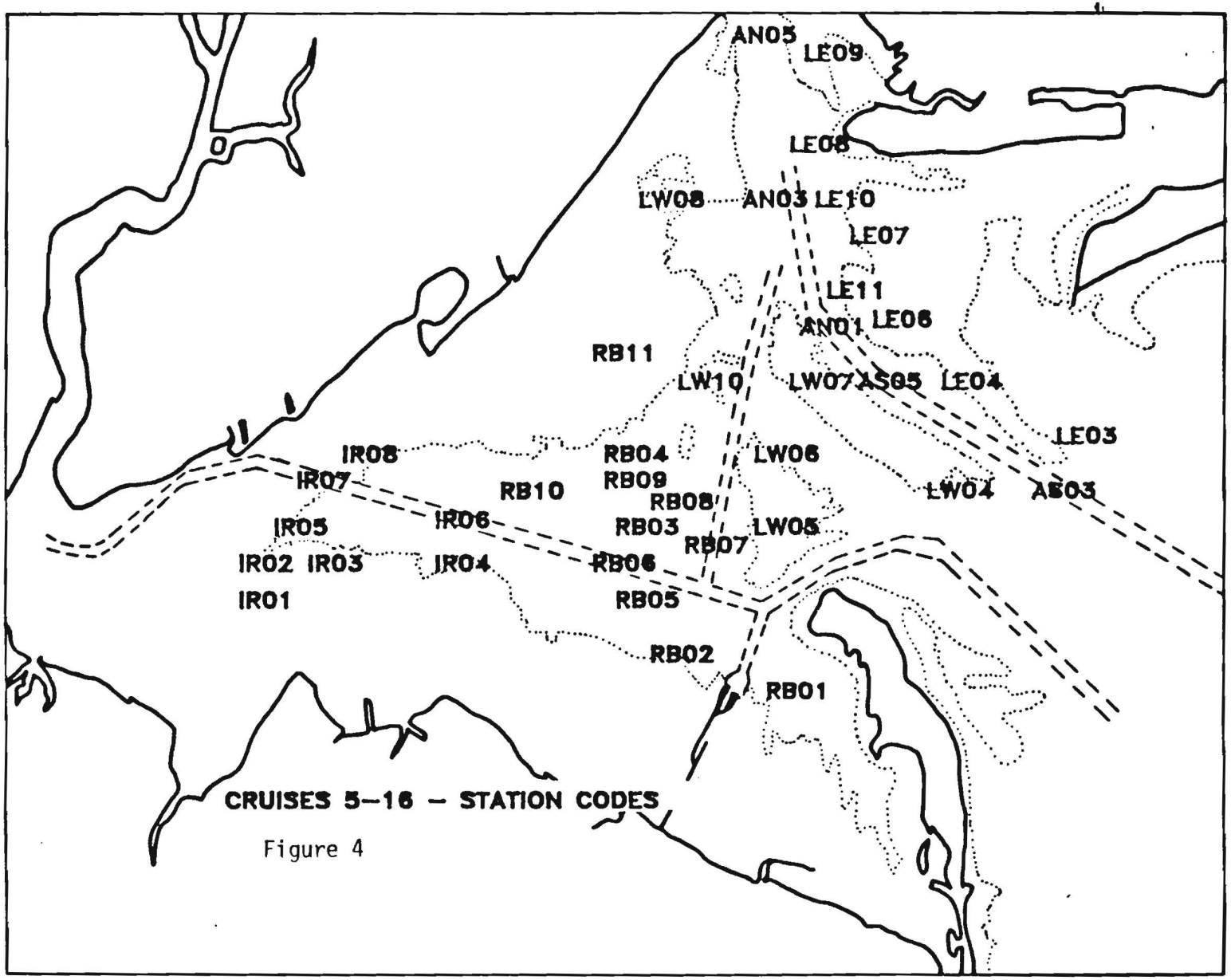
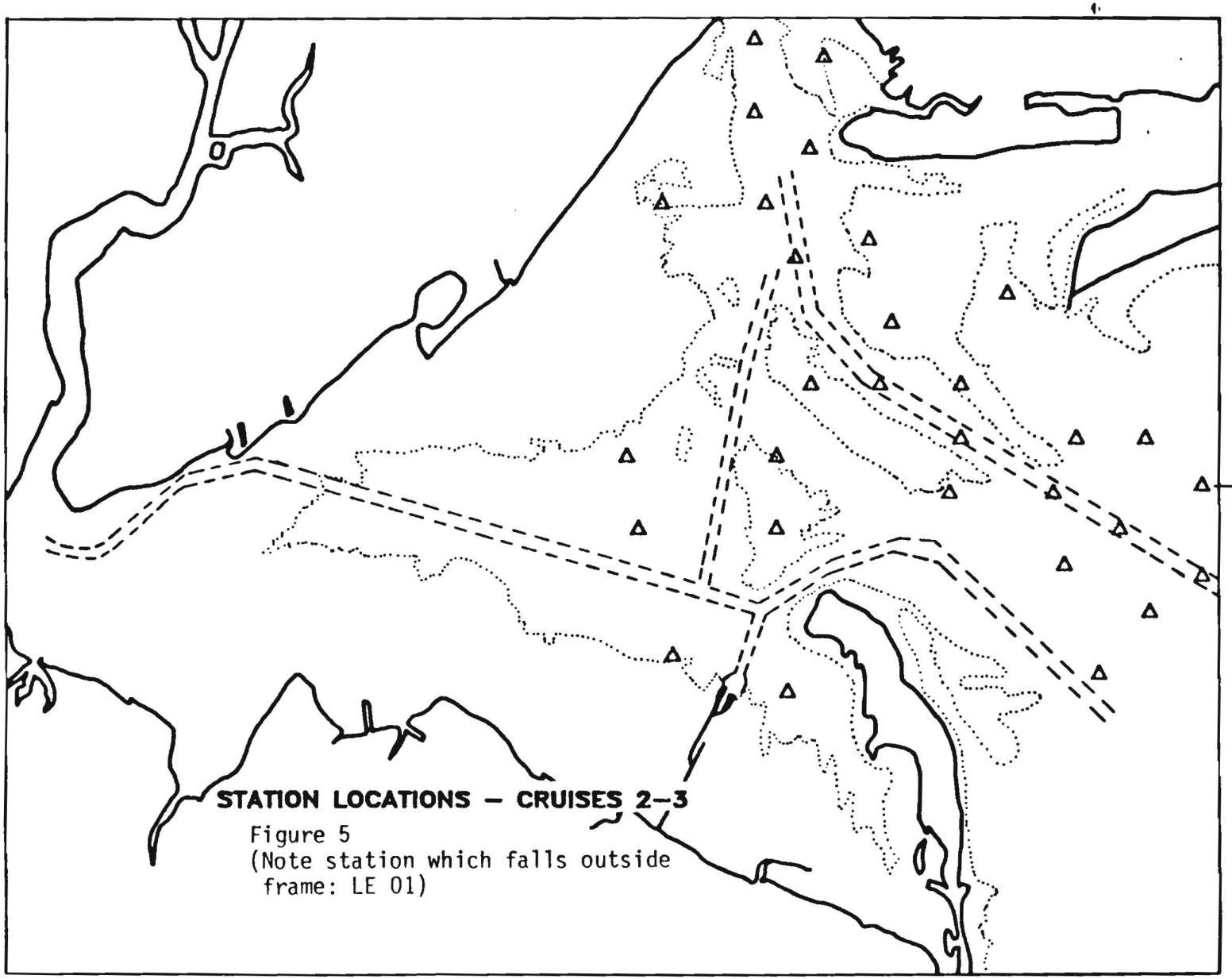


Figure 3



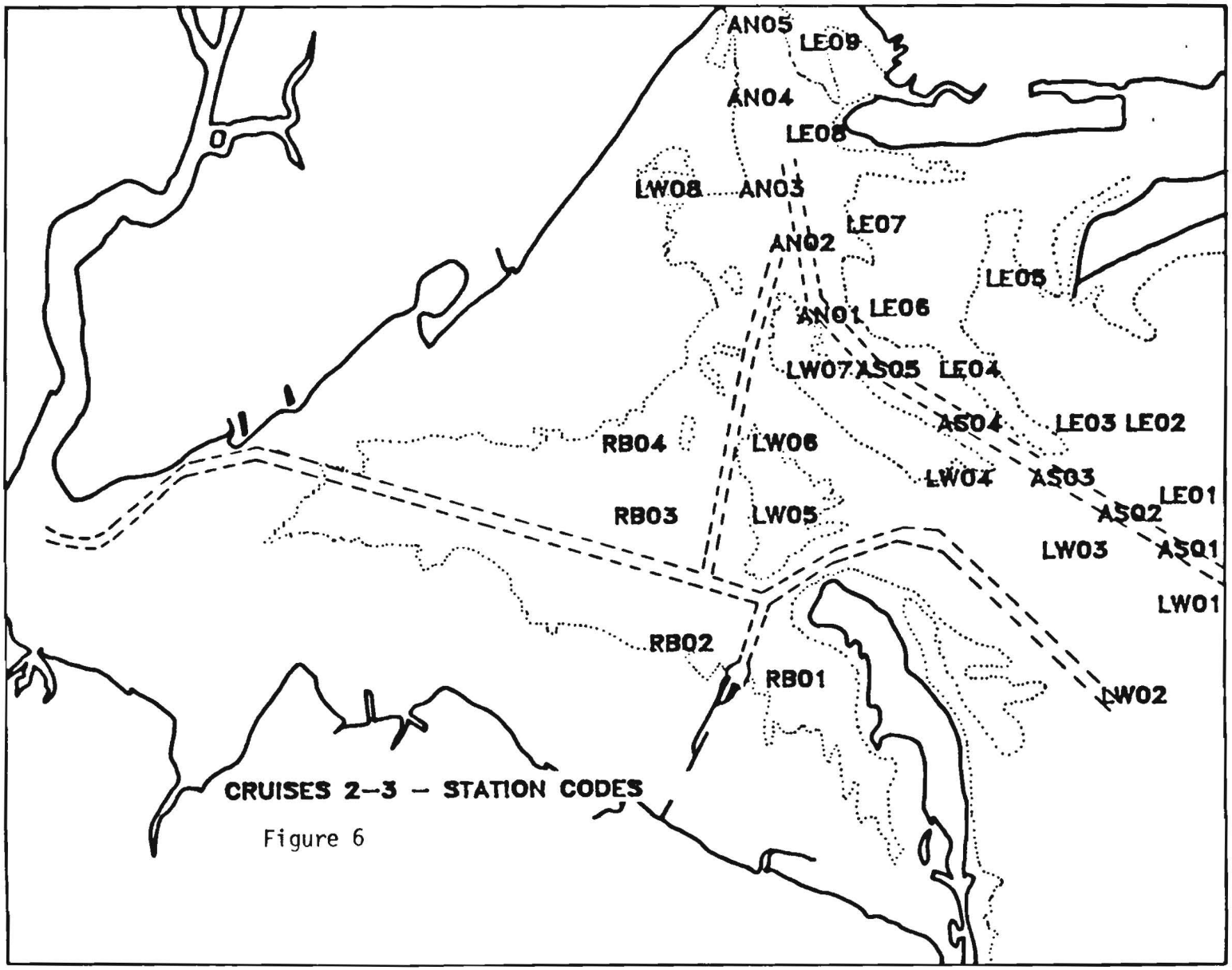
CRUISES 5–16 – STATION CODES

Figure 4



STATION LOCATIONS – CRUISES 2–3

Figure 5
(Note station which falls outside frame: LE 01)



CRUISES 2–3 – STATION CODES

Figure 6

The trawl samples of fishes were taken over a range of depths in the region from about 4 m to 15 m and included the shipping channels. These depths variable were grouped into three dedpth strata for the analyses:

Stratum 1: Shallow to 6 m
Stratum 2: 7 m to 10 m
Stratum 3: Deeper than 10 m

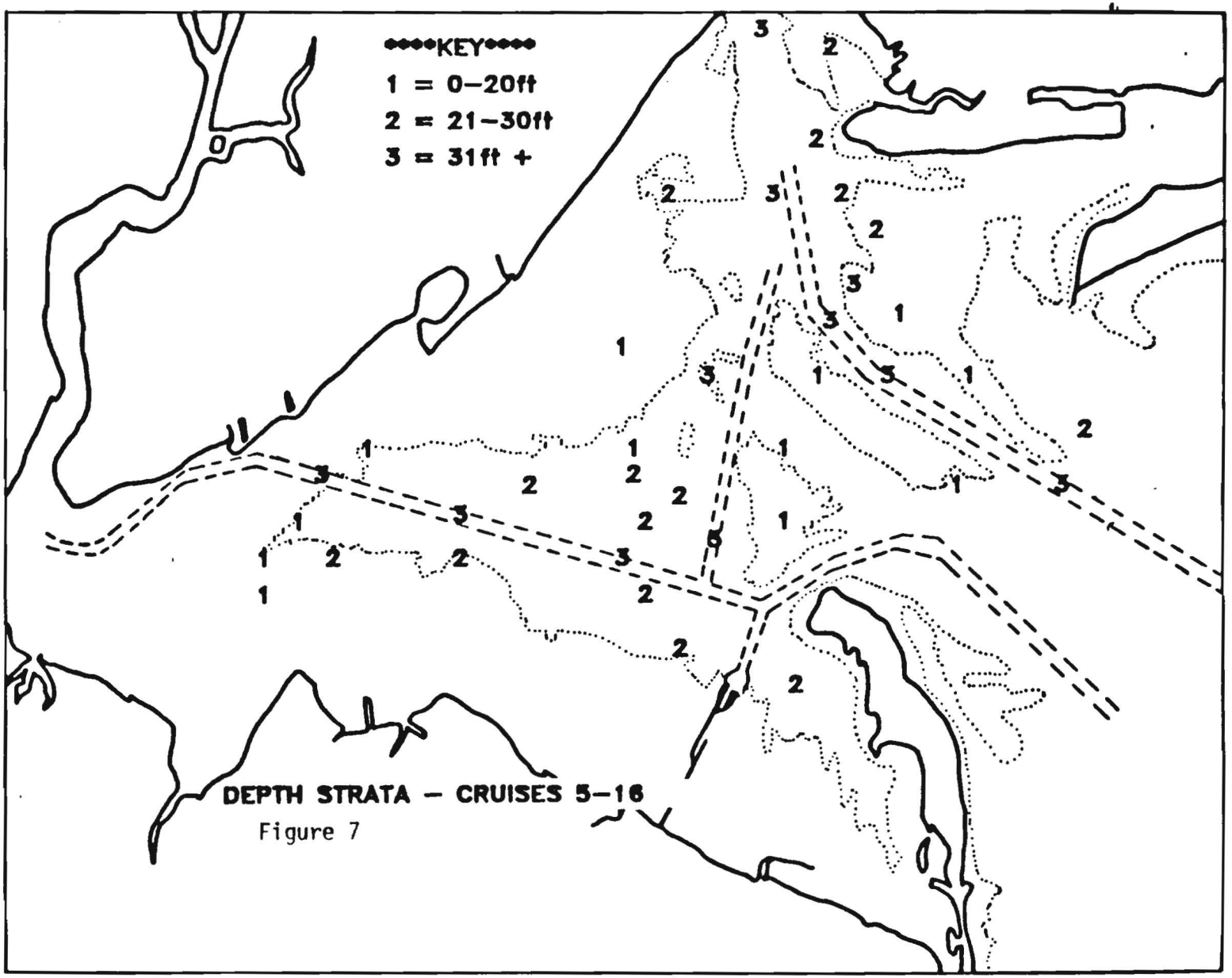
The distribution of stations by depth strata are shown for surveys 5 through 16, and for surveys 2 and 3 in Figures 7 and 8 respectively.

SURVEY METHODS

The survey vessels were R/V ONRUST, a 17 m steel hull trawler, and R/V CHALLENGER, a 20 m wooden trawler; R/V CHALLENGER was only used for survey 10, September 1985. The bottom trawl used throughout the survey series was a high-rise otter trawl with a 9 m footrope, and it was fished with 9 m legs to the trawl doors. The footrope was fitted throughout its length with neoprene 15 cm and 25 cm "cookie" discs. The trawl nets were 76 mm polypropylene stretch mesh, the cod-end was made of 38 mm mesh, and it fitted with a 15 mm nylon small-mesh liner.

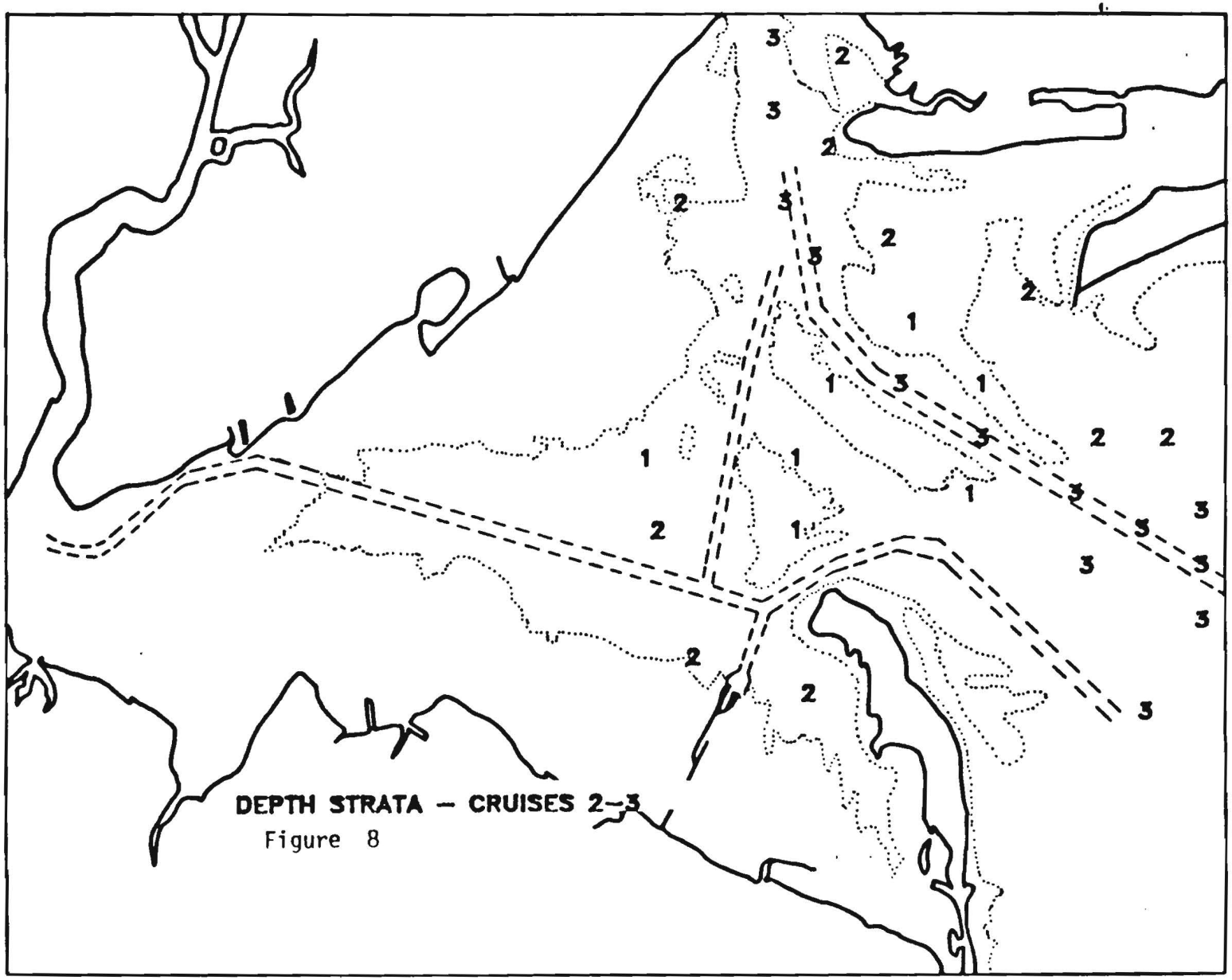
Standard trawl hauls were of 8 minutes duration at a towing speed of about 4.5 km/hr. An onboard computerized Loran navigator system gave precise position fixing and measured the distance covered and bearing of all trawl hauls. From the distance covered over the sea-bed and known dimensions of the trawl, the area of estuary bottom trawled was computed.

Fish collections were processed onboard immediately following each trawl tow. At each station, fish were sorted by species, the fish were counted and the total weight of each species was measured. Fish were returned to the sea as soon as the catch had been enumerated and processed.



DEPTH STRATA – CRUISES 5–16

Figure 7



DEPTH STRATA – CRUISES 2–3

Figure 8

COMMUNITY COMPOSITION

Species

Sixty-nine species of finfish were collected in the course of the twelve surveys covering the annual cycle of the whole area. However, fifteen species were only found at a single station (usually as single fish) during the year. The mean number of species caught annually at a station was twenty-four. Fourteen species were common year-round residents in the survey area.

A list of the common names of the fishes in the community and of their scientific, taxonomic, names is given in Table 1. Resident species status is indicated by "R" in the table; species which were caught at only one station (singletons) are indicated by given "S" in the Status column.

Numbers of Fish

The numerical abundance of the fishes in the community is given in Table 2, their abundance at each station was calculated as numbers per hectare ($m^2 x 10^4$). The total catch of each species for the year (surveys 5-16 inclusive) is given in the Table, together with the average catch of each species per station and its standard error. The fish species are also ranked by their abundance, in the Table 2.

The bay anchovy was by far the most abundant species, comprising 67% of the total catch. The three river herrings, blueback herring, alewife and American shad (Alosa aestivalis, A. pseudoharengus and A. sapidissima) were also dominant in catches and together were 13% of the total. The ten most abundant species accounted for 95% of the catch, in addition to the anchovy and herrings they included winter flounder, windowpane flounder, butterfish, weakfish, scup and American sandlance.

The average number of fish at a station (mixed species) during the surveys was 575 fish per hectare, which consisted of 388 bay anchovies and 187 fish of the remaining species.

Table 1. Finfish community, names and species codes.

CODE	COMMON NAME	SCIENTIFIC NAME	STATUS*
LAMPREY	lamprey	Petromyzon marinus	S
SM DOGF	smooth dogfish	Mustelus canis	
SP DOGF	spiny dogfish	Squalus acanthias	
LI SKATE	little skate	Raja erinacea	
RS SKATE	rosette skate	Raja garmani	S
W SKATE	winter skate	Raja sp.	
TH SKATE	thorny skate	Raja sp.	
AT STURG	Atlantic sturgeon	Acipenser oxyrhinchus	
AMER EEL	American eel	Anguilla rostrata	R
CON EEL	conger eel	Conger oceanicus	R
BB HERRG	blueback herring	Alosa aestivalis	
ALEWIFE	alewife	Alosa pseudoharengus	
AM SHAD	American shad	Alosa sapidissima	
AT MENHD	Atlantic menhadden	Brevoortia tyrannus	
AT HERRG	Atlantic herring	Clupea harengus	
RND HERR	round herring	Etrumeus teres	
BAY ANCH	bay anchovy	Anchoa mitchilli	
STR ANCH	striped anchovy	Anchoa hepsetus	
TOADFISH	oyster toadfish	Opsanus tau	
GOOSEF	goosefish	Lophius americanus	S
4 ROCKLG	fourbeard rockling	Enchelyopus climbrius	S
SL HAKE	sliver hake	Merluccius bilinearis	
TOMCOD	tomcod	Microgadus tomcod	
POLLOCK	pollock	Pollachius virens	S
SPT HAKE	spotted hake	Urophycis regius	R
W/R HAKE	white/red hake	Urophycis tenius/chuss	R
JUV. GAD	juvenile cod		S
CUSKEEL	cuskeel	Lepophidium cervinum	
CORNETF	cornetfish	Fistularia tabacaria	S
A SILVER	Atlantic silverside	Menidia menidia	
3 STICKL	3 spine stickleback	Gasterosteus aculeatus	
SEAHORSE	lined seahorse	Hippocampus erectus	R
PIPEFISH	northern pipefish	Syngnathus fuscus	R
SEA RAVN	sea raven	Hemipterus americanus	
GRUBBY	grubby	Myoxocephalus aenus	R
LN SCULP	longhorn sculpin	M. octodecemspinosus	
SH SCULP	shorthorn sculpin	Myoxocephalus scopios	S
UN SCULP	unident sculpin		
BL SEABS	black seabass	Centropristis striata	
GRY SNAP	grey snapper		S
MSC SERR	unident snapper		
STR BASS	striped bass	Morone saxatilis	
LEPOMIS	unident Lepomid		S
BLUEFISH	bluefish	Pomatomus saltatrix	
CREV JCK	crevelle jack	Caranx hippos	S
LOOKDOWN	lookdown	Selene vomer	
RH SCAD	rough scad	Trachurus trachurus	
SLPERCH	silverperch	Bairdiella chrysura	S
WEAKFISH	weakfish	Cynoscion regalis	
SPOT	spot	Leiostomus xanthurus	
SCUP	scup	Stenotomus chrysops	

Table 1. Continued.

CODE	COMMON NAME	SCIENTIFIC NAME	STATUS*
SP BUTFL	spotfin butterflyfish	Chaetodon ocellatus	S
ST MULL	striped mullet	Mugil cephalus	
N BARRAC	northern barracuda	Sphyraena borealis	
BLACKF	blackfish	Tautoga onitus	R
CUNNER	cunner	Tautogolabrus adspersus	R
RCK GUNN	rock gunnel	Pholis gunnellus	R
AM SANDL	American sandlance	Ammodytes americanus	R
BUTTERF	butterfish	Peprilus triacanthus	
AT MACKR	Atlantic mackerel	Scomber scombrus	
N SEARBN	Northern searobin	Prionotus carolinus	
ST SEARB	striped searobin	Prionotus evolans	
SMM FLND	smallmouth flounder	Etropus microstomus	
FLUKE	summer flounder	Paralichthys dentatus	
4SP FLND	4_spot flounder	Paralichthys oblongus	
WINDOWPN	windowpane	Scophthalamus aquosus	R
WN FLND	winterflounder	P. americanus	R
HOGCHOKR	hogchoker	Trinectes maculatus	S
PL FILEF	planehead filefish	Monocanthus hispidus	
N PUFFER	northern puffer	Sphaeroides maculatus	S
BLU CLAW	blueclaw crab	Callinectes sapidus	
LOBSTER	American lobster	Homarus americanus	

* R = Resident species S = species only occurs once in surveys.

Table 2. Total and mean annual catch abundance, surveys 5 to 16.

Name Code	Total	Average	±s.e.	Rank
LAMPREY	1.56	.04	.04	70
SM DOGF	93.34	2.46	.62	27
SP DOGF	5.74	.15	.11	50
LI SKATE	28.54	.75	.43	39
RS SKATE	2.34	.06	.06	59
W SKATE	30.21	.80	.38	37
TH SKATE	11.13	.29	.17	43
AT STURG	18.32	.48	.33	41
AMER EEL	41.69	1.10	.60	35
CON EEL	39.09	1.03	.58	36
BB HERRG	13065.91	343.84	124.30	2
ALEWIFE	12654.32	333.01	113.86	3
AM SHAD	3785.65	99.62	26.52	8
AT MENHD	315.94	8.31	4.78	19
AT HERRG	92.22	2.43	1.17	28
RND HERR	51.51	1.36	1.08	33
BAY ANCH	153731.70	4045.57	647.42	1
STR ANCH	77.73	2.05	.70	29
TOADFISH	5.59	.15	.08	51
GOOSEF	3.95	.10	.10	54
4 ROCKLG	1.73	.04	.04	67
SL HAKE	843.25	22.19	6.16	16
TOMCOD	74.80	1.97	1.93	30
POLLOCK	1.68	.04	.04	68
SPT HAKE	1156.93	30.45	13.78	13
W/R HAKE	1522.31	40.06	23.19	11
JUV GAD	1.77	.05	.05	65
CUSKEEL	10.46	.28	.16	44
CORNETF	1.99	.05	.05	63
A SILVER	376.34	9.90	2.53	17
3 STICKL	4.97	.13	.07	53
SEAHORSE	43.62	1.15	.32	34
PIPEFISH	141.75	3.73	.84	24
SEA RAVN	6.44	.17	.10	49
GRUBBY	323.90	8.52	2.40	18
LN SCULP	29.88	.79	.27	38
SH SCULP	3.55	.09	.09	57
UN SCULP	1.60	.04	.04	69
BL SEABS	122.40	3.22	1.38	25
GRY SNAP	2.05	.05	.05	62
MSC SERR	3.70	.10	.07	55
STR BASS	53.36	1.40	.59	32
LEPOMIS	1.82	.05	.05	64
BLUEFISH	283.61	7.46	4.86	20
CREV JCK	1.77	.05	.05	65
LOOKDOWN	146.34	3.85	1.53	23

Table 2. Continued.

Name Code	Total	Average	±s.e.	Rank
RH SCAD	23.37	.61	.24	40
SLPERCH	4.69	.12	.12	52
WEAKFISH	5280.41	138.96	71.74	6
SPOT	9.35	.25	.20	47
SCUP	2435.84	64.10	13.98	10
SP BUTFL	2.26	.06	.06	61
ST MULL	9.82	.26	.18	45
N BARRAC	8.09	.21	.10	48
BLACKF	904.36	23.80	3.80	15
CUNNER	271.68	7.51	2.06	21
RCK GUNN	60.73	1.60	.45	31
AM SANDL	5086.93	133.87	66.01	7
BUTTERF	7359.30	193.67	69.02	5
AT MACKR	3.64	.10	.07	56
N SEARBN	12.33	.32	.15	42
ST SEARB	1136.52	29.91	15.51	14
SMM FLND	100.77	2.65	.75	26
FLUKE	1454.91	38.29	5.11	12
4SP FLND	181.15	4.77	1.84	22
WINDOWPN	2978.01	78.37	18.75	9
WN FLND	11111.43	292.41	45.76	4
HOGCHOKR	2.34	.06	.06	59
PL FILEF	9.39	.25	.15	46
N PUFFER	2.34	.06	.06	59

Weight of Fish

The abundance of the fishes in the community expressed as their total weight (biomass, lbs) is given in Table 3, again their weight at each station was calculated from the catch data as weight per hectare (m^2x104). The catch of each species summed for survey 5-16 combined is given in the Table, together with the average weight of each species caught per station and its standard error.

Measured by weight, the winter flounder was the dominant species, comprising 35% of the catch. The second most abundant species was the blackfish, Tautoga onitis, at 16% of the total weight. The three flounders - winter flounder, fluke and windowpane flounder (Pseudopleurnectes americanus, Paralichthys dentatus and Scophthalamus aquosus) accounted for 56% of the total weight of fishes. The ten species with greatest total weights accounted for 87% of the biomass, in addition to these flounders and blackfish, the groundfish included red hake, scup, butterfish and smooth dogfish.

The numerically dominant pelagic fishes, the bay anchovy and herrings, were of reduced importance when measured by weight. The bay anchovy amounted to only 3.4% of the total biomass and the three river herrings (A. aestivalis, A. pseudoharengus and A. sapidissima), together with the Atlantic herring Clupea harengus, in combination comprised only 5.5% of the total biomass.

The average weight of fish at a station (all species) during the surveys was 12.7 lbs fish per hectare, of which 7.1 lbs were flounder species.

Exclusion of Bay Anchovy from the Analysis

The very large numbers of the dominant bay anchovy and the erratic distribution of the anchovy in the survey area strongly biased analyses of the data for the community. The anchovy is of no interest to the recreational and commercial fisheries of the Lower Harbor; it was excluded from further analyses at the request of USCOE.

Table 3. Total and mean annual catch biomass, surveys 5 to 16.

Name Code	Total	Average	±s.e.
LAMPREY	.00	.00	.00
SM DOGF	115.79	3.05	.85
SP DOGF	7.42	.20	.14
LI SKATE	16.15	.42	.25
RS SKATE	1.59	.04	.04
W SKATE	59.83	1.57	.83
TH SKATE	4.40	.12	.06
AT STURG	49.48	1.30	.78
AMER EEL	7.94	.21	.11
CON EEL	.86	.02	.01
BB HERRG	92.83	2.44	.63
ALEWIFE	148.71	3.91	1.28
AM SHAD	44.74	1.18	.24
AT MENHD	15.44	.41	.14
AT HERRG	31.02	.82	.42
RND HERR	.45	.01	.01
BAY ANCH	198.43	5.22	.90
STR ANCH	1.08	.03	.01
TOADFISH	1.74	.05	.04
GOOSEF	1.25	.03	.03
4 ROCKLG	.04	.00	.00
SL HAKE	54.74	1.44	.52
TOMCOD	5.96	.16	.15
POLLOCK	.00	.00	.00
SPT HAKE	67.26	1.77	.69
W/R HAKE	199.23	5.24	4.09
JUV GAD	.00	.00	.00
CUSKEEL	.24	.01	.00
CORNETF	.05	.00	.00
A SILVER	2.70	.07	.02
3 STICKL	.00	.00	.00
SEAHORSE	.51	.01	.00
PIPEFISH	.33	.01	.00
SEA RAVN	4.25	.11	.06
GRUBBY	5.72	.15	.04
LN SCULP	9.17	.24	.08
SH SCULP	.04	.00	.00
UN SCULP	.00	.00	.00
BL SEABS	12.30	.32	.18
GRY SNAP	.00	.00	.00
MSC SERR	.00	.00	.00
STR BASS	30.24	.80	.34
LEPOMIS	.04	.00	.00
BLUEFISH	45.54	1.20	.45
CREV JCK	.00	.00	.00
LOOKDOWN	.64	.02	.01

Table 3. Continued.

Name Code	Total	Average	±s.e.
RH SCAD	.10	.00	.00
SLPERCH	.42	.01	.01
WEAKFISH	53.61	1.41	.80
SPOT	.46	.01	.01
SCUP	109.95	2.89	.57
SP BUTFL	.00	.00	.00
ST MULL	1.41	.04	.03
N BARRAC	.00	.00	.00
BLACKF	922.16	24.27	8.50
CUNNER	26.48	.70	.29
RCK GUNN	.84	.02	.01
AM SANDL	23.78	.63	.29
BUTTERF	78.04	2.05	.60
AT MACKR	.00	.00	.00
N SEARBN	1.82	.05	.02
ST SEARB	63.14	1.66	1.22
SMM FLND	.47	.01	.00
FLUKE	712.29	18.74	2.12
4SP FLND	5.95	.15	.08
WINDOWPN	488.50	12.86	2.93
WN FLND	2046.96	53.87	6.70
HOGCHOKR	.05	.00	.00
PL FILEF	.32	.01	.01
N PUFFER	.05	.00	.00

AREA USE BY FISH POPULATIONS

The total data set for each of the continually sampled stations, surveys 5 through 16 inclusive, was analyzed in order to group together stations of similar catch composition. In this way subareas of similar usage by the fish community could be identified within the Lower Bay-Raritan Bay Complex. The method of analysis used, classification by clustering together similar stations, is a method routinely used for ecological studies of communities.

Classification of Stations by Clustering

The community data are bulky and complex, and the composition of the fish community is seen to change through the survey region, which is spatially heterogeneous. Classification is a form of community analysis which sets out to reduce the number entities (samples) to relatively few categories, the analysis should enhance the clarity of major patterns but will obscure minor variation. The objectives of our analysis were to identify the station samples with a similar faunal composition and to define boundaries between groups.

A variety of measures of distance are available to summarize the overall similarity between the community samples caught at different stations, taking all species into consideration. A simple measure of distance is the coefficient of similarity which gives equal weight to all species. Bray and Curtis applied a quantitative version of the coefficient of similarity to bring the abundance of each species into consideration, the Bray-Curtis Index of Similarity has been widely used in analysis of marine ecological data. The application of the similarity measures to the data and their classification, results in a matrix comparing samples with every other sample. The matrix could be arranged as a trellis diagram but is more conveniently summarized in a cluster diagram which combines similar station samples to form distinct small classes, clusters, then combine the clusters into large classes and so on. Cut-off levels of similarity can be applied to the stations clustered in groups of similar use, the groups may be coded and the codes plotted on charts to pictorially divide the survey area into similar station groups. We have applied these methods of classification to the fish community data. The Bray-Curtis Index of Similarity was used, following transformation of the abundance data to natural logarithms.

Results

The results of the cluster analysis of the total data set for surveys 5 through 16, using the Bray-Curtis Index as the distance measure of similarity, are shown as a dendrogram in Figure 9 in which the survey stations have been placed in 9 groups. Four of the groups contain only a single station, although Groups 7 (LW04) and 9 (LE03) are associated with Group 8, and Group 6 (LE07) is associated with Group 5, Figure 9.

The groups identified by the cluster analysis have been plotted for the survey area to divide it into areas of similar station groupings, Figure 10. The groupings of stations divide the Lower Bay-Raritan Bay into fish usage areas. The deep stations in the shipping channels, together with the Borrow Pits (LW08, LW10 and LE11), all fall into Group 2 (with the single exception of AN05 at the Verranzano Narrows). Raritan Bay is characterized by two groups of stations, 11 stations falling into Group 4 and four shallower stations falling in Group 3; it is notable that no other station in these two groups occurs outside the Raritan Bay. East of Raritan Bay, the shallow stations on Flynns Knoll and Romer Shoal Bank are in Group 5. The outer shallow stations to the south east of Lower Bay fall in three associated groups, LW04 in Group 7, LW04 and 06 in Group 8 and LE03 in Group 9. The division of Lower Bay/Raritan Bay into fish usage areas by this method is rather clear-cut, providing a satisfactory summarization of the survey results.

SEASONALITY IN THE FISH COMMUNITY

Analysis for Seasonality

The data from the entire series of cruises was examined for seasonality. The data from each complete cruise was compared with data for other cruises for their similarity by the technique of classification. Classification sets out to identify all the samples (cruises) of similar faunal composition, grouping them together in clusters and defining boundaries between clusters. The results of classification are more conveniently presented diagrammatically as a dendrogram which shows how similar cruises cluster together. To carry out classification a measure of similarity must be used, we used one of the most common marine ecological measures, the Bray Curtis Index of Similarity, which gives more weight to abundant species than to rare ones, to compare the cruises.

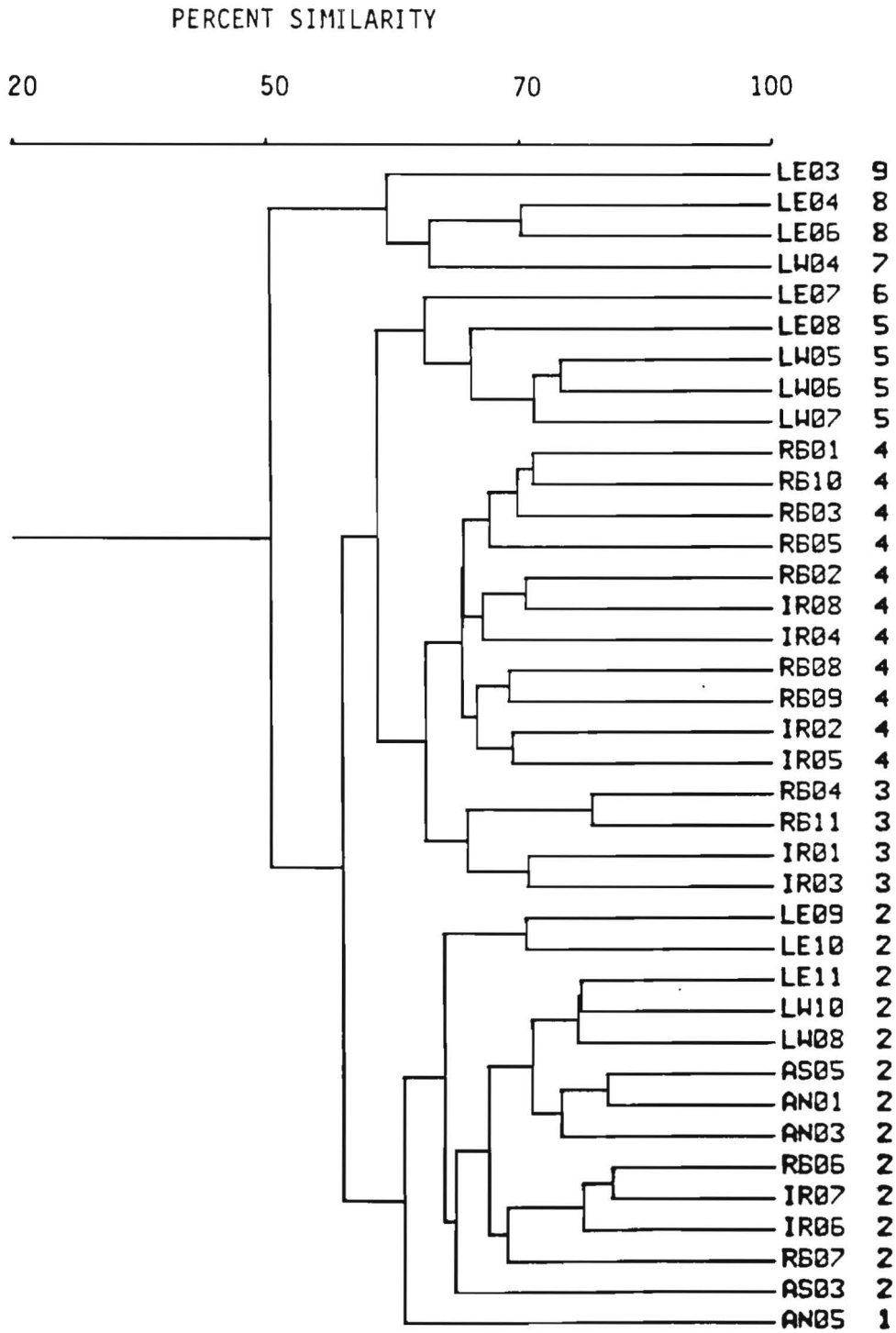
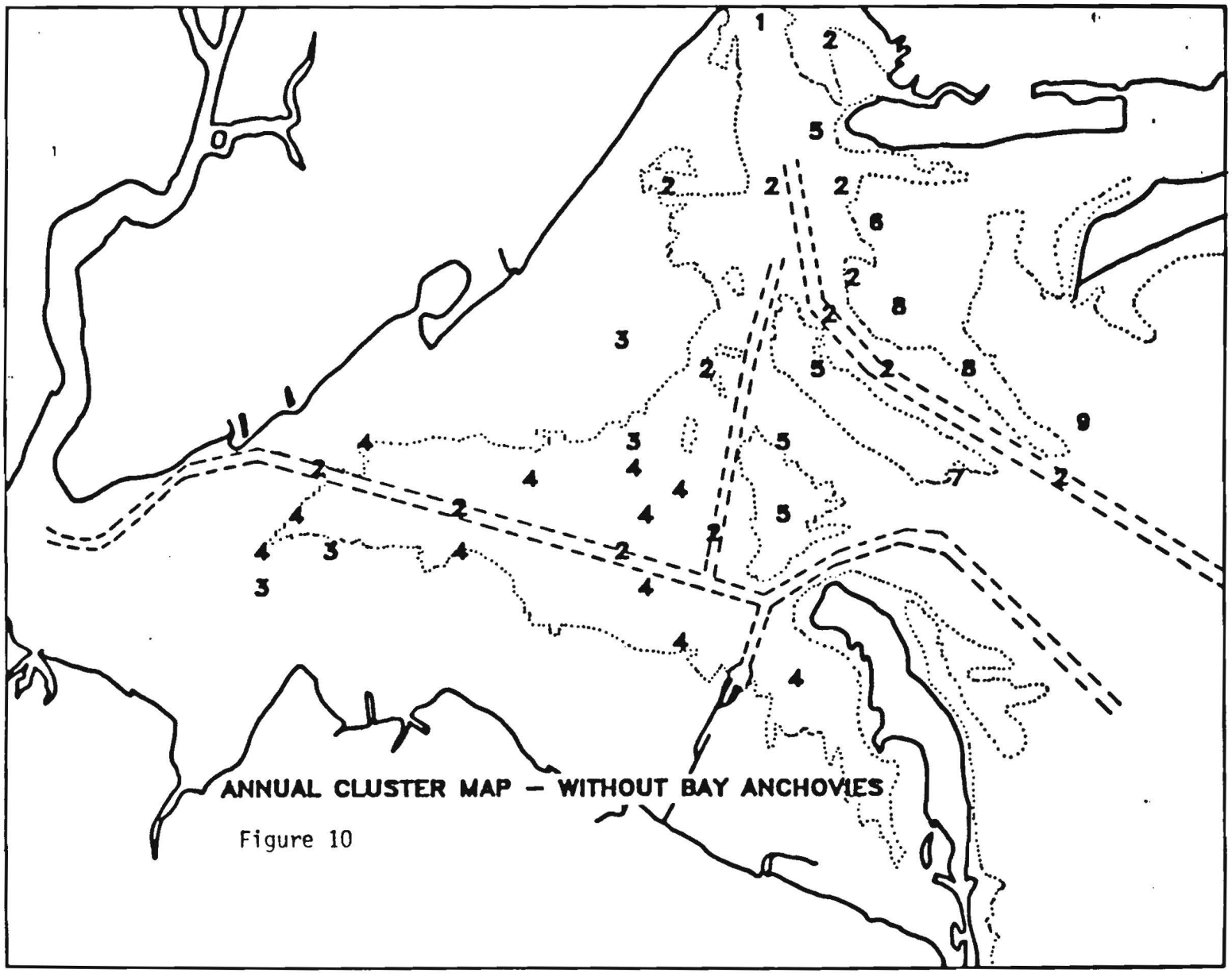


Figure 9. Grouping of stations by fish usage.



ANNUAL CLUSTER MAP – WITHOUT BAY ANCHOVIES

Figure 10

Using the Bray Curtis index to measure similarity between the cruises classification was used cluster similar cruises, Figure 11. There were two principal subsets of the data according to the time of year, cruises between November and March clustering separately from cruises between April and October. Within each of these groups two further sub-sets were formed, to give four distinct clusters of cruises. The four clusters approximated in timing to the four seasons, with some lag as the year progressed; the four groups were therefore named as the four seasons.

January - March	"Winter"	Cruises 5, 6, 15, 16
April - July	"Spring"	Cruises 7, 8, 9
August - October	"Summer"	Cruises 10, 11, 12
November - December	"Fall"	Cruises 13, 14

The cruise catch data were combined for each of these four seasonal clusters and the four sets of combined data were then analyzed to examine seasonal changes in the fish community of the area.

Changes in Numbers

The station average catch in numbers per hectare, for each of the four combined seasonal survey groupings is given in Table 4 for each species. There was considerable change in numerical abundance and dominance in the community from season to season. This is summarized more simply by ranking species by their abundance in Table 5.

Residents

There are fourteen resident species, which varied in abundance from dominant to fairly common, listed below. Lobsters and blueclaw crabs are also resident although showing marked changes in catches due to seasonal changes in activity, or hibernation.

Resident Fish Species

American eel	cunner
conger eel	rock gunnel
spotted hake	grubby sculpin
red hake	windowpane flounder
lined seahorse	winter flounder
northern pipefish	American sandlance
blackfish	small mouth flounder

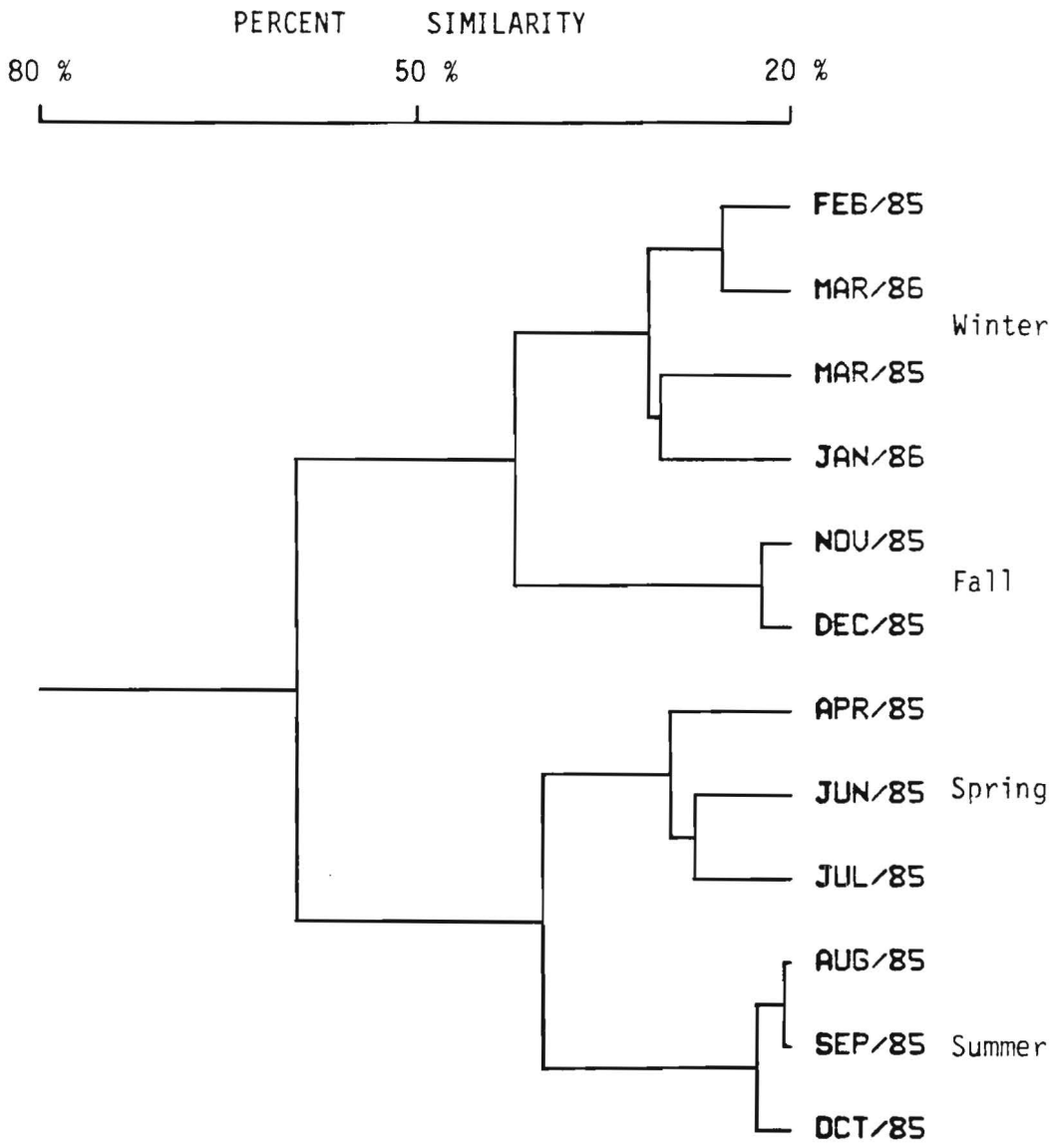


Figure 11. Cluster diagram showing grouping of cruises by the seasons.

Table 4. Seasonal average catch abundance

Name Code	Winter,	±se	Spring,	±se	Summer,	±se	Fall,	±se
LAMPREY	-		-		-		0.04	0.04
SM DOGF	-		0.48	0.15	1.98	0.61	-	
SP DOGF	-		-		-		0.15	0.11
LI SKATE	0.36	0.36	0.39	0.25	-		-	
RS SKATE	0.06	0.06	-		-		-	
W SKATE	0.52	0.23	-		-		0.28	0.28
TH SKATE	0.40	0.40	-		-		0.25	0.16
AT STURG	-		0.18	0.10	0.24	0.19	0.06	0.06
AMER EEL	0.14	0.10	0.72	0.48	0.18	0.18	0.05	0.05
CON EEL	-		-		0.69	0.51	0.33	0.17
BB HERRG	42.98	9.85	4.46	1.47	-		296.40	120.92
ALEWIFE	170.20	68.74	2.55	1.36	0.10	0.07	160.15	84.80
AM SHAD	13.87	3.91	3.86	1.29	0.05	0.05	81.84	24.97
AT MENHD	5.53	4.43	0.26	0.12	0.06	0.06	2.46	1.64
AT HERRG	2.29	1.17	-		-		0.14	0.10
RND HERR	-		1.26	1.08	1.10	0.07	-	
BAY ANCH	0.75	0.38	459.00	136.27	3561.53	596.73	24.29	6.50
STR ANCH	-		0.56	0.27	1.48	0.56	-	
TOADFISH	0.05	0.05	-		0.05	0.05	0.05	0.05
GOOSEF	-		-		-		0.10	0.10
4 ROCKLG	0.04	0.04	-		-		-	
SL HAKE	1.56	1.16	9.94	2.72	0.16	0.11	10.53	3.57
TOMCOD	1.91	1.87	0.06	0.06	-		-	
POLLOCK	-		0.44	0.44	-		-	
SPT HAKE	4.91	1.69	19.13	12.18	0.58	0.41	5.82	2.04
W/R HAKE	10.90	8.97	11.58	5.21	0.51	0.40	17.11	12.67
JUV GAD	-		0.05	0.05	-		-	
CUSKEEL	0.08	0.08	0.19	0.14	-		-	
CORNETF	-		-		0.05	0.05	-	
A SILVER	2.85	1.73	-		-		7.05	1.95
3 STICKL	0.13	0.07	-		-		-	
SEAHORSE	0.20	0.09	0.13	0.09	0.24	0.12	0.58	0.20
PIPEFISH	0.22	0.09	1.26	0.51	0.69	0.22	1.58	0.61
SEA RAVN	0.09	0.06	0.08	0.08	-		-	
GRUBBY	4.27	1.74	3.74	1.38	0.15	0.11	0.36	0.22
LN SCULP	0.72	0.26	-		0.06	0.06	-	
SH SCULP	-		-		-		0.09	0.09
UN SCULP	0.04	0.04	-		-		-	
BL SEABS	-		0.10	0.07	3.00	1.39	0.15	0.09
GRY SNAP	-		-		-		0.05	0.05
MSC SERR	0.10	0.07	-		-		-	
STR BASS	0.15	0.11	0.08	0.06	0.11	0 11	1.06	0.55
LEPOMIS	-		-		-		0.05	0.05
BLUEFISH	-		1.38	0.50	6.20	4.45	0.06	0.06
CREV JCK	-		0.05	0.05	-		-	
LOOKDOWN	-		0.04	0.04	3.81	1.53	-	

Table 4. Continued

Name Code	Winter,	±se	Spring,	±se	Summer,	±se	Fall,	±se
RH SCAD	-		0.32	0.19	0.30	0.17	-	
SLPERCH	-		-		-		0.12	0.12
WEAKFISH	-		0.49	0.24	133.63	70.55	4.84	1.87
SPOT	-		-		0.10	0.10	0.15	0.11
SCUP	-		36.56	9.88	27.54	6.43	-	
SP BUTFL	-		-		0.06	0.06	-	
ST MULL	0.90	0.06	-		-		0.17	0.13
N BARRAC	-		-		0.21	0.21	-	
BLACKF	0.29	0.11	15.54	3.23	6.31	1.73	1.66	0.60
CUNNER	0.40	0.16	3.71	1.96	1.50	0.56	-	
RCK GUNN	0.72	0.22	0.49	0.31	0.21	0.10	1.55	0.71
AM SANDL	37.40	13.43	90.79	57.36	0.06	0.06	0.18	0.13
BUTTERF	-		42.80	11.00	147.83	62.60	5.62	2.98
AT MACKR	-		0.10	0.07	-		-	
N SEARBN	-		0.23	0.11	0.09	0.07	-	
ST SEARB	-		5.31	4.50	24.40	14.91	0.20	0.16
SMM FLND	0.49	0.29	0.05	0.05	0.52	0.21	1.59	0.49
FLUKE	0.10	0.07	19.93	3.11	17.95	3.39	0.30	0.14
4SP FLND	-		0.51	0.32	2.54	1.14	1.72	0.67
WINDOWPN	16.63	4.80	39.57	9.79	8.88	3.11	13.29	3.79
WN FLND	102.40	32.03	101.30	21.31	12.27	2.65	76.44	18.96
HOGCHOKR	-		-		0.06	0.06	-	
PL FILEF	-		-		0.25	0.15	-	
N PUFFER	-		-		0.06	0.06	-	

Change in Species by Seasons for Cruises 5-16

Fall-winter community, November to March

During the fall and winter the bottom fish community is dominated by resident species, the winter flounder, windowpane flounder, spotted hake, red hake, grubby sculpin; Atlantic silversides and silver hake also migrate into the region in the fall. There is a large community of pelagic fishes in the region at this time; it is dominated by the river herrings (alewife, blueback herring and American shad) and Atlantic menhaden, but also during winter (January-March) included American sandlance and Atlantic herring.

Spring-summer community, April to October

The groundfish community is dominated by flounders, resident winter flounder and windowpane flounder and small mouth flounder being joined by large adult fluke and four-spot flounder. Butterfish and striped searobin are abundant, and bluefish, lookdown, black seabass and weakfish all appear in spring and increase in numbers during summer. Large blackfish and scup are caught on shell grounds and are especially associated with mussel-beds.

The pelagic community changes radically with increasing temperatures, in spring and summer the ubiquitous bay anchovies are the most numerous fish in catches, they are accompanied by small numbers of striped anchovy and round herring. The three river herrings decrease in numbers markedly in spring and few are caught in summer. American sandlance are caught commonly in spring but not during summer, when they aestivate in the seabed.

The seasonal change in species in the community is summarized in Table 6 in which commonly caught fishes have been characterized as occurring in the Lower Bay Complex during cold or warm water periods of the year.

Table 6. Seasonally caught common fishes.

Warm water species	Cold water species
smooth dogfish	little skate
Atlantic sturgeon	winter skate
round herring	blueback herring
bay anchovy	alewife
stripped anchovy	American shad
black seabass	Atlantic herring
bluefish	silver hake
lookdown	tomcod
rough scad	Atlantic silverside
weakfish	
scup	
butterfish	
striped searobin	
fluke	
four-spot flounder	

Migrants

Several of the more abundant species taken in the surveys were seasonal migrants through the lower estuary and are listed below.

Migrant Species

Atlantic sturgeon	Atlantic silverside
blueback herring	striped bass
alewife	weakfish
American shad	American eel

In spring adult weakfish and Atlantic silversides passed quickly through the region on their way to spawn in shallows and wetlands of the estuary and associated rivers. Atlantic sturgeon were caught during summer in their passage to areas of the river upstream of the Tappan Zee.

The three river herrings (American shad, alewife and blueback herring) all arrived in large numbers in the fall during their upstream migration. Many of the herrings, especially juveniles, persisted through winter in the lower estuary. Adult striped bass also migrated upstream in good numbers during October, November and December en route to their spawning areas.

NURSERY GROUNDS

Juveniles of many species of finfish occurred commonly in the region. It is well known that the estuary and the associated wetlands have an important nursery function - juvenile fishes feed and grow rapidly in various parts of the estuary system. Species living and growing in the estuary as juveniles have been listed in Table 7.

Resident species spawned within the estuary or nearby in the nearshore New York Bight. Juveniles of these fishes usually settled and grew within the shallows of the system but some were more widespread and juvenile red hake, spotted hake and windowpane flounder were incidentally caught in small numbers throughout the region.

Table 7. Fishes using the Lower Bay Complex as Nursery Grounds.

Resident species
winter flounder
windowpane flounder
rock gunnel
cunner
blackfish
lined seahorse
northern pipefish
red hake
spotted hake
grubby sculpin
Immigrants
weakfish
bluefish
striped searobin
scup
butterfish
lookdown
silver hake
bay anchovy
blueback herring
alewife
American shad

The very abundant bay anchovies spawned through the summer and large numbers of newly metamorphosed juveniles were taken. Their distribution was patchy, high catches being taken at a few stations on a cruise. Juvenile anchovy were caught most frequently within Raritan Bay, rather than the Lower Bay.

Juveniles of sea spawning fishes, which moved into the estuary to feed were taken mainly during the warm summer-fall period. They included butterfish, scup, and lookdown; "snappers", (juvenile bluefish) occurred in small numbers throughout the lower estuary during summer. During August and early September large numbers of small striped searobin, Prionotus evolans, apparently newly metamorphosed, were caught at 10 to 11 m in the shipping channels of Raritan Bay. During the fall juvenile silver hake, Merluccius bilinearis, appear throughout the lower estuary and remain there into the winter. The three river herrings (alewife, blueback herring and American shad) are dominant estuarine spawners. All three species enter the lower estuary in the fall both as adults and large numbers of juveniles; they all remain through the winter. In May adult weakfish, Cynoscion regalis, enter the estuary to spawn in shallow areas; during spring-summer, the juveniles feed in the system and grow rapidly to achieve lengths of 10 to 16 cm. In September and October juvenile weakfish migrate from the estuary to the sea, moving through the Lower Bay Complex; they were principally taken in the Lower Bay in the shipping channels and in holes below 10 m.

DISTRIBUTION PATTERNS

Community Parameters

The data for the trawl surveys were combined for each station and the summed station data for each station were processed to provide seven simple community parameters for that station. These station data were plotted as a series of seven distribution charts, the summed community parameters for each station used in the charts were:

Total number of finfishes (excluding anchovy), N.
Total number of species (excluding anchovy), S.
Four indices of species diversity,

1. Shannon-Weaver function, H'.
2. Simpson's index, D.
3. Margalef's species richness, d.
4. Probability of interspecific encounter, PIE.

Indices of Species Diversity

Measures of diversity, as used in this report, are dependent not only on the number of species but also on the relative abundance of each. A community with all species in about equal population numbers is more diverse than another community of the same number of species but with some species common and others rare. A variety of indices of diversity have been devised to express both the number of species and their relative abundances as a single numerical measure. We use these measures to express the relative diversities of communities, so that we can try to assess diversity differences.

It is well known that the number of species in a community (S) is related to the logarithm of the total number of individuals (N) so that the simplest diversity index could be expressed as:

$$\frac{S}{\log N}$$

Margalef derived a related expression (species richness, d) which reduces to 0 when all individuals are from the same species. We use this species richness index, d, in assessing the trawl survey data.

$$\text{Margalef's species richness, } d = \frac{S-1}{\log N}$$

The Shannon Weaver index, H', measured the uncertainty of predicting the species of an individual drawn from the community of species. H' expresses the evenness of the abundances of all the species,

$$H' = -\sum_{i=1}^{s} p_i \log_e p_i^2$$

Based on probability theory, the Simpson index, D, describes probability that the second individual drawn from a community will be the same species as the first. D expresses the dominance, or concentration of abundance into the commonest species in the community

$$\text{Simpson index, } D = 1 - \sum_{i=1}^{s} p_i^2$$

The fourth index is the probability of interspecific encounter, PIE,

$$PIE = \sum_{i=1}^{s} \left(\frac{n_i}{N}\right)\left(\frac{N-n_i}{N-1}\right)$$

For these formulae S is the total number of species in the collection, N is the total number of individuals in the collection, n_i is the number of individuals in the i-th species and p_i is the proportion of individuals in the i-th ($p_i=n_i/N$).

For each index used, its value increases with higher diversities.

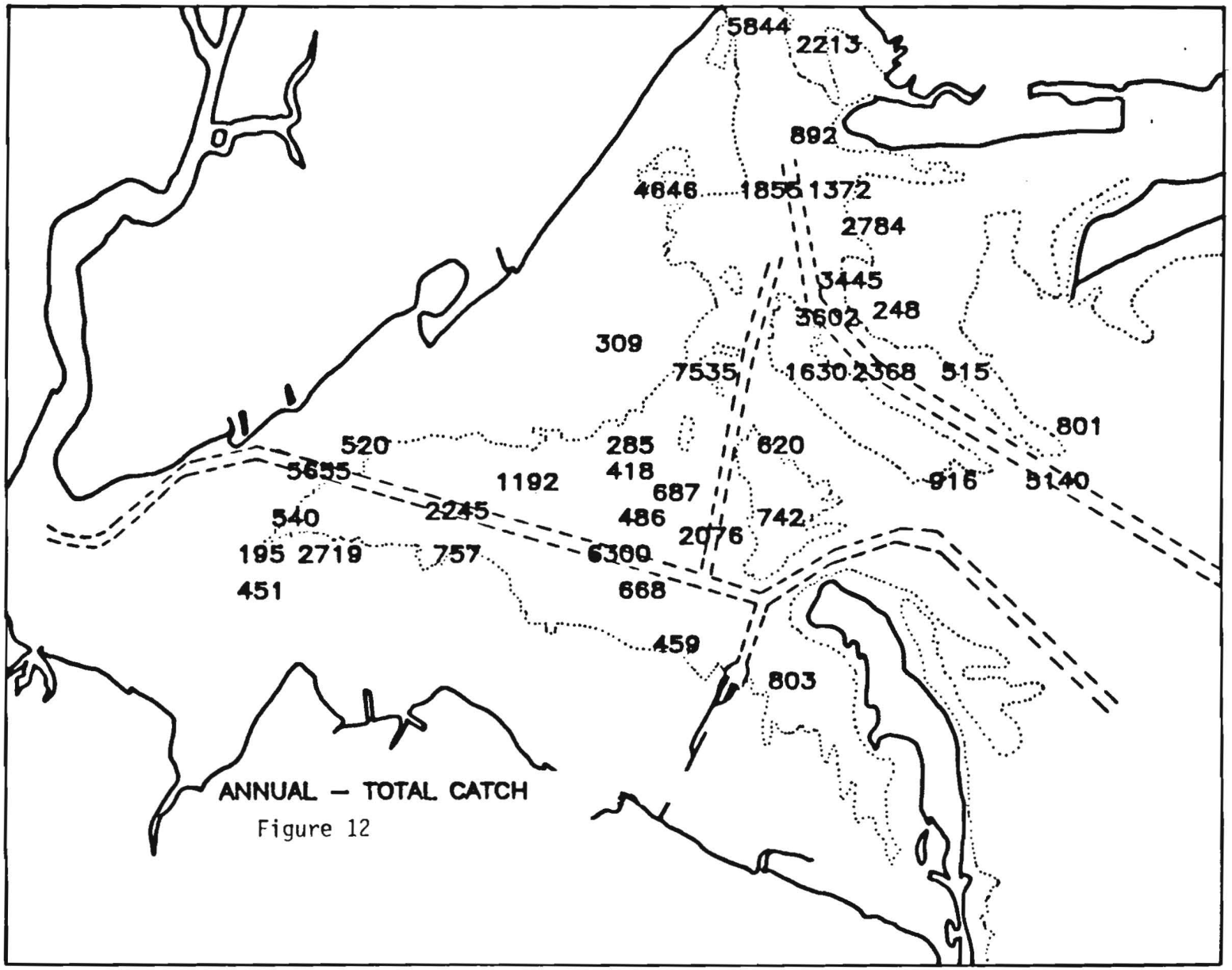
Annual Cycle, Cruises 5 to 16

The community parameters derived for the combined data set for the surveys 5 through 16, made from February '85 to March '86, have been set out as a series of 6 distribution charts;

Figure 12. Total catch, numbers of fish (except bay anchovy)
Figure 13. Number of species
Figure 14. Shannon Weaver index, H'
Figure 15. Simpson's index, D
Figure 16. Margalef's index, d
Figure 17. Probability of interspecific encounter, PIE.

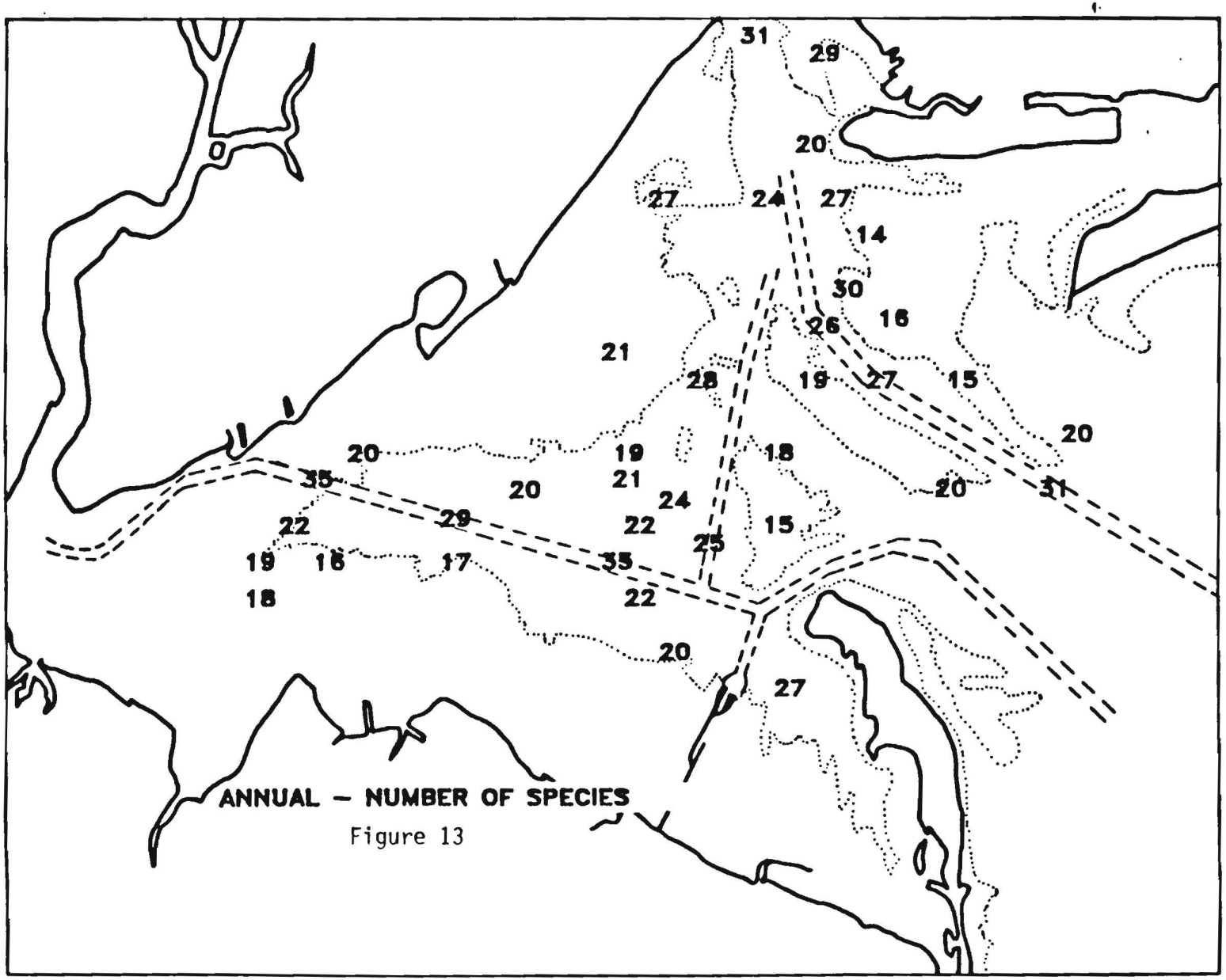
Bay anchovy were excluded from the analysis, but for reference, the total catch of anchovy is shown in Figure 18. The numbers of fishes caught, Figure 12, were consistently larger in the deeper parts of the region, in the ship channels and in borrow pits, Stratum 3 of Figure 7. Equally, the numbers of species, the diversity of the catches, Figure 13 were also greatest in the deeper channels, pits and holes of Stratum 3.

The catches of blueclaw crabs and of lobsters are given in Figures 19 and 20, respectively. The catches of blueclaw crabs were made principally in the northern areas of the Ambrose Channel and in Raritan Bay. Within these areas, the largest catches were made at deeper stations usually in the shipping channels. Like the crabs, lobsters were also distributed principally in the northern areas associated with the Ambrose Channel and throughout Raritan Bay, the largest catches were taken in the deep channels.



ANNUAL — TOTAL CATCH

Figure 12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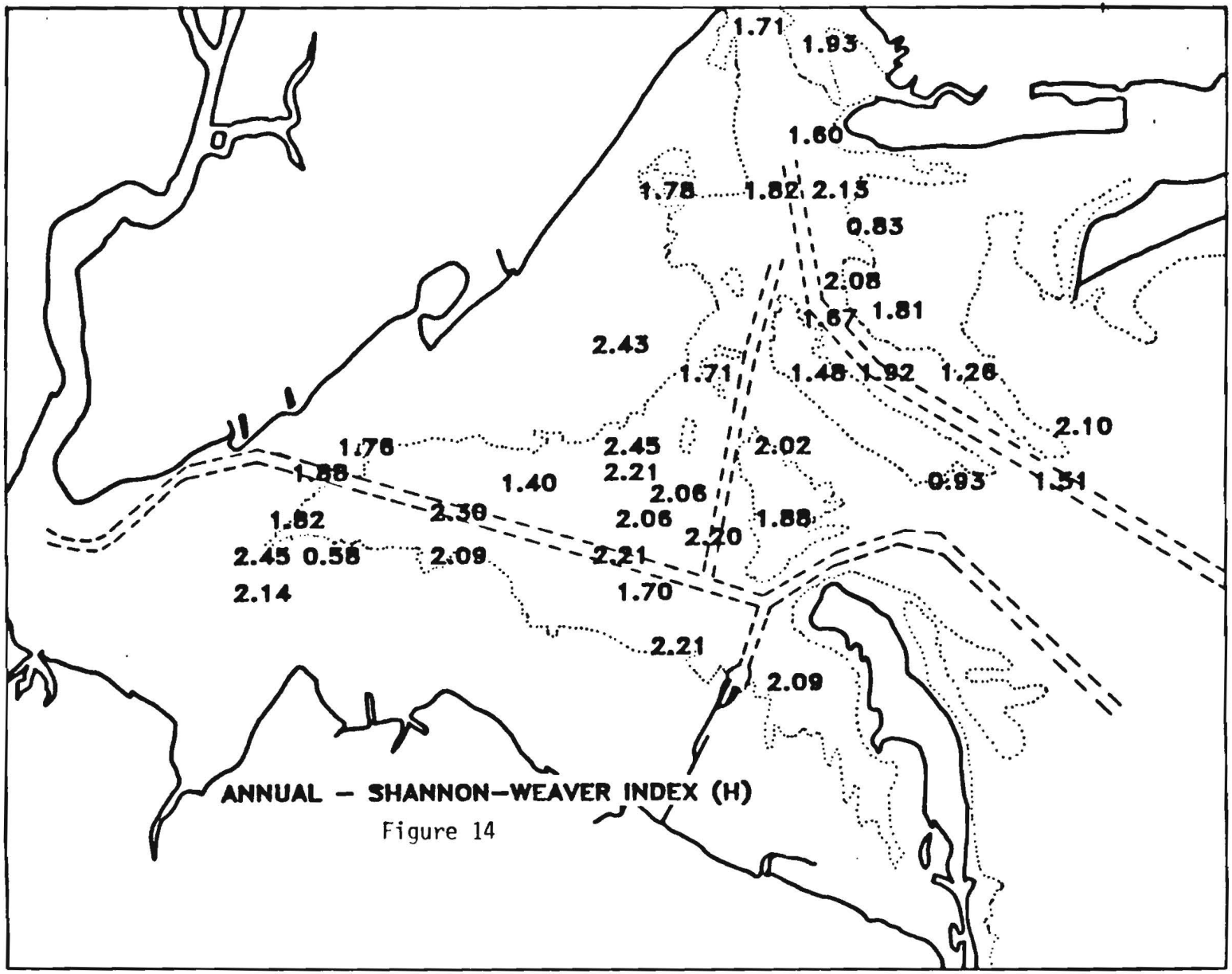
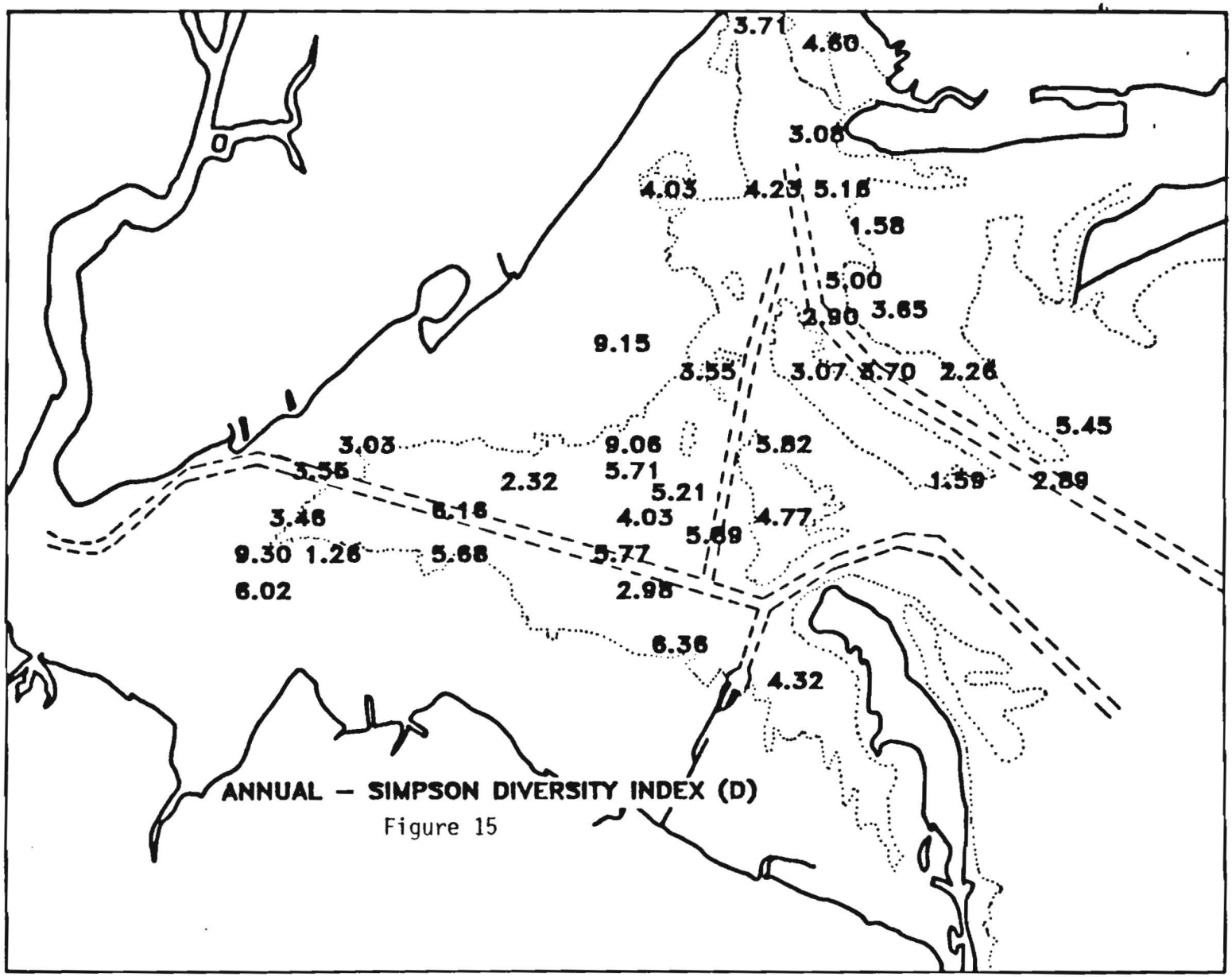
ANNUAL – NUMBER OF SPECIES

Figure 13



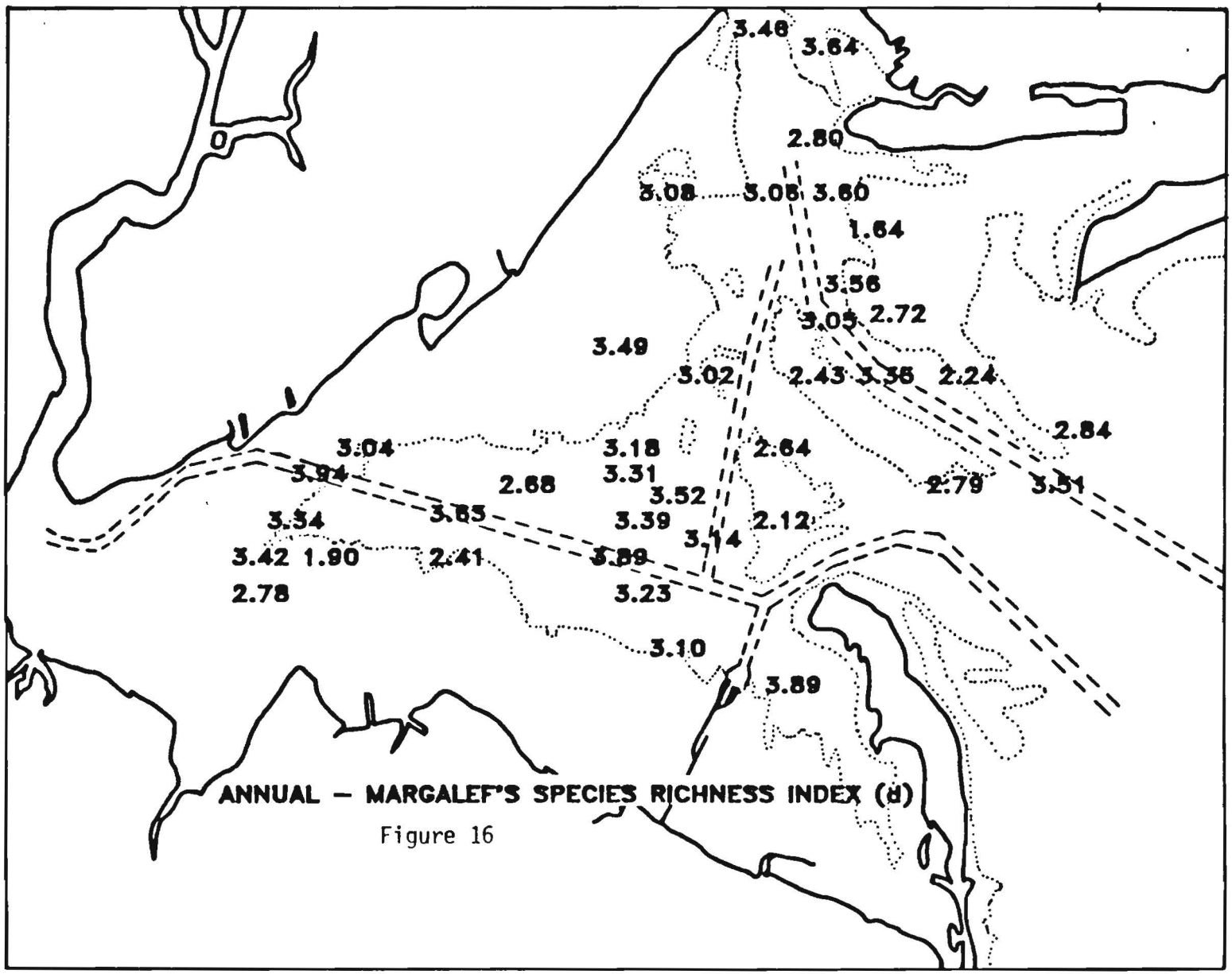
ANNUAL – SHANNON–WEAVER INDEX (H)

Figure 14



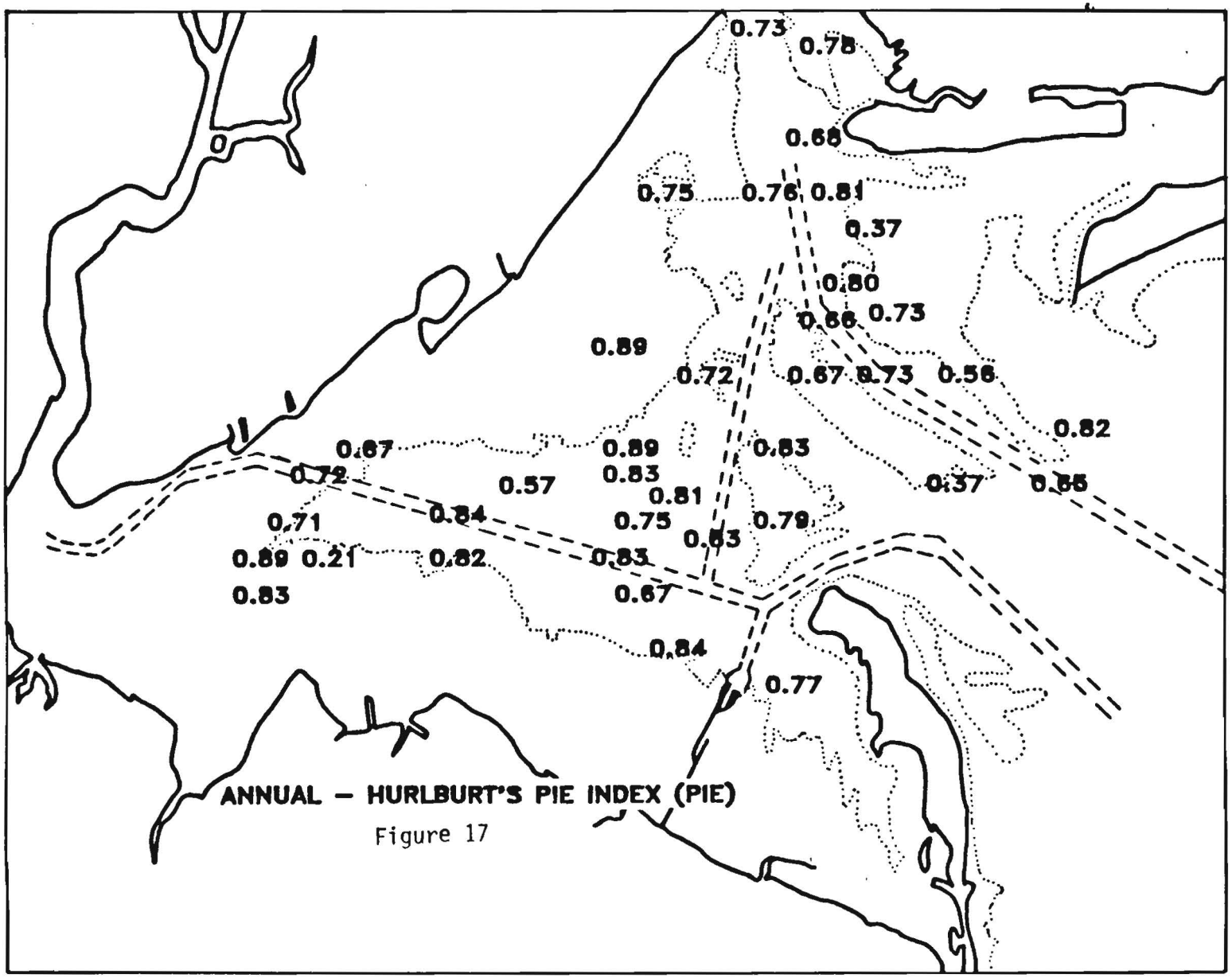
ANNUAL – SIMPSON DIVERSITY INDEX (D)

Figure 15



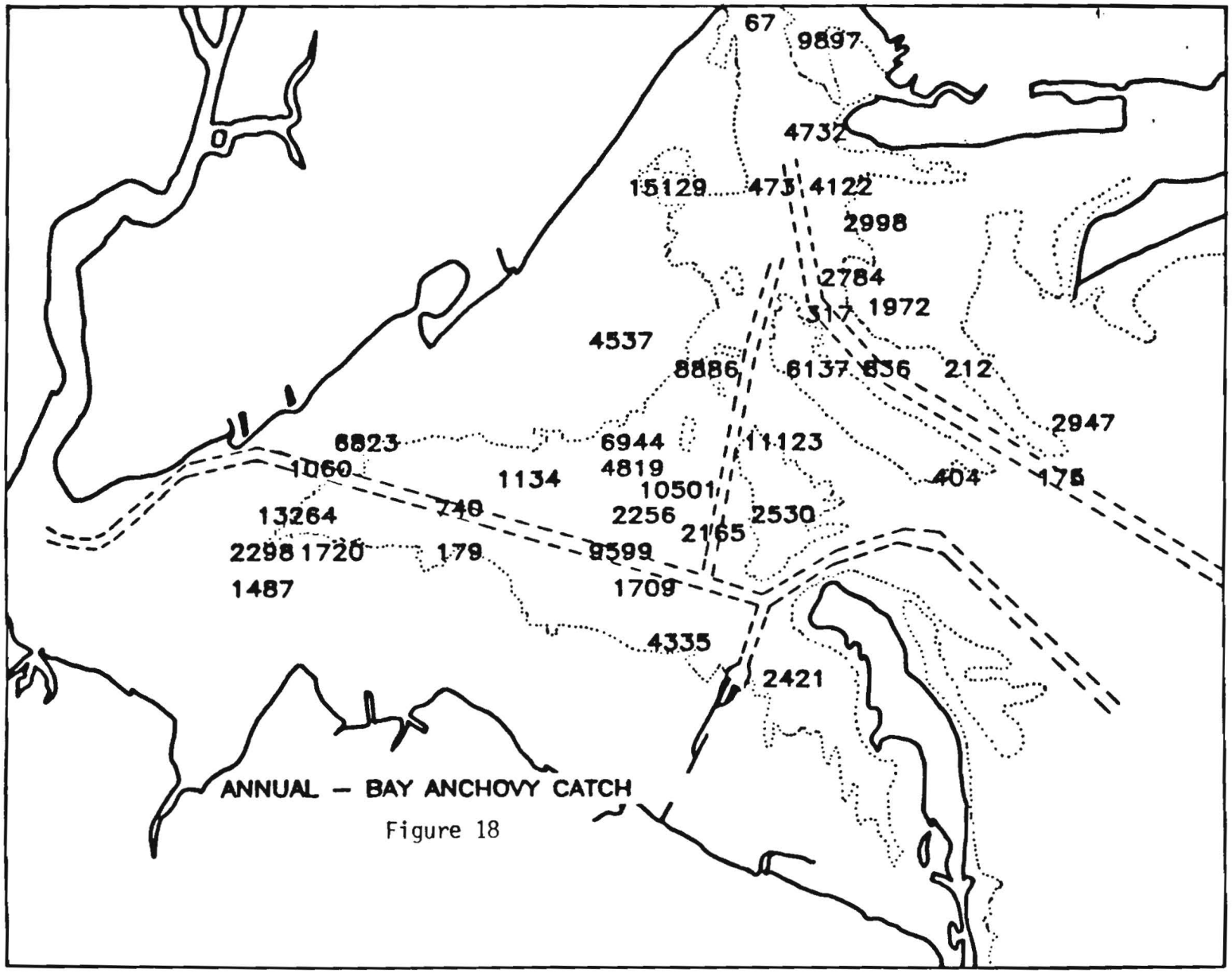
ANNUAL – MARGALEF'S SPECIES RICHNESS INDEX (d)

Figure 16



ANNUAL – HURLBURT'S PIE INDEX (PIE)

Figure 17



ANNUAL — BAY ANCHOVY CATCH

Figure 18

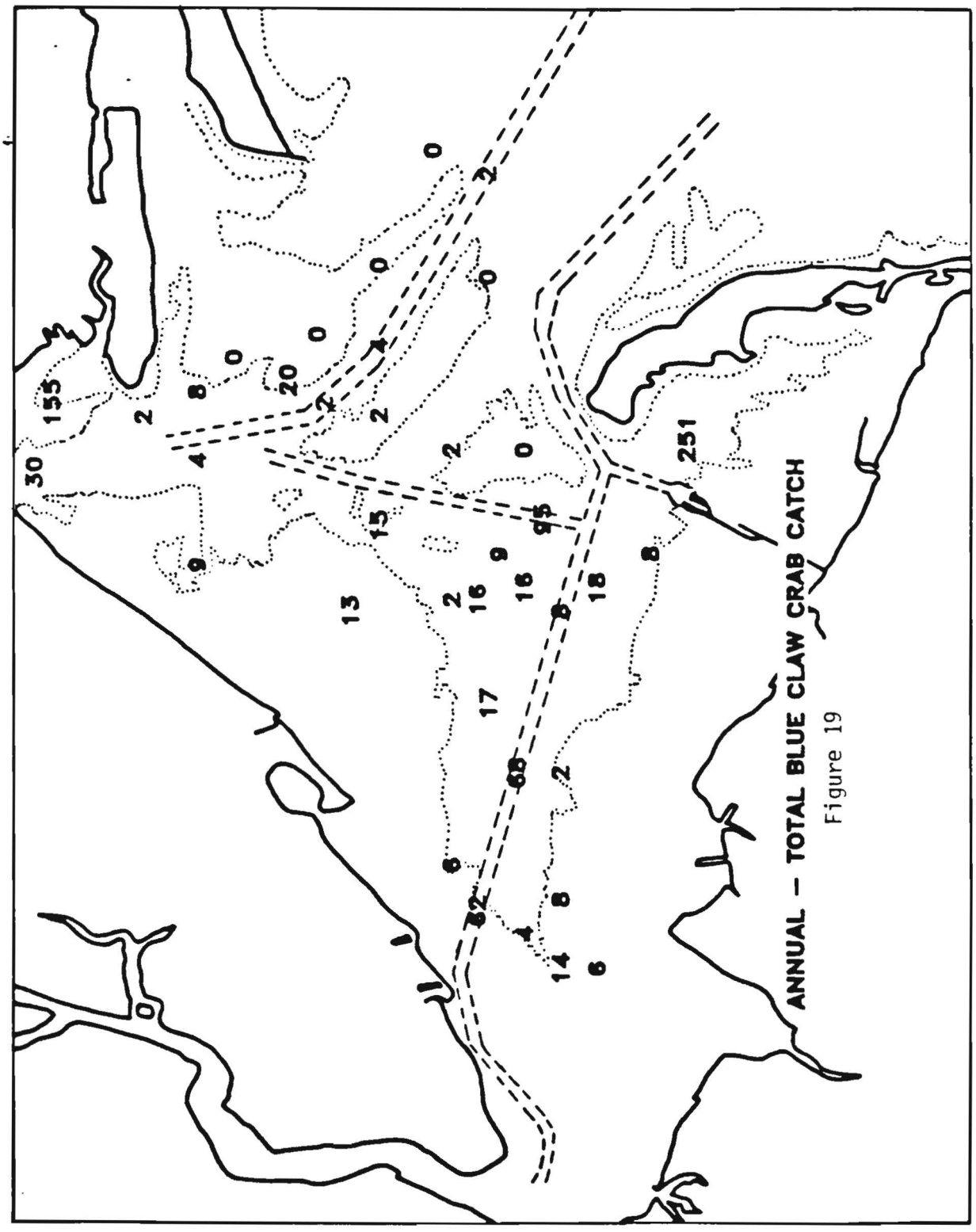
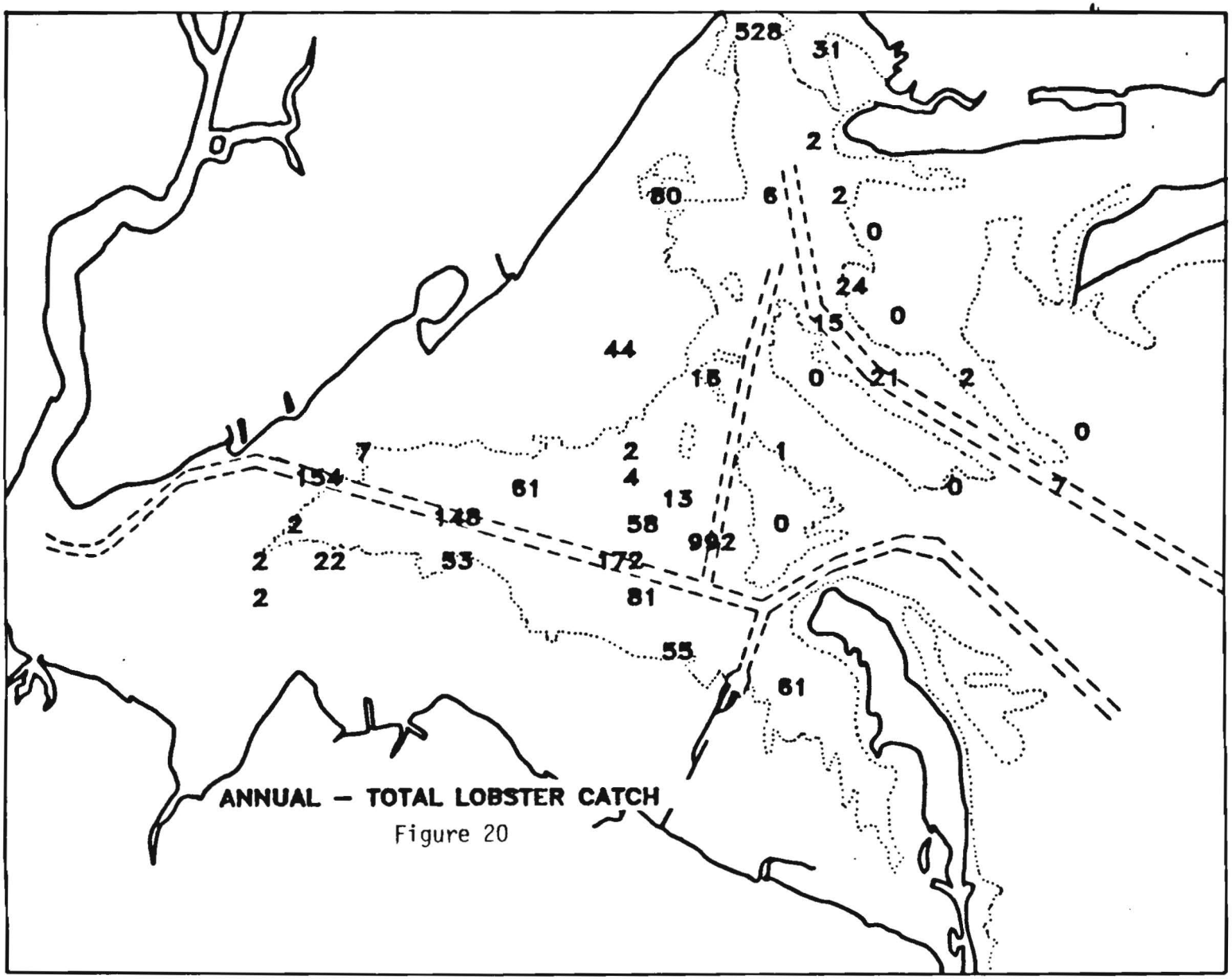


Figure 19



ANNUAL – TOTAL LOBSTER CATCH

Figure 20

Surveys 2 and 3 Combined

For the combined surveys 2 and 3, made in September-October 1984, an equivalent set of charts shows the distribution of community parameters, as follows:

Figure 21. Total catch
Figure 22. Number of species
Figure 23. Shannon-Weaver Index H'
Figure 24. Simpson's Index, D
Figure 25. Margalef's Index, d
Figure 26. Probability of interspecific encounter, PIE.

The total catch of bay anchovy, excluded from this analysis is shown for reference in Figure 27.

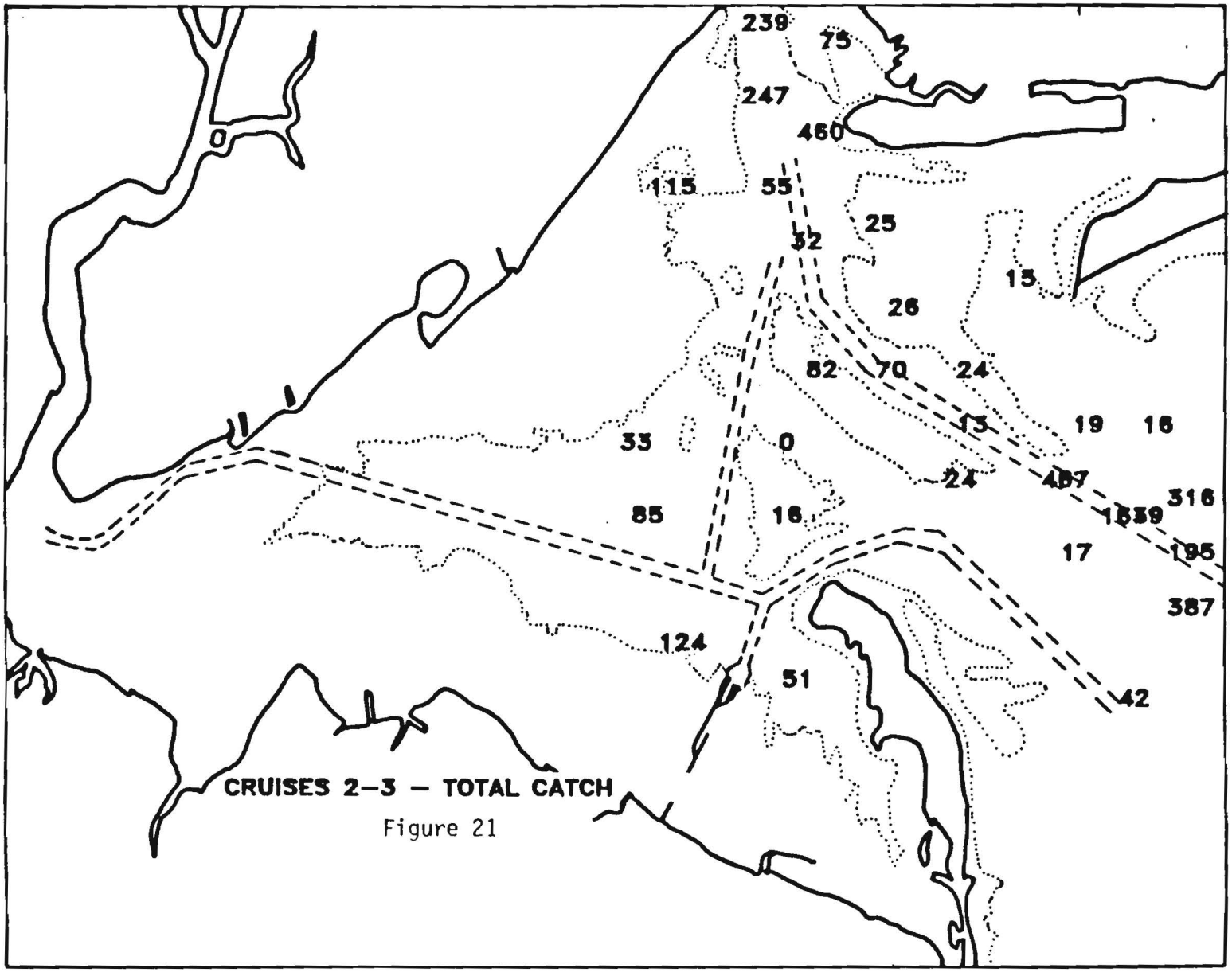
As had been seen for the annual cycle of surveys, the largest numbers of fishes of surveys 2 and 3 caught were principally in the deep ship channels, Figure 20, Statum 3, Figure 8. The more diverse catches of different species were morewidely distributed, in this area, Figure 22, but again they tended to be larger in the deeper trawl hauls, Figure 8.

Catches of blueclaw crabs and of lobsters taken on surveys 2-3 are given in Figures 28 and 29, respectively. Very few blueclaw crabs were caught at this time and no comment could be made. Lobsters were principally taken in the northern part of the Ambrose Channel and in Raritan Bay, as had been the case for the annual cycle of surveys.

AREAS OF LOW DIVERSITY AND USE BY FISH

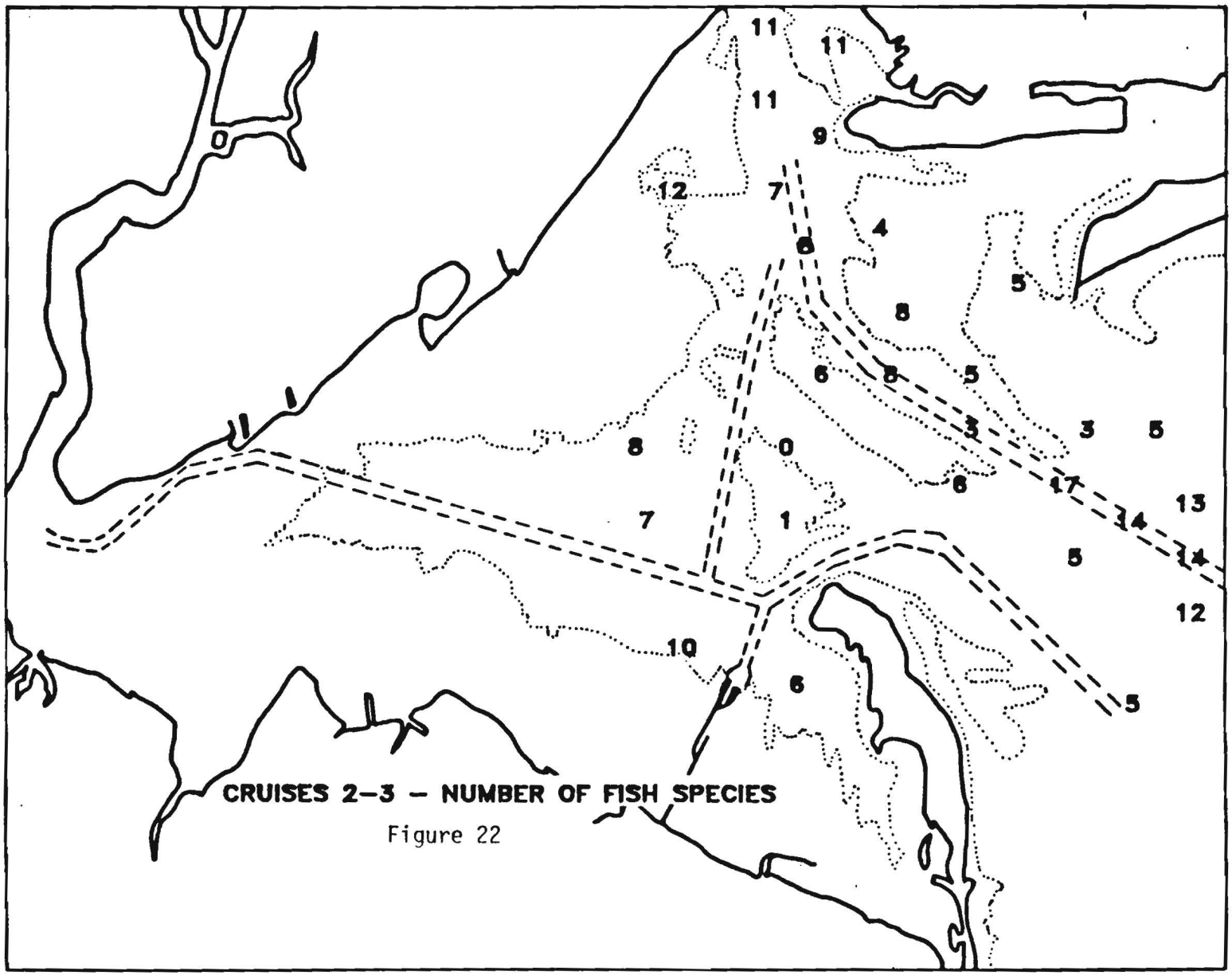
Annual Survey Series, Cruises 5 to 16 (February '85 to March '86)

The series of charts for distributions of the different community parameters derived from the combined data of the annual surveys, were inspected to identify areas of low diversity and low use by the fish community of the Lower Bay/Raritan Bay region; use by lobsters and by blueclaw crabs was also included on two additional charts.



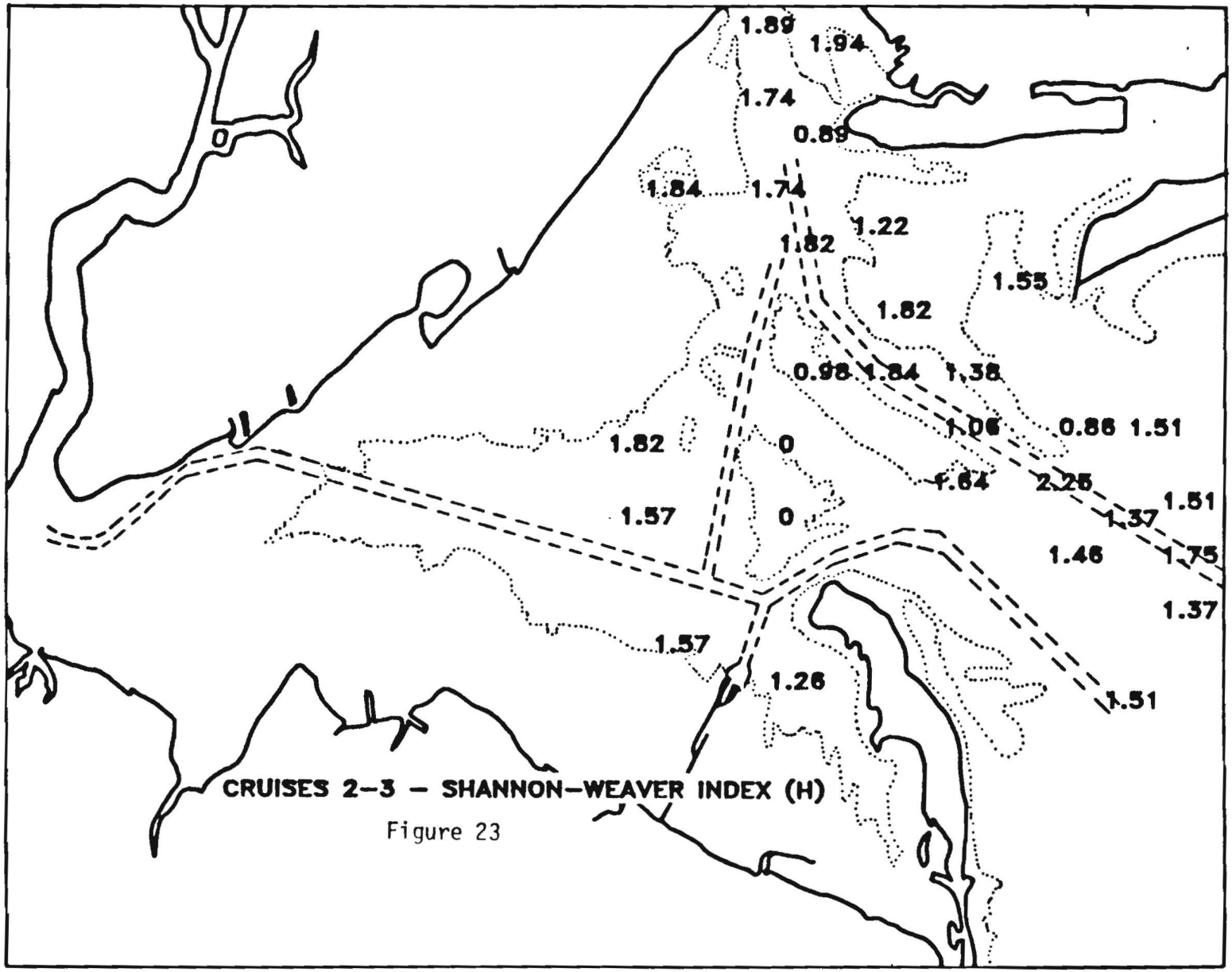
CRUISES 2–3 – TOTAL CATCH

Figure 21



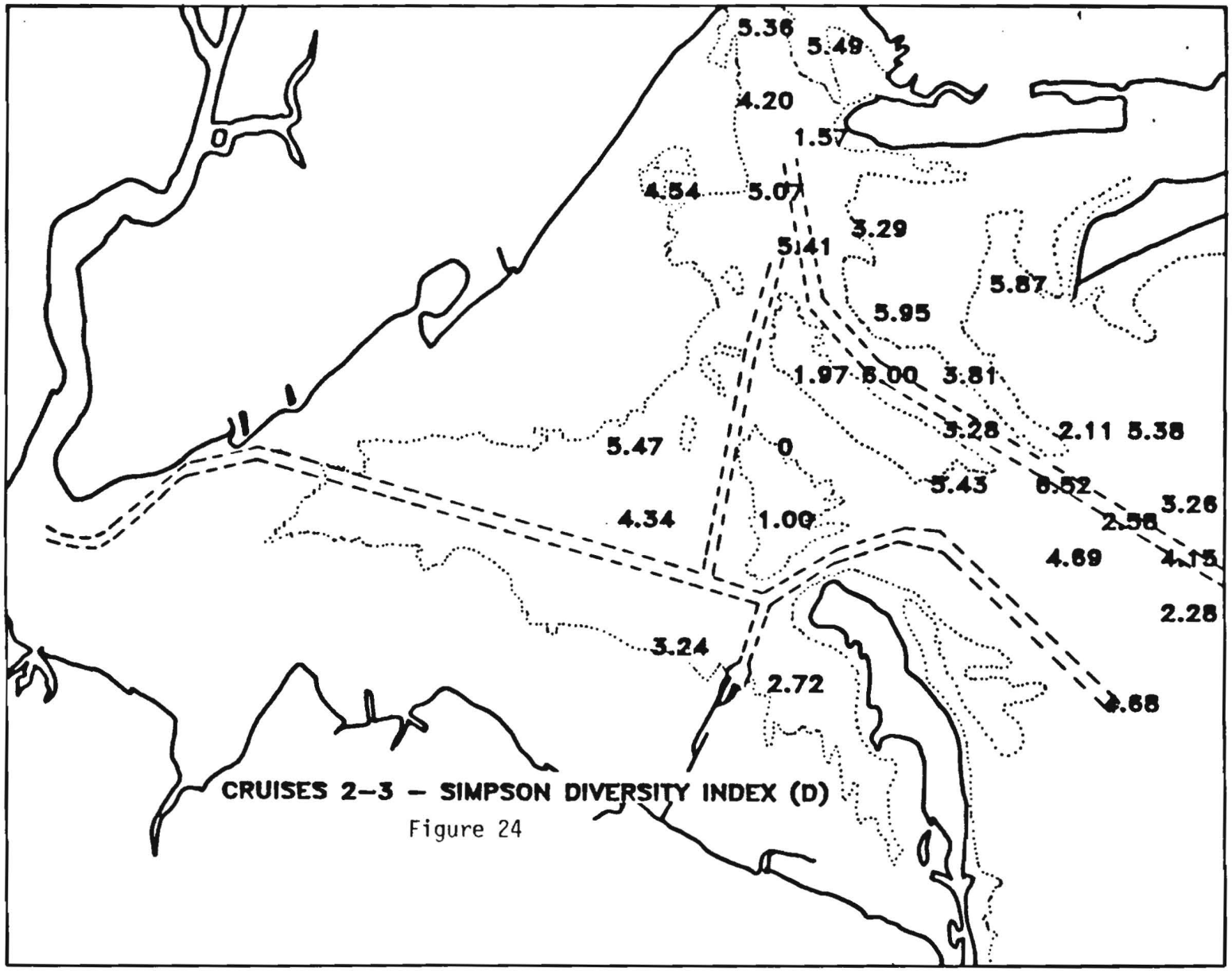
CRUISES 2–3 – NUMBER OF FISH SPECIES

Figure 22



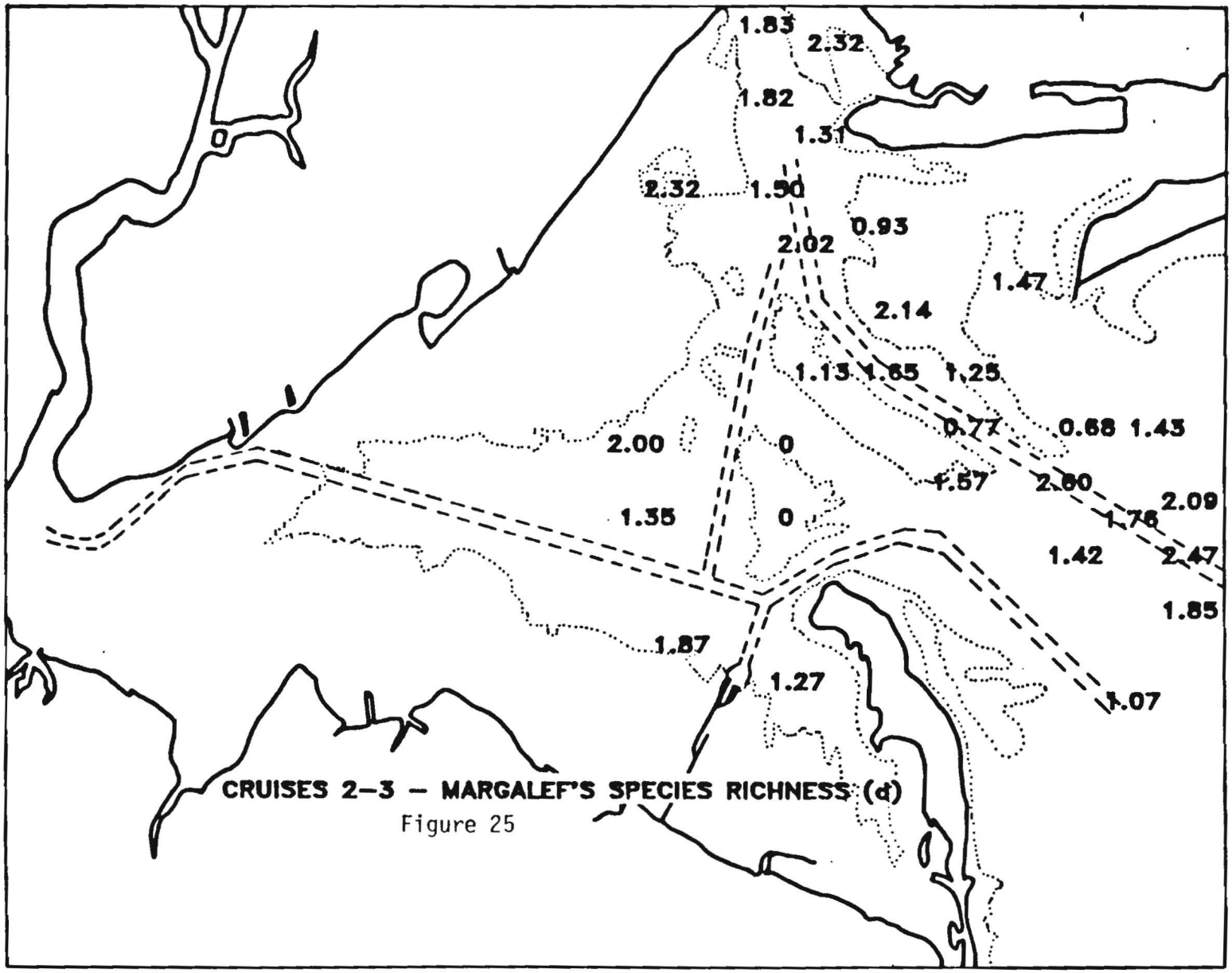
CRUISES 2-3 – SHANNON-WEAVER INDEX (H)

Figure 23



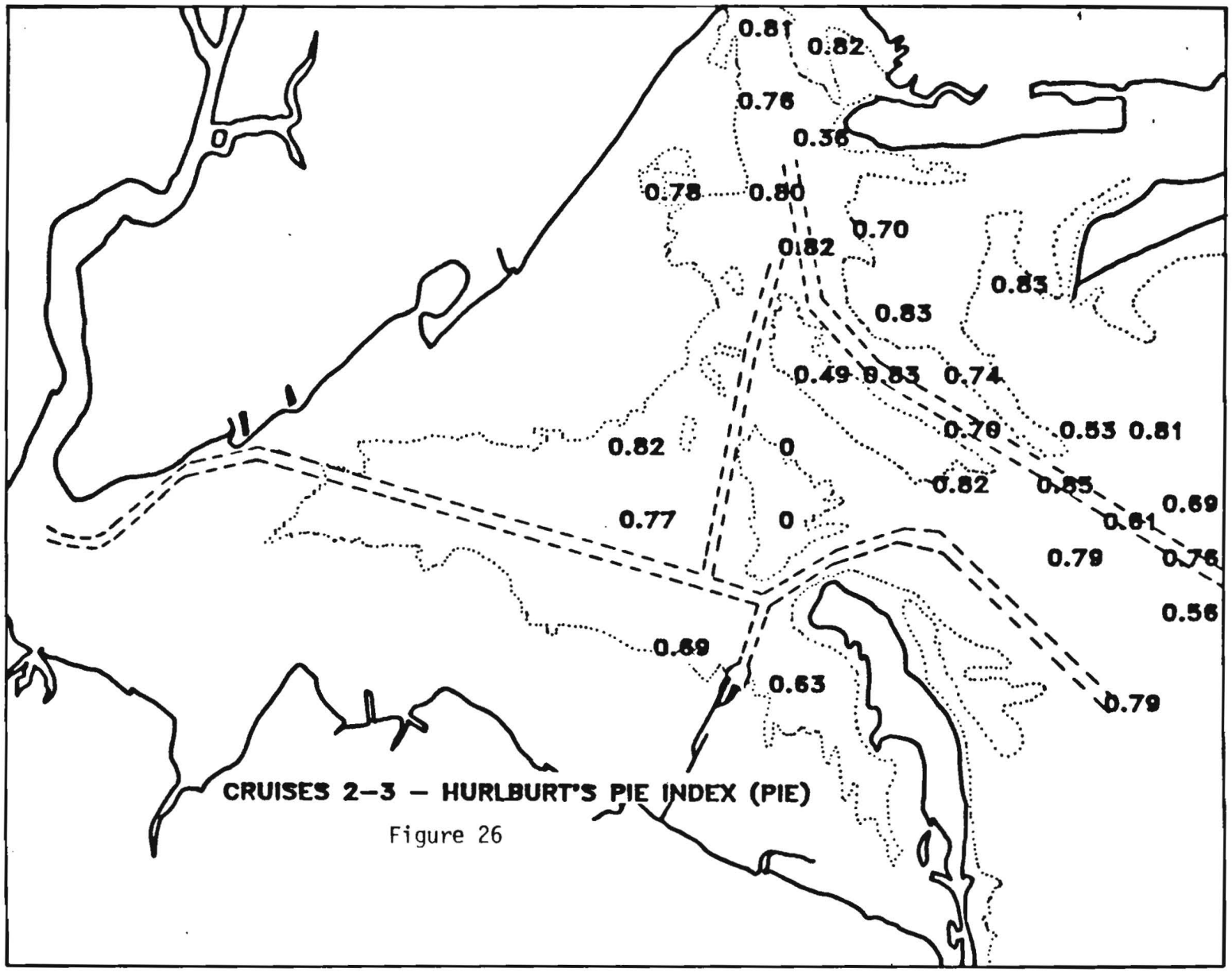
CRUISES 2–3 – SIMPSON DIVERSITY INDEX (D)

Figure 24



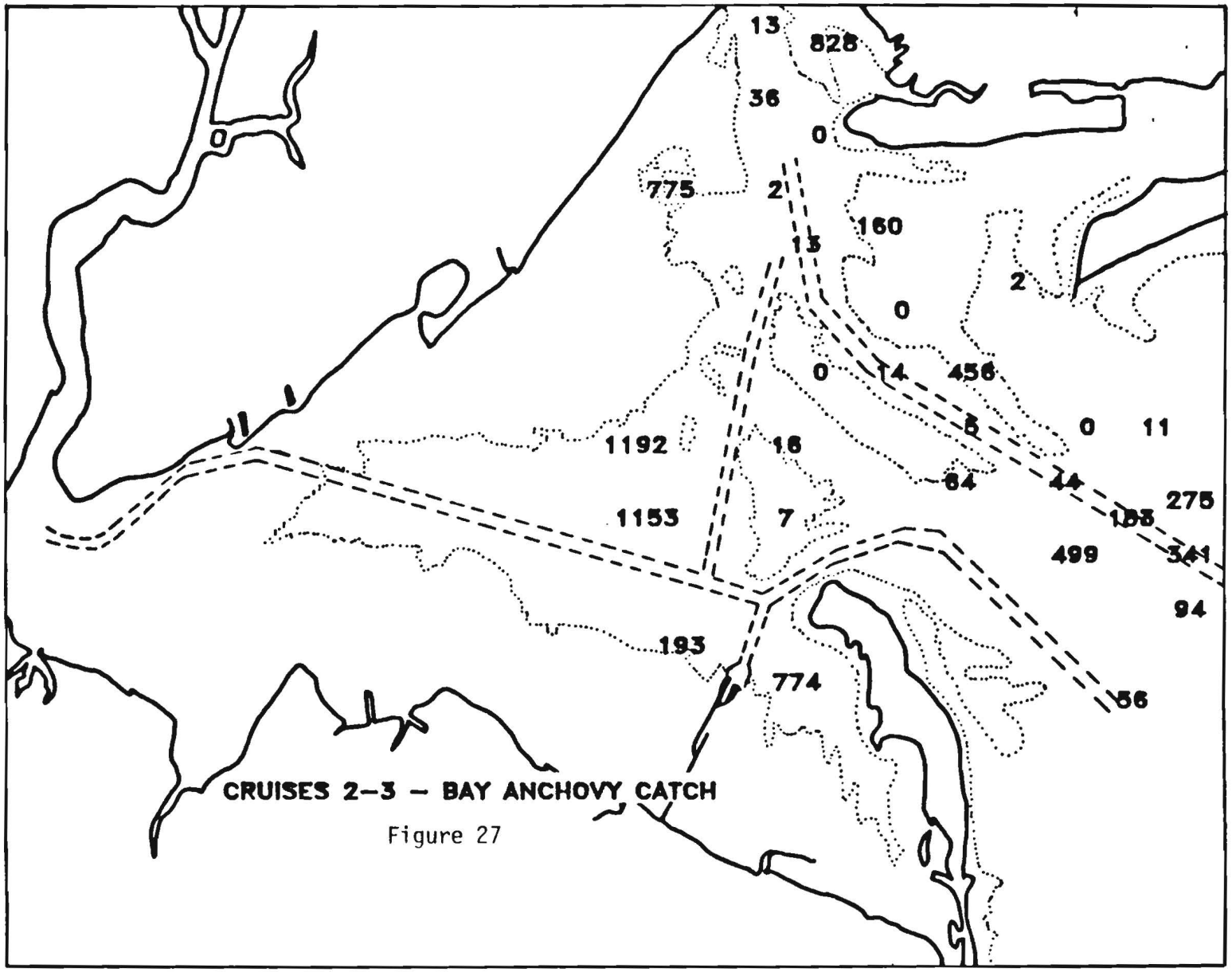
CRUISES 2–3 – MARGALEF'S SPECIES RICHNESS (d)

Figure 25



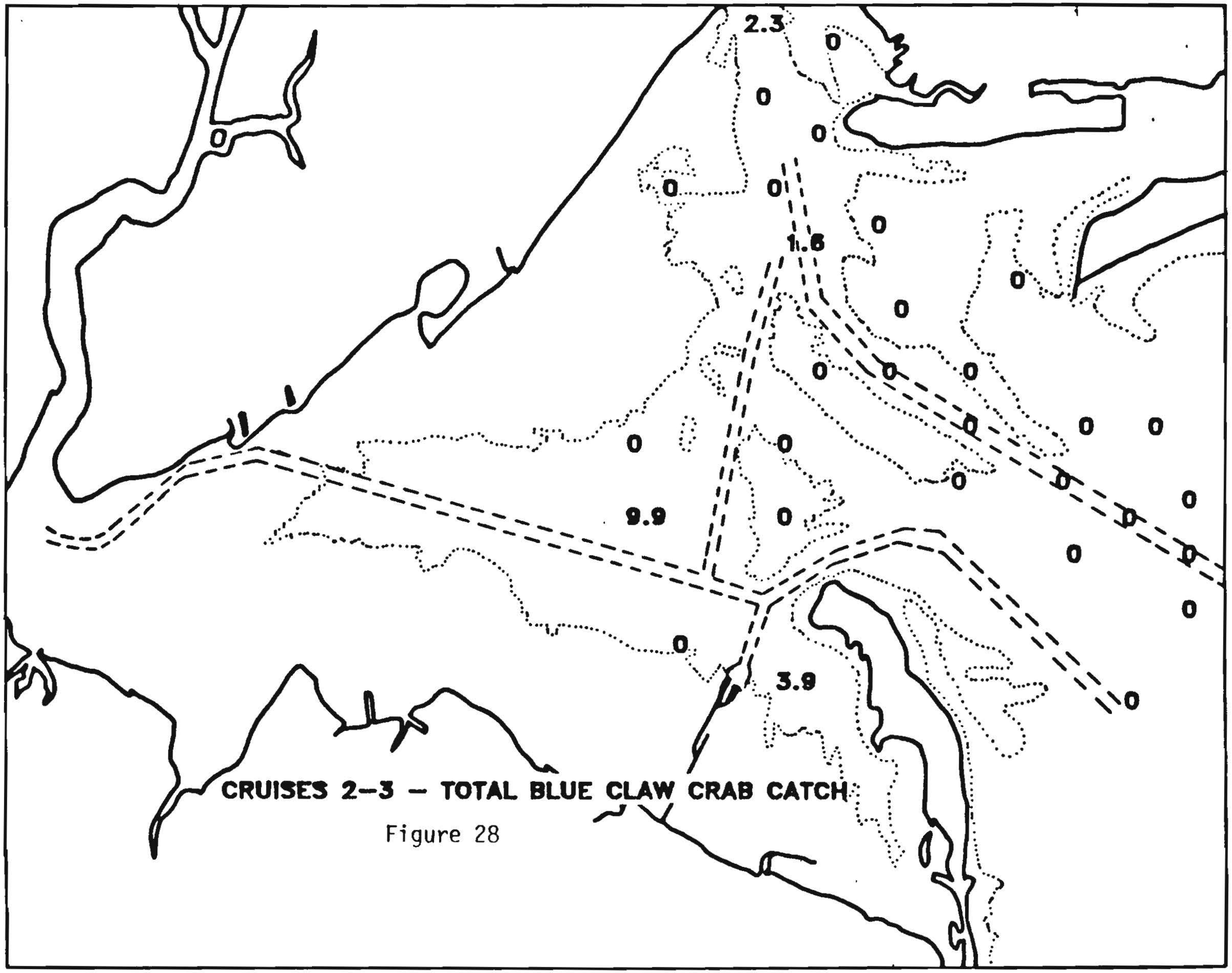
CRUISES 2–3 – HURLBURT'S PIE INDEX (PIE)

Figure 26



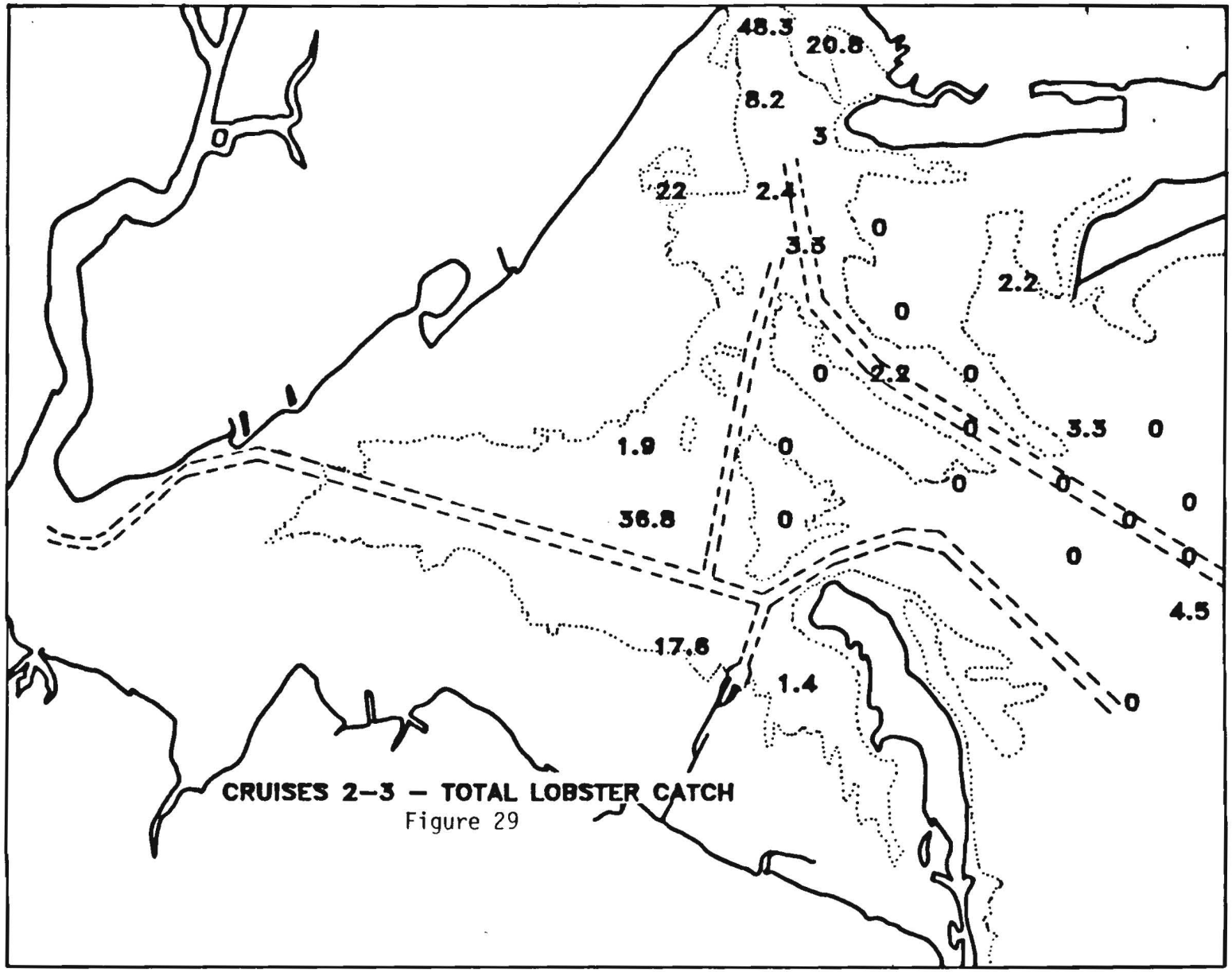
CRUISES 2-3 – BAY ANCHOVY CATCH

Figure 27



CRUISES 2–3 – TOTAL BLUE CLAW CRAB CATCH

Figure 28



CRUISES 2–3 – TOTAL LOBSTER CATCH

Figure 29

For each single community parameter, the values recorded for all of the stations surveyed were ranked numerically and the bounding value for the lowest 30% of these ranks was noted. The method used to find areas of relatively low use in the region was to delimit with contours on each of the distribution charts the stations with values falling below this 30% bound. After examining the charts, a list was drawn up of stations within the contoured areas of low values for each parameter, Table 8.

The list in Table 8 was reviewed for coincidence of the positions (trawl stations) with low values as determined from the different parameters, greater importance was given to the values for total fish abundance and number of species than was given to individual diversity indices.

The process of reviewing the low value stations for all of the separate community parameters, identified five (5) sites within the Lower Bay Complex which were of relatively low diversity and use by the fish. The five areas were identified solely by reference to trawl catch data, no consideration was given th physical properties at the sites nor to conflicting usage. The five sites contained the following stations:

Area 1	LE 04, 06, 07	"East Bank"
Area 2	LW 04	"South Romer"
Area 3	RB 04, 10	"East Raritan Bay"
Area 4	RB 02, 05	"North Belford"
Area 5	IR 01, 02, 03	"Inner Raritan Bay"

Three of the low diversity areas are in Raritan Bay and there is also one low diversity area each on the banks to the east and west of the Ambrose Channel, the five areas identified are shown on a separate chart, Figure 30.

Description of Low Use Areas

Area 1, "East Bank"

This is a large area extending over LE 04, 06, 07 on the eastern banks of the Ambrose Channel at depths of 4 to 6 m. It is covered by sand, with some patches of shells.

e 8. Stations with low value annual community parameters, Surveys 5 to 16.

ameter	SUBAREAS Inner Raritan Sta. Code, IR	 East Raritan Sta. Code, RB	 West Bank Sta. Code, LW	 East Bank Sta. Code, LE
al Catch	01, 02, 05	02, 03, 04, 09, 11	06	04, 06
al Biomass	01, 02, 03	02, 04, 05, 08, 11	04, 06, 11	03, 04, 06
ber Species	01, 02, 03, 04	02, 04, 10	05, 06, 07	04, 06, 07
ersity Indices				
nnon Weaver, H'	03, 05	05, 10	04, 07, 10	04, 07, 08
pson, D	03, 05, 08	05, 10	04, 07	04, 07, 08
galef, d	01, 03, 04	10	04, 05, 06, 07	04, 06, 07
lburt, PIE	03, 08	05, 07, 10	04, 07	04, 07, 08

ation numbers which have been underlined have the lowest values.

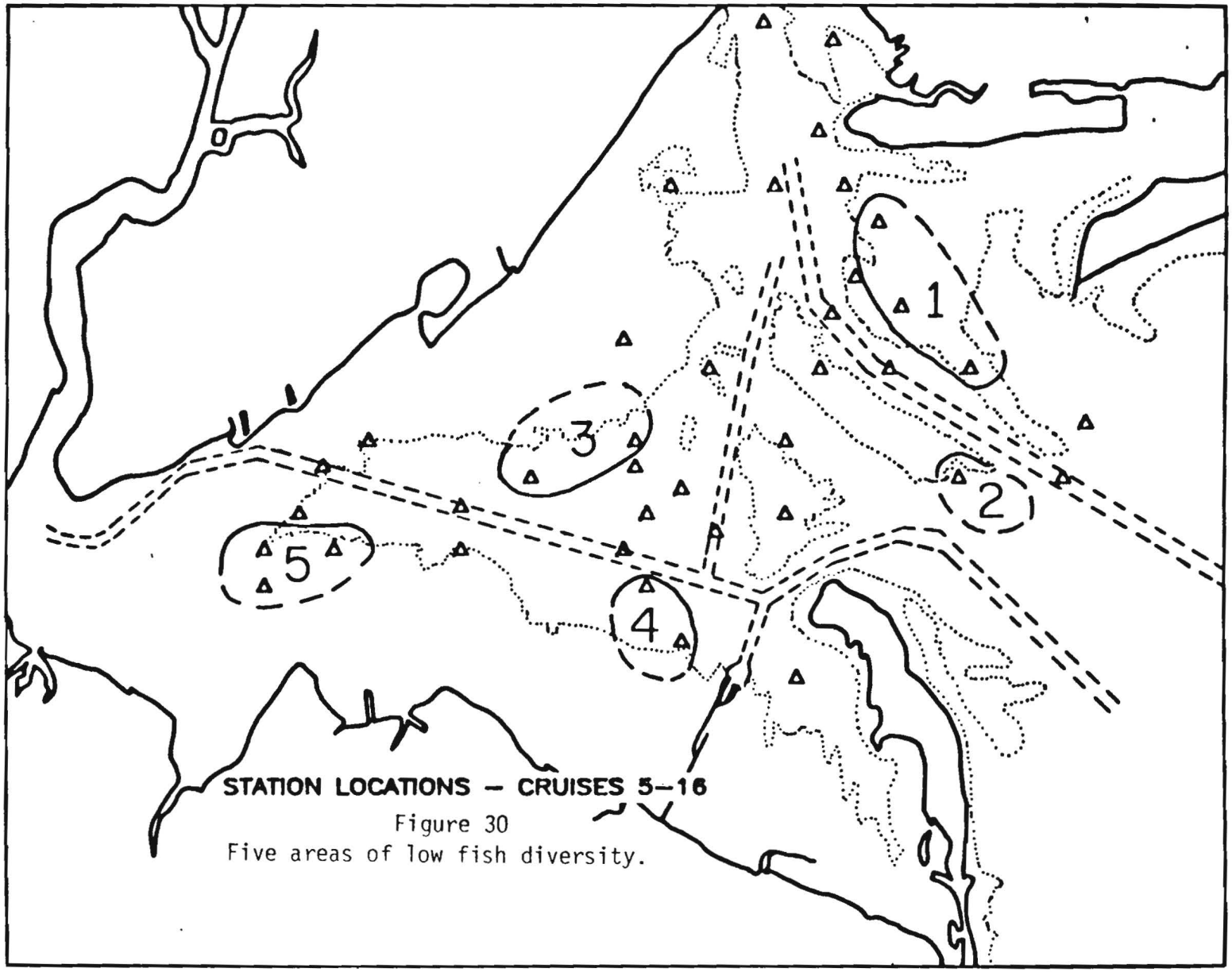


Figure 30
Five areas of low fish diversity.

The annual catches of finfish are dominated by bay anchovy and blueback herrings; American sandlance are also abundant. The dominant groundfish is the winter flounder although the numbers caught were only 44% of the average for the entire survey per station. The average annual fish catch per hectare for Area 1 is compared with the average for the region in Table 9. Only fifteen species were caught, compared with the survey average of 24 species per station. Catches of fishes of recreational or commercial significance were low in numbers and did not exceed half of their catch for average survey stations. There were no catches of blueclaw crabs and only a single lobster catch.

Area 2, "South Romer"

This area is represented by a single station LW 04 on hard sand ground at about 6 m. The site is exposed to seas from the south and east. A pipeline area passes east-west through this area and a shipping anchorage also lies to the south of the area.

Fish catches are dominated by American sandlance and anchovys, the most abundant groundfish is the butterfish. The annual catch for this stations is compared with the survey average catches in Table 9. Only thirteen species were caught compared with a station average of 24 species for the entire survey. Only six fishes of commercial or recreational interest were caught, and all in numbers less than the survey average. No lobsters or blueclaw crabs were taken.

Area 3, "East Raritan Bay"

Area 3 lies to the north of the Raritan Bay East Reach ship channel on mud bottoms about 7 m deep, to the north of the area some patches of sand may occur. It contains stations RB 04 and RB 10, and it can be extended north in the vicinity of Old Orchard Shoal, toward RB 11. The area is clear of obstructions or anchorages for shipping.

The fish catch for the East Raritan Bay stations was dominated by bay anchovy and by winter flounders, scup and blackfish were common. Table 9 gives the average catch for Area 3 and compares it with the average annual catch for

Table 9. Annual catch in selected low diversity areas

Fish Species	Area 1 Avg	% Survey Average*	Area 2 Avg	% Survey Average*	Area 3 Avg	% Survey Average*	Area 4 Avg	% Survey Average*	Area 5 Avg	% Survey Average*
Smooth Dogfish	0.8	33	2.3	96						
Winter Skate	2.0	250					2.7	340		
Alewife					9.7	3			10.7	3
Blueback Herring	736.1	214	6.3	2	30.1	9	28.0	2	832.2	242
American Shad	59.5	59			31.6	32	11.0	11	14.1	14
Atlantic Herring			3.6	150						
Bay Anchovy	1727.4	43	403.6	10	4039.3	99	3021.8	75	1835.0	45
Stripe Anchovy	2.7	13	12.7	635					2.8	14
Silver Hake	2.7	12								
Bluefish			6.6	88						
Lookdown	1.5	39	10.6	279						
Weakfish	0.8	1					5.3	4		
Scup	7.3	11	5.3	8	83.3	130			21.2	33
American Sandlance	192.2	143	717.7	536	6.8	5				
Butterfish	16.4	8	108.3	56	29.6	15	31.6	16	20.0	10
Fluke	14.0	36	10.7	27	9.8	26	62.2	162	27.7	72
Windowpane	7.5	9	14.6	19	31.4	40	51.5	66	24.1	31
Winter Flounder	130.2	44	1.7	1	408.8	140	253.9	86	86.5	29
Atlantic Silverside					15.7	158			9.1	92
Seahorse					4.3	388				
Blackfish					42.0	176			13.6	57
Cunner					6.5	91				
Pipefish									8.0	216
Spotted Hake									45.8	151
Rock Gunnel							5.3	331	2.4	150
Red/White Hake							3.2	8		
Grubby Sculpin							28.2	331		
4 Spot Flounder							1.3	27		
Conger eel							1.0	97		
Atlantic menhaden							1.5	18		
Blueclaw Crabs		0		0	9.2	40	25.3	109	9.3	40
Lobster	0.7	1		0	31.5	45	68.0	97	8.5	12

* Percent Average Survey = $\frac{\text{Annual average catch per station in selected low use areas} \times 100}{\text{Annual average catch per station for entire survey area}}$

the survey. Fourteen species of fish were taken compared with a station average of 24 species for the whole survey. The catches of three species, the winter flounder, blackfish and scup (species of importance to the recreational fishery in the area) exceeded the average catches for the region. Catches of blueclaw crabs and lobsters were at 40% and 45% of the catch for the survey region.

Area 4, "North Belford"

Area 4 is to the south of the Raritan Bay East Reach ship channel, north-west of the U.S. Navy Leonardo ship terminal. The area contains stations RB 02 and RB 05, it is 6 to 7 m deep with a mud bottom. It includes a part of the New Jersey fish trap area in the south and a pipeline area passes east-west through the middle of the site.

The catches of fish at the site were dominated by bay anchovy and by flounders; Table 9 compares these catches with the average catch for the region. Fifteen finfish species were caught compared with a station average of 24 species for the overall surveys. The only species of recreational importance occurring in the catches is significant numbers were flounders, - winter flounder and windowpane flounder were taken at 86% and 66% of the survey average respectively, only fluke exceeded the average at 162%.

In Area 4 the catches of blueclaw crabs and of lobsters were the largest at any of the low use sites, being 109% and 97% of the survey averages. Both species of shellfish are important to the commercial fisheries and it is significant that they were each caught in relatively high numbers.

Area 5, "Inner Raritan Bay"

This is a large sheltered area in western Raritan Bay extending over IR 01, 02, 03, with a soft mud bottom at depths of 5 to 7 m. A pipeline area passes east-west through the southern part of the area, between stations IR 01 and IR 02. The New Jersey fish trap area also extends north over the southern part of the area, however the northern half of the area is clear for use.

Fish catches are dominated by bay anchovy and blueback herrings, the dominant ground fish is the winter flounder although the flounder catch is only 29% of the average for the whole survey area. Only 15 species of finfish were taken compared with the survey average of 24 species per station. The average annual fish catch per hectare for Area 5 is compared with the annual average for the region, Table 9. None of the commercially finfishes of commercial or recreational importance was taken in numbers exceeding the survey averages. Although lobsters and blueclaw crabs were caught, their numbers were less than half those of the survey averages.

Seasonal Changes in Selected Species at Low Use Sites

To review the use of the selected sites in more detail, ten target species were selected which are of significance to the recreational or the commercial fishery and their importance in catches was considered by seasons. The target species were:

Fluke	Blueclaw crabs
Winter Flounder	Lobsters
Windowpane	
Weakfish	
Scup	
Bluefish	
Blackfish	
Butterfish	

To consider seasonal changes in catch at the five sites identified as being of low use, cruises were combined into seasons in accordance with the groups earlier selected by classification, Figure 11. The average catches taken at each of the five sites, compared with the catch averages for the entire survey area are given in four tables, one for each season: spring, Table 10; summer, Table 11; fall, Table 12; winter, Table 13.

In spring catches of all species in Area 1 were below survey averages, in Area 2 only bluefish catches were above average, as they were also in Area 5, Table 10. In Area 3 catches of both scup and blackfish were about twice the

Table 10. Spring catch in the selected low diversity areas

Fish Species	Area 1 Avg	% Survey Average*	Area 2 Avg	% Survey Average*	Area 3 Avg	% Survey Average*	Area 4 Avg	% Survey Average*	Area 5 Avg	% Survey Average*
Bluefish	1.07	77	4.25	308	0	0	0	0	1.72	124
Weakfish	0	0	0	0	0	0	0.96	195	0	0
Scup	2.81	8	5.32	14	72.80	198	34.19	93	15.61	43
Butterfish	4.92	11	9.69	23	13.00	30	24.20	56	5.52	13
Fluke	8.82	44	6.71	34	5.32	27	39.04	196	18.71	91
Windowpane	0	0	0	0	27.57	70	45.79	116	21.41	54
Winter Flounder	57.38	57	1.80	2	342.79	34	204.97	201	36.31	36
Blackfish	0	0	0	0	37.94	244	10.00	64	10.74	69
Blueclaw Crabs	0	0	0	0	0	0	0	0	0	0
Lobster	0.71	2	0	0	21.53	49	49.19	111	8.57	19

* Percent Average Survey = $\frac{\text{Annual average catch per station in selected low use areas x 100}}{\text{Annual average catch per station for entire survey area}}$

Table 11. Summer catch in the selected low diversity areas

Fish Species	Area 1 Avg	% Survey Average*	Area 2 Avg	% Survey Average*	Area 3 Avg	% Survey Average*	Area 4 Avg	% Survey Average*	Area 5 Avg	% Survey Average*
Bluefish	0	0	0	0	0	0	0	0	0	0
Weakfish	0.81	1	0	0	2.26	2	43.50	32	1.99	1
Scup	4.05	15	0	0	10.53	38	18.52	67	5.66	20
Butterfish	9.56	6	98.63	67	16.66	11	7.42	5	4.38	3
Fluke	5.17	29	4.04	22	4.52	25	23.20	128	9.53	53
Windowpane	0	0	4.17	47	0	0	0	0	0.68	8
Winter Flounder	2.43	20	0	0	4.13	34	10.47	85	1.90	15
Blackfish	0	0	0	0	2.15	34	0.93	15	1.63	26
Blueclaw Crabs	0	0	0	0	8.39	116	11.11	153	7.38	102
Lobster	0	0	0	0	5.59	40	10.47	75	0	0

* Percent Average Survey = $\frac{\text{Annual average catch per station in selected low use areas x 100}}{\text{Annual average catch per station for entire survey area}}$

Table 12. Fall catch in the selected low diversity areas

Fish Species	Area 1 Avg	% Survey Average*	Area 2 Avg	% Survey Average*	Area 3 Avg	% Survey Average*	Area 4 Avg	% Survey Average*	Area 5 Avg	% Survey Average*
Bluefish	0	0	2.12	3785	0	0	0	0	0	0
Weakfish	0	0	0	0	0	0	0	0	0	0
Scup	0	0	0	0	0	0	0	0	0	0
Butterfish	2.02	66	0	0	0	0	0	0	0	0
Fluke	0	0	0	0	0	0	0	0	0	0
Windowpane	5.13	37	7.29	55	3.12	23	4.90	37	1.42	11
Winter Flounder	15.00	20	0	0	30.33	40	13.00	17	30.23	39
Blackfish	0	0	0	0	2.00	120	0	0	0.67	40
Blueclaw Crabs	0	0	0	0	0	0	1.77	13	0.75	5
Lobster	0	0	0	0	1.00	14	2.77	38	0	0

* Percent Average Survey = $\frac{\text{Annual average catch per station in selected low use areas x 100}}{\text{Annual average catch per station for entire survey area}}$

Table 13. Winter catch in the selected low diversity areas

Fish Species	Area 1 Avg	% Survey Average*	Area 2 Avg	% Survey Average*	Area 3 Avg	% Survey Average*	Area 4 Avg	% Survey Average*	Area 5 Avg	% Survey Average*
Bluefish	0	0	0	0	0	0	0	0	0	0
Weakfish	0	0	0	0	0	0	0	0	0	0
Scup	0	0	0	0	0	0	0	0	0	0
Butterfish	0	0	0	0	0	0	0	0	0	0
Fluke	0	0	0	0	0	0	0	0	0	0
Windowpane	3.90	23	3.12	19	0.73	4	0.86	5	0.56	3
Winter Flounder	55.40	54	0	0	31.62	31	25.53	25	18.12	18
Blackfish	0	0	0	0	0	0	0	0	0.55	192
Blueclaw Crabs	0	0	0	0	0.91	49	0	0	1.13	61
Lobster	0	0	0	0	3.40	68	5.59	112	0	0

* Percent Average Survey = $\frac{\text{Annual average catch per station in selected low use areas x 100}}{\text{Annual average catch per station for entire survey area}}$

survey averages. However in Area 4 catches of four fish species exceeded their survey averages, weakfish, fluke, windowpane and winter flounder, lobster catches were also equal to average at this site.

During summer catches of all fishes were low, or very low, at all five sites, Table 11; only the catch of fluke in Area 4 slightly exceeded the survey average catch. Blueclaw crab catches in Areas 3, 4 and 5 were equal to, or greater than survey average catches; no crabs or lobsters were caught in Areas 1 and 2.

The fall catches of target fishes were reduced to only 2 or 3 species in each Area, Table 12. A high catch of juvenile bluefish in Area was based on only a single station; blackfish exceeded the survey average catch in Area 3. Other catches were all below average, - this included the catches of blueclaw crabs and lobsters which were very low.

Winter, like fall, was a season with catches reduced to only 2 or 3 target fish species, Table 13. Only the catch of blackfish in Area 5 exceeded the survey averages. Catches of lobsters and blueclaw crabs had increased in Areas 3, 4 and 5, but were below survey average, except for lobsters in Area 4.

The summary review of seasonal catches for target species at the five sites confirmed their selection as being areas of low use. Catches of fishes were consistently lowest in Areas 1 and 2 and few lobsters and no blueclaw crabs were caught. Catches in Area 5 were almost always below survey averages for each season. Of the 4 Areas, Area 4 had relatively higher fish catches and included significant catches of lobsters and blueclaw crabs, this Area was awarded the lowest priority in ranking the five sites. These rankings are in close agreement with the priorities allocated to the five sites in the preceding section of this Report.

Supplementary Surveys, Cruises 2 and 3 (September, October 1984)

On cruises 2 and 3 thirty trawl survey stations were sampled in the eastern half of the region. These surveys were especially important because the outer stations were in positions further south and east than were included

in the annual series (cruises 5 to 16, above), and provided unique information on additional areas which had been identified by PICG as potential new pit sites.

To find areas of low diversity and use by fish, the same method was applied in analysis of the annual survey data. Individual community parameter values were ranked numerically to determine the bound of the lowest 30% of ranks. The stations with parameter values falling below the 30% lower bound were limited with contours around low value areas on the distribution charts. A list of stations falling within low value areas for each parameter is given in Table 14. The list was reviewed for coincidence of stations with low values for different parameters, as was done for the annual survey series.

From the review of the low value stations for all of the parameters for this limited September-October survey, three (3) areas were identified which were of relatively low use by the fish, they are shown on a separate chart, Figure 31. It must be noted that the positions identified from these two surveys at one time of year, are altogether more tentative than those identified through the analysis of the twelve surveys included in the annual cycle. East of the Ambrose Channel the low diversity area identified around LE 04, 06 and 07 from the annual data review, Figure 30, was expanded considerably to also include LE 02, 03, and 05. The low area, LW 04, to the west of the Ambrose Channel which was also identified from the annual survey series, was increased to include LW 03, Figure 31. North of Sandy Hook a third area of low diversity was identified on the Flynn's Knoll bank, LW 05 and 06, - although this third area was <u>not</u> identified as being of consistently low diversity by the analysis of the comprehensive annual survey series.

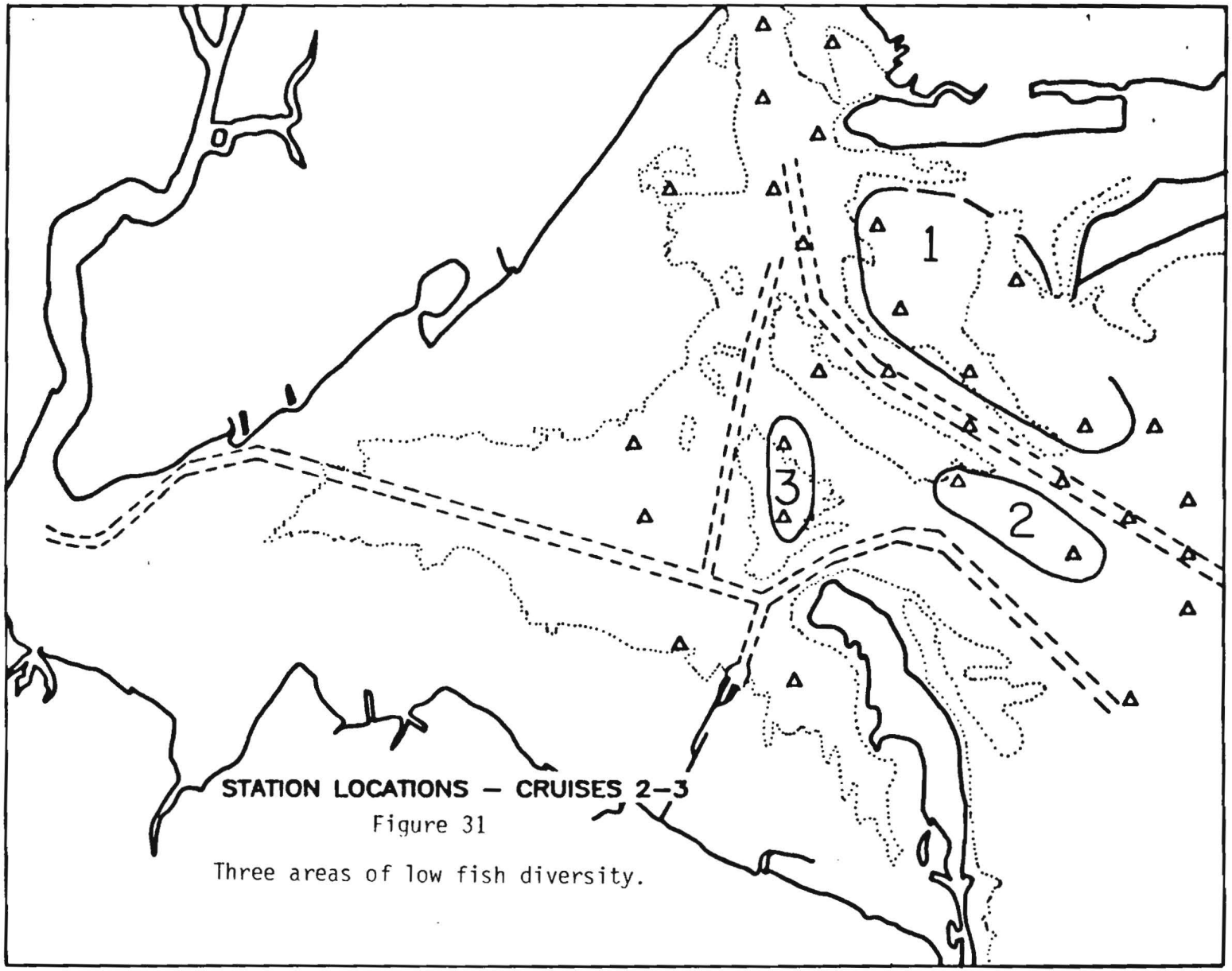
Conclusions and Prioritization of Low Use Areas

The very large data set for cruises 5 through 16, covering the annual cycle of the region was used to identify five (5) areas of relatively low fish diversity and density, Figure 30. The areas have been allotted priorities.

Table 14. Stations with low value community parameters, Surveys 2 and 3.

Parameter	SUBAREAS: West Bank Station Code, LW	East Bank Station Code, LE
Total Catch	03, 04, 05, 06	02, 03, 04, 05
Total Biomass	03, 04, 05, 06	02, 03, 04, 05
Number Species	03, 05, 06	02, 03, 04, 05, 07
Diversity Indices		
Shannon Weaver, H'	05, 06, 07	03, 04, 07, 08
Simpson, D	01, 05, 06, 07	01, 03, 08
Margalef, d	02, 05, 06, 07	03, 04, 07
Hurlburt, PIE	05, 06, 07	01, 03, 08

Station numbers which have been underlined have the lowest values.



STATION LOCATIONS – CRUISES 2–3

Figure 31

Three areas of low fish diversity.

1. Area 1 is the largest area and has no obstructions nor shipping anchorages. It has little use by fishes of importance to the recreational or commercial fisheries, and no catch of lobsters or crabs, - it is given first priority.
2. Area 2 is small, but it may be expanded to the south, no fishes of interest are taken in large numbers nor are lobsters or crabs caught. On the basis of fish diversity alone, this site is given second priority. However there are obstructions at the site which may effect its usefulness.
3. Area 5, Inner Raritan Bay, is a large area in which catches of fishes of interest to the recreational fishery are small; blueclaw crabs and lobsters are taken in Area 5 but are relatively low in numbers.. It is given third priority on its use by fishes, there are some obstructions in the southern part of this site but significant areas remain clear for use. This site is far from the likely areas of interest for potential development.
4. Area 3 is the second largest site, it is unobstructed and there are no anchorages. Area 3 has higher than average catches of three species of interest, scup, winter flounder and blackfish. Blueclaw crabs and lobsters are taken in Area 3 but are relatively low catches, being less than half the regional average.
5. Area 4, North Belford is a small site. Although catches of fish of interest are relatively low, the catches of crabs and of lobsters are as high as the average for region. The site has considerable obstruction from pipelines and lies partly in the New Jersey fish trap area. It is given lowest priority.

The additional information derived from the separate surveys 2 and 3 is valuable. In particular it suggests that the low diversity areas identified to both the east and to the west of the Ambrose Channel may be expanded in size. The western area in the vicinity of LW 04 may extend as far as LW 03, a pipeline area passes through this large area and there is also a general anchorage marked, but the greatest part of this area is clear. The low diversity area to the east of the Channel in the vicinity of LE 04, 06, and 07 may extend further to include LE 02, 03, and 05, which would make it by far the largest area of all the five identified. A pipeline area is marked passing

from north to south-east through this eastern low use area, but the major parts of the area are quite clear.

COMMENT ON PICG PROPOSED PIT SITES

The Public Involvement Coordination Group (PICG) for the dredged material disposal management plan for the Port of New York and New Jersey has suggested four areas where new pits could be dug and used as dredged material disposal sites. The four sites are shown on a separate chart, and labelled A, B, C, and D, Figure 32 for cruises 5 to 16, and Figure 33 for cruises 2 and 3. They are named as follows:

A. Raritan Reach Pit
B. East Bank Pit Area
C. Ambrose Channel Pit
D. Sandy Hook Channel Pit

Our survey stations RB 04 and RB 10 fall in the vicinity of site A and this is also an area which we have identified as of low use, Area 3, "East Raritan Bay", in our survey. The East Bank Pit, site B, contains station LE 05 and is in the vicinity of LE 04, LE 06, all of which lie in a large area of low density, Area 1, "East Bank" in our survey. The Sandy Hook Channel Pit, site D, contains a low use station, LW 03; to the north of site D, LW 04 is also a low use station, Area 2, "South Romer" in our survey. There are none of our survey stations sufficiently close to PICG site C, Ambrose Channel Pit to comment usefully.

Thus three of the new sites suggested by PICG, - sites A, B, and D, fall approximately within areas which we have independently identified from our survey data as being of low diversity and low use by the fish community of the Lower New York Harbor.

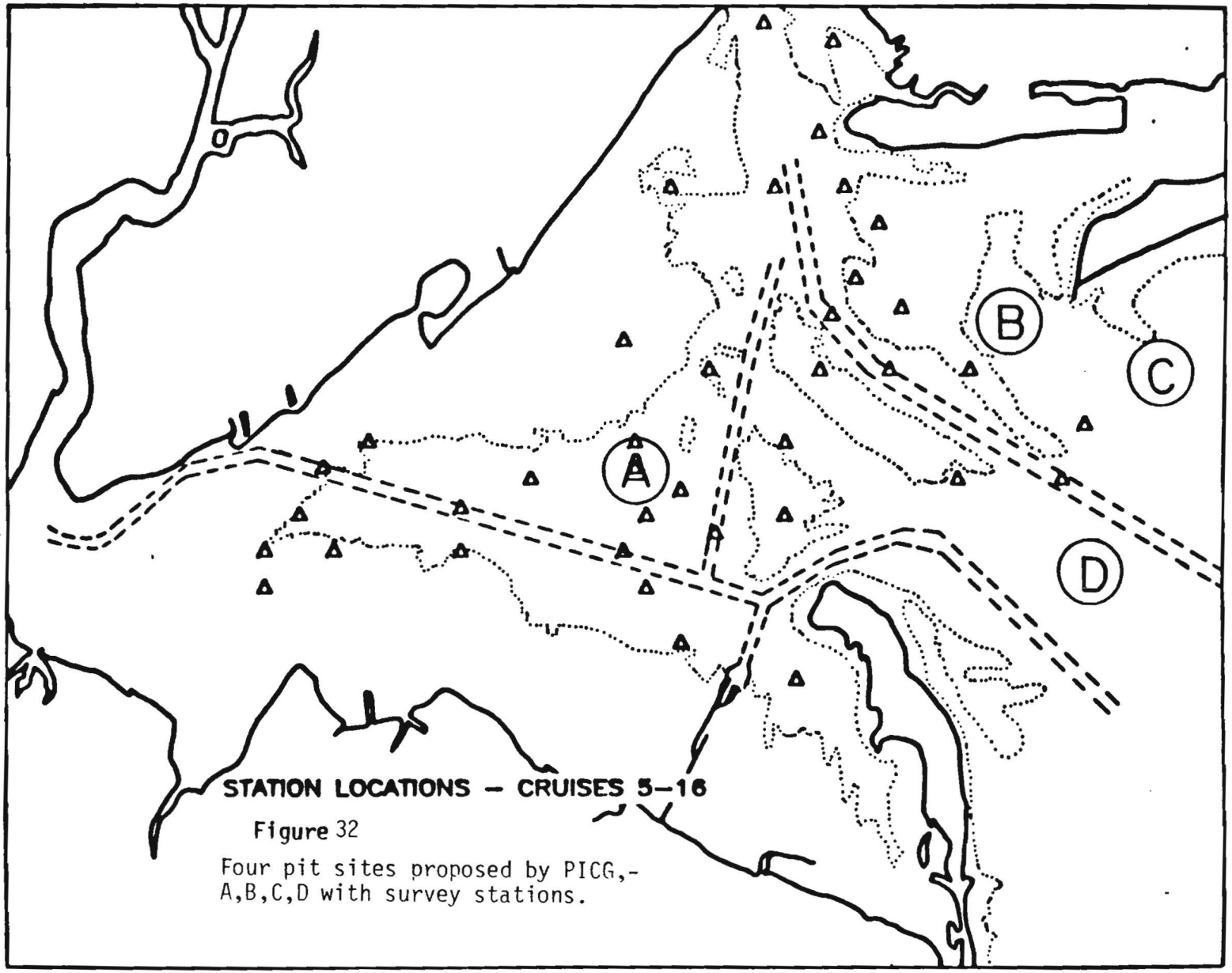
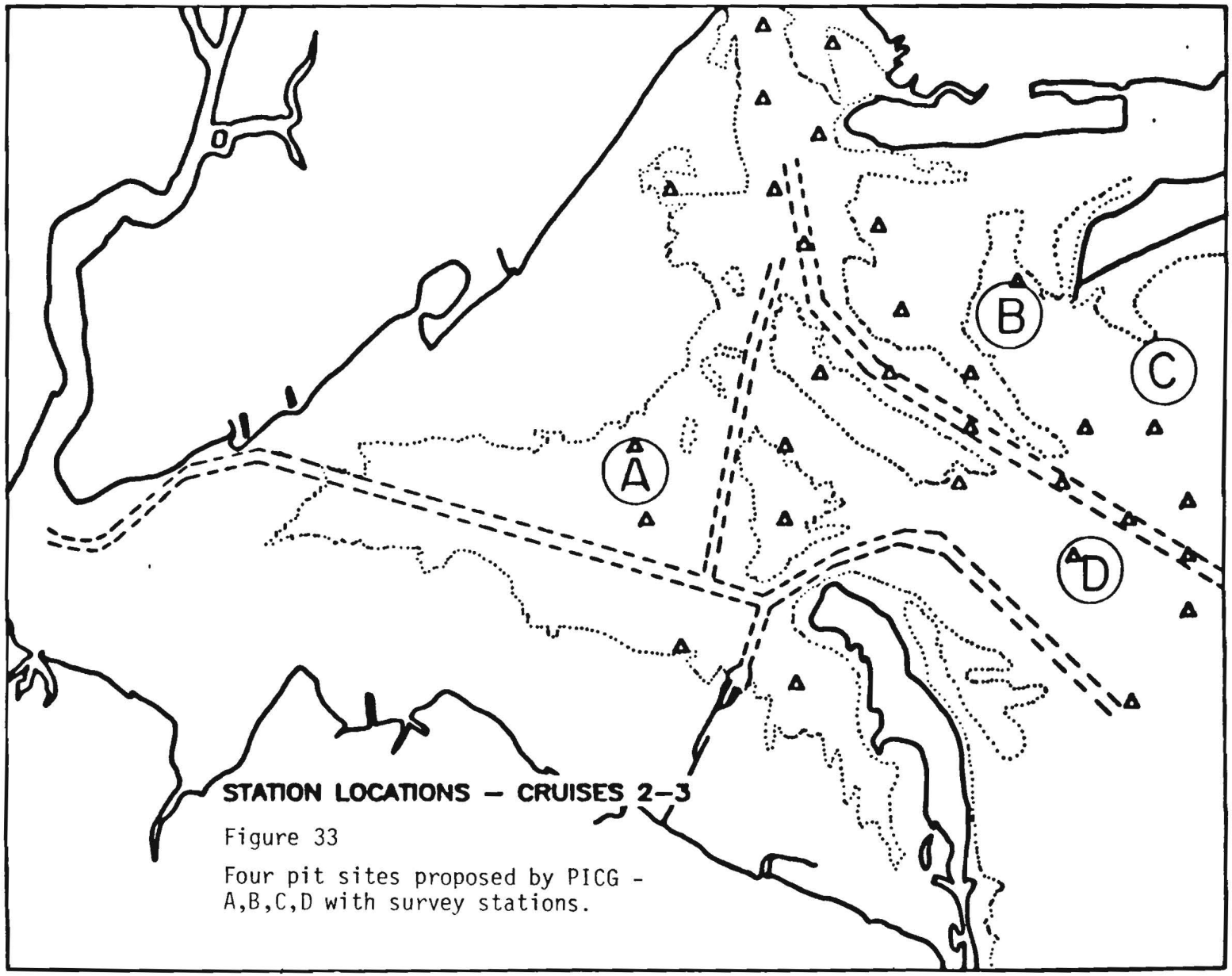


Figure 32

Four pit sites proposed by PICG,-
A,B,C,D with survey stations.



STATION LOCATIONS – CRUISES 2–3

Figure 33

Four pit sites proposed by PICG - A,B,C,D with survey stations.

FISH POPULATIONS OF THE BORROW PITS

Comparison of Populations between Pits

The Borrow Pits named "Large West Bank", "CAC" and "East Bank" are shown in Figure 2; the trawl stations worked in these three pits during the annual cycle of surveys are LW08, LW10 and LE11, respectively, are shown in Figure 4. In making comparisons with trawl catches taken in the Borrow Pits, the anchovys have been omitted from all of the analyses.

The total number of fish of different species caught at each Borrow Pit station during the annual survey series, cruises 5 through 16, is given in Table 15 (the catches are expressed as numbers per hectare). The catches for the three stations have also been combined and are expressed as averages. These species catches have been ranked and listed in Table 16, in this Table the average species catches for the three combined stations have also been ranked and listed as mean ranks.

The average total catch in the Pits was 5,205 fish (with a standard error of 1,215 fish), the highest catch was in the CAC Pit (LW10), the catches in the two other Pits (LW08 and LE11) were similar. Twenty-six species were caught in the Large West Bank Pit (LW08), twenty-eight in the CAC Pit and twenty-nine species in the East Bank Pit (LE11). The ten most abundant species taken in the individual Borrow Pits were considered to be the dominants and comparisons between these dominant assemblages taken in the different Pits revealed similarities in their communities, Table 16. The three river herrings, American shad, blueback herring and alewife and three flounders, fluke, winter flounder and windowpane were dominant (or near dominant) in all of the Pits. Butterfish and weakfish were dominant in all three Pits. Scup were dominant in the Large West Bank and East Bank Pits and of fifteenth rank in the CAC Pit; silver hake were dominant in CAC and East Bank Pits and of fourteenth rank in the Large West Bank Pit. Bluefish and lookdown were present in all Pits but only dominant in the Large West Bank Pit; similarly red hake were present but were only dominant in the CAC Pit. It was concluded that although there were some differences in numerical dominance of species between individual Pits, the same assemblage of fish occurred in all three Pits.

Table 15. Fish abundance at Borrow Pit stations, totals for annual survey (numbers per hectare fished).

	LW08	LW10	LE11	MEAN	SE
SM DOGF	8.527	3.890	8.140	6.852	1.485
LI SKATE					
W SKATE			2.524	.841	.841
TH SKATE			1.526	.509	.509
AT STURG		1.773		.591	.591
AMER EEL					
CON EEL					
BB HERRG	1069.418	3535.891	229.198	1611.502	992.295
ALEWIFE	620.426	1537.391	1286.832	1148.216	273.628
AM SHAD	363.010	246.491	135.841	248.447	65.585
AT MENHD	3.454	5.680	2.524	3.886	.936
AT HERRG	1.682	1.823	1.396	1.634	.126
RND HERR					
GOOSEF					
SL HAKE	10.804	71.782	92.361	58.316	24.487
SPT HAKE	6.776	69.247	12.327	29.450	19.963
W/R HAKE	1.426	144.613	21.275	55.771	44.789
CORNETF					
A SILVER	3.454	6.689	66.113	25.419	20.369
3 STICKL					
SEAHORSE					
PIPEFISH	3.454		2.983	2.146	1.081
GRUBBY		1.930	1.396	1.109	.575

Table 15. Continued

	LW08	LW10	LE11	MEAN	SE
LN SCULP			2.524	.841	.841
BL SEABS	1.600	2.625		1.408	.764
GRY SNAP					
STR BASS					
BLUEFISH	186.615	1.562	12.241	66.806	59.984
CREV JCK		1.773		.591	.591
LOOKDOWN	53.101	11.895	4.039	23.012	15.215
RH SCAD					
WEAKFISH	181.050	816.035	138.355	378.480	219.124
SCUP	50.286	8.937	145.152	68.125	40.321
ST MULL					
N BARRAC	1.773	2.117		1.297	.656
BLACKF	6.951	19.523	8.948	11.807	3.901
CUNNER	1.773	2.117	17.895	7.262	5.318
RCK GUNN					
AM SANDL			6.898	2.299	2.299
BUTTERF	1900.779	540.019	529.728	990.175	455.312
N SEARBN					
ST SEARB	13.749	9.475	17.398	13.541	2.290
SMM FLND	1.727	1.312	1.526	1.522	.120
FLUKE	81.572	95.576	44.466	73.871	15.248
4SP FLND	17.268	6.350	4.971	9.530	3.890
WINDOWPN	38.750	164.301	88.393	97.148	36.507
WN FLND	13.195	224.429	551.878	263.167	156.706
N PUFFER					

Table 16. Fish abundance at Borrow Pit stations, by rank, totals for annual survey.

	LW08	LW10	LE11	MEAN
SM DOGF	15	19	18	20
LI SKATE				
W SKATE			24	29.5
TH SKATE			26.5	33
AT STURG		25.5		31.5
AMER EEL				
CON EEL				
BB HERRG	2	1	4	1
ALEWIFE	3	2	1	2
AM SHAD	4	5	7	6
AT MENHD	19	18	24	21
AT HERRG	24	24	28.5	24
RND HERR				
GOOSEF				
SL HAKE	14	10	8	11
SPT HAKE	17	11	15	13
W/R HAKE	26	8	12	12
CORNETF				
A SILVER	19	16	10	14
3 STICKL				
SEAHORSE				
PIPEFISH	19		22	23
GRUBBY		23	28.5	28

Table 16. Continued

	LW08	LW10	LE11	MEAN
LN SCULP			24	29.5
BL SEABS	25	20		26
GRY SNAP				
STR BASS				
BLUEFISH	5	27	16	10
CREV JCK		25.5		31.5
LOOKDOWN	8	13	21	15
RH SCAD				
WEAKFISH	6	3	6	4
SCUP	9	15	5	9
ST MULL				
N BARRAC	21.5	21.5		27
BLACKF	16	12	17	17
CUNNER	21.5	21.5	13	19
RCK GUNN				
AM SANDL			19	22
BUTTERF	1	4	3	3
N SEARBN				
ST SEARB	12	14	14	16
SMH FLND	23	28	26.5	25
FLUKE	7	9	11	8
4SP FLND	11	17	20	18
WINDOWPN	10	7	9	7
WN FLND	13	6	2	5
N PUFFER				

Diversity parameters for the catches in each Pit station, together with average parameter values are summarized in Table 17. Diversity indices were all largest for LE11, the East Bank Pit, this is because the greatest number of species were taken at that station, although the catch numbers were relatively low. These parameters will be used below to make comparison between the populations within the Pits and populations on associated shoals, as well as with populations in the shipping channels.

Comparisons of Pits Populations with Populations on Shoals

To compare the populations of fish in the Pits with the fish in associated shoal areas, two alternate data sets for shoal stations were examined. The shoal stations chosen were those most close to each Borrow Pit, the two sets of stations were: a) RB08 (c.f. LW10) RB11 (c.f. LW08) and LE07 (c.f. LE11); b) RB04 (c.f. LW10), RB11 (c.f. LW08) and LE06 (c.f. LE11). It is noted that RB11 occurs in each set because there was no second alternate station sufficiently close to the Large West Bank Pit (LW08).

There was considerable similarity in the fish fauna in both sets of shoal stations, the ten dominant fishes were the same ten species in both sets although their ordering changed to some extent. A total of 19 species was caught in the first set of shoal stations and 17 species were caught at the second set.

First set of shoal stations compared with Pits

The fish taken over the annual surveys in the shoal stations RB08, RB11 and LE06 are given in Table 18. For ease of comparisons the catches of fish in the three Borrow Pits are also given in the Table. A total of 404 fish belonging to 19 species were caught at these three shallow stations. These species catches have also been ranked by abundance and are listed in Table 19, again the species caught in the Pit stations have been ranked in for comparison. The catches of fish were larger and more diverse on average in the Pits than on the shoals, more than ten times as many fish, belonging to 28 species, were taken in the Pits.

Table 17. Diversity parameters for Borrow Pit stations.

	LW08	LW10	LE11	MEAN	SE
*TOT CPUE	4642.620	7535.248	3438.848	5205.572	1215.568
NUM SP	26.000	28.000	29.000	27.667	.882
H*	1.772	1.710	2.065	1.849	.109
SIMP D	4.027	3.549	4.982	4.186	.421
MSR	2.961	3.024	3.439	3.141	.150
PIE	.752	.718	.799	.756	.024

*TOT CPUE = Total number fish caught (as number per hectare fished)
NUM SP = Total number of fish species caught
H* = Shannon Weaver index
SIMP D = Simpson's index of diversity
MSR = Margalef's species richness index
PIE = Probability of interspecific encounter

Table 18. Fish abundance at Borrow Pit stations compared with first set shoal stations (numbers per hectare fished).

	LW08	LW10	LE11	MEAN	SE	RB08	RB11	LE06	MEAN	SE
DGF	8.527	3.890	8.140	6.852	1.485					
KATE										
ATE			2.524	.841	.841			3.860	1.287	1.287
KATE			1.526	.509	.509					
TURG		1.773		.591	.591					
EEL										
EEL										
ERRG	1069.418	3535.891	229.198	1611.502	992.295	9.796	60.841	3.505	24.714	18.155
IFE	620.426	1537.391	1286.832	1148.216	273.628	1.875	1.682		1.186	.595
HAD	363.010	246.491	135.841	248.447	65.585	51.767	18.787	3.645	24.733	14.206
ENHD	3.454	5.680	2.524	3.886	.936	1.875			.625	.625
ERRG	1.682	1.823	1.396	1.634	.126					
HERR										
EF										
AKE	10.804	71.782	92.361	58.316	24.487	8.749		2.678	3.809	2.588
HAKE	6.776	69.247	12.327	29.450	19.963	2.187	3.365		1.851	.986
HAKE	1.426	144.613	21.275	55.771	44.789	1.875			.625	.625
ETF						1.988			.663	.663
LVER	3.454	6.689	66.113	25.419	20.369	10.623	16.965		9.196	4.949
ICKL						1.562			.521	.521
ORSE							2.853		.951	.951
FISH	3.454		2.983	2.146	1.081					
BY		1.930	1.396	1.109	.575	3.125	1.773		1.633	.905

Table 18. Continued.

	LW08	LW10	LE11	MEAN	SE	RB08	RB11	LE06	MEAN	SE
CULP			2.524	.841	.841					
EABS	1.600	2.625		1.408	.764	1.988			.663	.663
SNAP										
BASS							1.562	1.339	.967	.488
FISH	186.615	1.562	12.241	66.806	59.984	3.355	2.117	3.201	2.891	.390
JCK		1.773		.591	.591					
DOWN	53.101	11.895	4.039	23.012	15.215		1.600	2.117	1.239	.637
CAD						1.773		3.201	1.658	.926
FISH	181.050	816.035	138.355	378.480	219.124		2.117		.706	.706
	50.286	8.937	145.152	68.125	40.321	83.342	23.851	4.233	37.142	23.784
ULL							1.682		.561	.561
RRAC	1.773	2.117		1.297	.656					
CKF	6.951	19.523	8.948	11.807	3.901	27.553	20.011		15.855	8.221
NER	1.773	2.117	17.895	7.262	5.318	7.954			2.651	2.651
GUNN							1.426		.475	.475
SANDL			6.898	2.299	2.299			119.938	39.979	39.979
TERF	1900.779	540.019	529.728	990.175	455.312	179.220	43.769	33.936	85.642	46.875
EARBN								1.600	.533	.533
SEARB	13.749	9.475	17.398	13.541	2.290	3.547			1.182	1.182
FLND	1.727	1.312	1.526	1.522	.120		1.426		.475	.475
KE	81.572	95.576	44.466	73.871	15.248	41.253	30.698	15.830	29.260	7.374
FLND	17.268	6.350	4.971	9.530	3.890					
DOWPN	38.750	164.301	88.393	97.148	36.507	19.263	6.390	14.144	13.266	3.742
FLND	13.195	224.429	551.878	263.167	156.706	215.011	44.777	30.669	96.819	59.236
UFFER						2.343			.781	.781

Table 19. Fish abundance at Borrow Pit stations compared with first set shoal stations, by rank.

	LW08	LW10	LE11	MEAN	RB08	RB11	LE06	MEANS
OGF	15	19	18	20				
KATE								
ATE			24	29.5			7	17
KATE			26.5	33				
TURG		25.5		31.5				
EEL								
EEL								
ERRG	2	1	4	1	9	1	9	7
IFE	3	2	1	2	20	15.5		19
HAD	4	5	7	6	4	7	8	6
ENHD	19	18	24	21	20			27.5
ERRG	24	24	28.5	24				
HERR								
EF								
AKE	14	10	8	11	10		12	11
HAKE	17	11	15	13	16	10		14
HAKE	26	8	12	12	20			27.5
ETF					17.5			25.5
LVER	19	16	10	14	8	8		10
ICKL					23			31
ORSE	-					11		22
FISH	19		22	23				
BY		23	28.5	28	14	14		16

Table 19. Continued.

	LW08	LW10	LE11	MEAN	RB08	RB11	LE06	MEANS
CULP			24	29.5				
EABS	25	20		26	17.5			25.5
SNAP								
BASS						18	15	21
FISH	5	27	16	10	13	12.5	10.5	12
JCK		25.5		31.5				
DOWN	8	13	21	15		17	13	18
CAD					22		10.5	15
FISH	6	3	6	4		12.5		24
	9	15	5	9	3	5	6	4
ULL						15.5		29
RRAC	21.5	21.5		27				
KF	16	12	17	17	6	6		8
ER	21.5	21.5	13	19	11			13
GUNN						19.5		32.5
ANDL			19	22			1	3
ERF	1	4	3	3	2	3	2	2
ARBN							14	30
SEARB	12	14	14	16	12			20
FLND	23	28	26.5	25		19.5		32.5
E	7	9	11	8	5	4	4	5
FLND	11	17	20	18				
DWPN	10	7	9	7	7	9	5	9
LND	13	6	2	5	1	2	3	1
FFER					15			23

Of the ten dominant species in the Pits, seven species were also dominant at the shoal stations and included blueback herring, American shad, winter flounder and windowpane flounders, fluke, butterfish and scup. Alewives ranked second by abundance in the Pits, but very few were caught in the shallows. Likewise juvenile weakfish and bluefish migrating from the estuary through deeper areas in late summer were abundant in the Pits, but few in the shoals. Conversely, American sandlance and Atlantic silversides were dominant at the shallow stations but few were caught in the deeper Pits; blackfish were also dominants in the shoals, often being associated with shellfish beds.

The diversity parameters for the catches at the Pit and shoal stations together with average parameter values, are summarized in Table 20. From examination of the Table it is obvious that the populations in the Pits are several times more abundant and contain one-third more species than at the shoal stations, - usage of the Pits by the fish populations is clearly much greater, per unit area of the seabed.

Alternate set of shoal stations compared with the Pits

The alternate set of shoal stations associated with the Borrow Pits were RB04, RB11 and LE07 and the catches made in them are given in Table 20. For ease of comparisons the catches of fish in the three Borrow Pits are again given in Table 21. A total of 1,117 fish belonging to 17 species were caught at the three alternate shoal stations. The species catches have also been ranked by their abundance and ranks are listed in Table 22, which also include for comparison the ranked catches in the Pits. The same species comprised the ten dominants at both sets of shoal stations and so the same comments apply as for the first set of shoal stations, above.

The diversity parameters for the catches in the Pits and at the alternate set of shoal stations, together with average parameter values are summarized in Table 23. Examination of the Table again shows that the catches in the Pits were several times abundant and contained more than 50% more species than the second set of associated shoal stations. The same conclusion must be drawn, that usage by fish populations of seabed in the Pits is clearly greater than usage of the associated shoal areas.

Table 20. Diversity parameters for Borrow Pit stations and first set of shoal stations.

	LW08	LW10	LE11	MEAN	SE	RB08	RB11	LE06	MEAN	SE
CPUE	4642.620	7535.248	3438.848	5205.572	1215.568	682.024	287.692	243.896	404.537	139.318
SP	26.000	28.000	29.000	27.667	.882	23.000	20.000	15.000	19.333	2.333
	1.772	1.710	2.065	1.849	.109	2.029	2.336	1.753	2.039	.168
D	4.027	3.549	4.982	4.186	.421	5.130	8.269	3.531	5.643	1.392
	2.961	3.024	3.439	3.141	.150	3.372	3.356	2.547	3.092	.272
	.752	.718	.799	.756	.024	.805	.879	.717	.800	.047

Table 21. Fish abundance at Borrow Pit stations compared with alternate set shoal stations (numbers per hectare fished).

	LW08	LW10	LE11	MEAN	SE	RB04	RB11	LE07	MEAN	SE
OGF	8.527	3.890	8.140	6.852	1.485			2.430	.810	.810
KATE								1.727	.576	.576
ATE			2.524	.841	.841					
KATE			1.526	.509	.509					
TURG		1.773		.591	.591					
EEL										
EEL										
ERRG	1069.418	3535.891	229.198	1611.502	992.295	49.451	60.841	2193.382	767.891	712.753
IFE	620.426	1537.391	1286.832	1148.216	273.628	1.930	1.682		1.204	.606
HAD	363.010	246.491	135.841	248.447	65.585	18.975	18.787	149.981	62.581	43.700
ENHD	3.454	5.680	2.524	3.886	.936			1.727	.576	.576
ERRG	1.682	1.823	1.396	1.634	.126					
HERR										
EF										
AKE	10.804	71.782	92.361	58.316	24.487					
HAKE	6.776	69.247	12.327	29.450	19.963	1.875	3.365		1.747	.974
HAKE	1.426	144.613	21.275	55.771	44.789					
NETF										
ILVER	3.454	6.689	66.113	25.419	20.369	29.144	16.965	2.343	16.151	7.747
TICKL										
HORSE						8.705	2.853		3.853	2.562
EFISH	3.454		2.983	2.146	1.081	3.977			1.326	1.326
BBY		1.930	1.396	1.109	.575	1.930	1.773	1.875	1.859	.046

Table 21. Continued.

	LW08	LW10	LE11	MEAN	SE	RB04	RB11	LE07	MEAN	SE
CULP			2.524	.841	.841					
EABS	1.600	2.625		1.408	.764					
SNAP										
BASS							1.562		.521	.521
FISH	186.615	1.562	12.241	66.806	59.984		2.117		.706	.706
JCK		1.773		.591	.591					
DOWN	53.101	11.895	4.039	23.012	15.215	4.380	1.600		1.993	1.280
CAD										
FISH	181.050	816.035	138.355	378.480	219.124	4.525	2.117	2.430	3.024	.756
	50.286	8.937	145.152	68.125	40.321	6.350	23.851	15.498	15.233	5.054
ULL							1.682		.561	.561
RRAC	1.773	2.117		1.297	.656					
CKF	6.951	19.523	8.948	11.807	3.901	8.221	20.011		9.411	5.807
NER	1.773	2.117	17.895	7.262	5.318					
GUNN							1.426		.475	.475
SANDL			6.898	2.299	2.299	13.576		132.199	48.592	41.987
TERF	1900.779	540.019	529.728	990.175	455.312	35.018	43.769	4.105	27.631	12.031
EARBN										
SEARB	13.749	9.475	17.398	13.541	2.290					
FLND	1.727	1.312	1.526	1.522	.120	1.875	1.426		1.100	.565
KE	81.572	95.576	44.466	73.871	15.248	19.692	30.698	15.871	22.087	4.445
FLND	17.268	6.350	4.971	9.530	3.890					
DOWPN	38.750	164.301	88.393	97.148	36.507	13.287	6.390	8.360	9.346	2.051
FLND	13.195	224.429	551.878	263.167	156.706	57.657	44.777	252.199	118.211	67.097
UFFER										

Table 22. Fish abundance at Borrow Pit stations compared with alternate set shoal stations, by rank.

	LW08	LW10	LE11	MEAN	RB04	RB11	LE07	MEANS
DGF	15.000	19.000	18.000	20.000	.000	.000	9.500	19.000
KATE	.000	.000	.000	.000	.000	.000	13.500	21.500
ATE	.000	.000	24.000	29.500	.000	.000	.000	.000
KATE	.000	.000	26.500	33.000	.000	.000	.000	.000
TURG	.000	25.500	.000	31.500	.000	.000	.000	.000
EEL	.000	.000	.000	.000	.000	.000	.000	.000
EEL	.000	.000	.000	.000	.000	.000	.000	.000
ERRG	2.000	1.000	4.000	1.000	2.000	1.000	1.000	1.000
IFE	3.000	2.000	1.000	2.000	15.500	15.500	.000	17.000
HAD	4.000	5.000	7.000	6.000	6.000	7.000	3.000	3.000
ENHD	19.000	18.000	24.000	21.000	.000	.000	13.500	21.500
ERRG	24.000	24.000	28.500	24.000	.000	.000	.000	.000
HERR	.000	.000	.000	.000	.000	.000	.000	.000
EF	.000	.000	.000	.000	.000	.000	.000	.000
AKE	14.000	10.000	8.000	11.000	.000	.000	.000	.000
HAKE	17.000	11.000	15.000	13.000	17.500	10.000	.000	15.000
HAKE	26.000	8.000	12.000	12.000	.000	.000	.000	.000
ETF	.000	.000	.000	.000	.000	.000	.000	.000
LVER	19.000	16.000	10.000	14.000	4.000	8.000	11.000	7.000
ICKL	.000	.000	.000	.000	.000	.000	.000	.000
ORSE	.000	.000	.000	.000	9.000	11.000	.000	11.000
FISH	19.000	.000	22.000	23.000	14.000	.000	.000	16.000
BY	.000	23.000	28.500	28.000	15.500	14.000	12.000	14.000

Table 22. Continued.

	LW08	LW10	LE11	MEAN	RB04	RB11	LE07	MEANS
CULP	.000	.000	24.000	29.500	.000	.000	.000	.000
EABS	25.000	20.000	.000	26.000	.000	.000	.000	.000
SNAP	.000	.000	.000	.000	.000	.000	.000	.000
BASS	.000	.000	.000	.000	.000	18.000	.000	24.000
FISH	5.000	27.000	16.000	10.000	.000	12.500	.000	20.000	
JCK	.000	25.500	.000	31.500	.000	.000	.000	.000
DOWN	8.000	13.000	21.000	15.000	13.000	17.000	.000	13.000
CAD	.000	.000	.000	.000	.000	.000	.000	.000
FISH	6.000	3.000	6.000	4.000	12.000	12.500	9.500	12.000
	9.000	15.000	5.000	9.000	11.000	5.000	6.000	8.000
ULL	.000	.000	.000	.000	.000	15.500	.000	23.000
RRAC	21.500	21.500	.000	27.000	.000	.000	.000	.000
CKF	16.000	12.000	17.000	17.000	10.000	6.000	.000	9.000
ER	21.500	21.500	13.000	19.000	.000	.000	.000	.000
GUNN	.000	.000	.000	.000	.000	19.500	.000	25.000
SANDL	.000	.000	19.000	22.000	7.000	.000	4.000	4.000
TERF	1.000	4.000	3.000	3.000	3.000	3.000	8.000	5.000
EARBN	.000	.000	.000	.000	.000	.000	.000	.000
SEARB	12.000	14.000	14.000	16.000	.000	.000	.000	.000
FLND	23.000	28.000	26.500	25.000	17.500	19.500	.000	18.000
KE	7.000	9.000	11.000	8.000	5.000	4.000	5.000	6.000
FLND	11.000	17.000	20.000	18.000	.000	.000	.000	.000
DOWPN	10.000	7.000	9.000	7.000	8.000	9.000	7.000	10.000
FLND	13.000	6.000	2.000	5.000	1.000	2.000	2.000	2.000
UFFER	.000	.000	.000	.000	.000	.000	.000	.000

Table 23. Diversity parameters for Borrow Pit stations and alternate set of shoal stations.

	LW08	LW10	LE11	MEAN	SE	RB04	RB11	LE07	MEAN	SE
CPUE	4642.620	7535.248	3438.848	5205.572	1215.568	280.568	287.692	2784.127	1117.462	833.335
SP	26.000	28.000	29.000	27.667	.882	18.000	20.000	14.000	17.333	1.764
	1.772	1.710	2.065	1.849	.109	2.410	2.336	.825	1.857	.516
D	4.027	3.549	4.982	4.186	.421	8.786	8.269	1.577	6.211	2.322
	2.961	3.024	3.439	3.141	.150	3.016	3.356	1.639	2.670	.525
	.752	.718	.799	.756	.024	.886	.879	.366	.710	.172

Conclusion concerning shoal areas

Catches in the shoal areas in the vicinity of the Borrow Pits were much less abundant than in the Pits, less than 25% of the Pit catches. The shoal stations were less diverse with fewer species and there were some changes in species dominance. Blackfish, American sandlance and Atlantic silversides were important on the shoals although not in the Pits, conversely species important in the Pits but not on the shoals were alewife, juvenile weakfish and juvenile bluefish.

It is quite clear from the foregoing analysis that the shoal areas in the vicinity of the Borrow Pits are used much less by the fish community of the Lower Bay/Raritan Bay than are the Pits themselves. Indeed inspection of fish catches at all 25 shoal stations (30 ft) deep, in the survey area, Figure 12, shows that in no case was the catch more abundant than in the Pits. Diversity was greater in the Pits, of the 25 shoal stations only two (LE10 and RB01) contained as many species, twenty-seven, as the least diverse Pit (LW08), Figure 13.

Comparison of Populations between Pits and the Shipping Channels

The three channel stations which are closest to the Borrow Pits are AN03 for the Large West Bank Pit (LW08), AN01 for the East Bank Pit (LE11) and RB07 for the CAC Pit (LW10), Figure 4. About the same number of fish species was taken in all of the channel stations, 26, 24 and 25 species in AN01, AN03 and RB07, respectively.

The total catches of different fish species taken over the annual cycle at each of the channel stations are given in Table 24; the catches made in the same period at each of the Pit stations are given in the same Table for easy reference. The catches for the three channel stations have been combined and expressed as averages in Table 24, and the Pit station averages are also given. In a simplified presentation, the species catches have been ranked and listed in Table 25; the catch averages for the three stations combined have also been ranked and listed as mean ranks in the Table. Considering the ten most

Table 24. Fish abundance at Borrow Pit stations compared with channel stations (numbers per hectare fished).

	LW08	LW10	LE11	MEAN	SE	AN01	AN03	RB07	MEAN	SE
DGF	8.527	3.890	8.140	6.852	1.485	2.343	5.635		2.659	1.634
KATE										
ATE			2.524	.841	.841	2.625			.875	.875
KATE			1.526	.509	.509	1.988			.633	.633
TURG		1.773		.591	.591					
EEL								1.773	.591	.591
EEL								1.988	.663	.663
ERRG	1069.418	3535.891	229.198	1611.502	992.295	60.782	108.838	566.981	245.534	161.321
IFE	620.426	1537.391	1286.832	1148.216	273.628	2033.800	610.540	111.081	918.474	576.000
HAD	363.010	246.491	135.841	248.447	65.585	18.601	55.930	69.816	48.116	15.292
ENHD	3.454	5.680	2.524	3.886	.936	172.521	16.633		63.051	54.945
ERRG	1.682	1.823	1.396	1.634	.126		2.916		.972	.972
HERR										
EF						3.947			1.316	1.316
AKE	10.804	71.782	92.361	58.316	24.487	41.004	29.427	12.414	27.615	8.303
HAKE	6.776	69.247	12.327	29.450	19.963	18.959	1.640	15.843	12.147	5.330
HAKE	1.426	144.613	21.275	55.771	44.789	5.965		24.641	10.202	7.422
NETF										
ILVER	3.454	6.689	66.113	25.419	20.369	2.187	5.559		2.582	1.617
TICKL										
HORSE								1.988	.663	.663
EFISH	3.454		2.983	2.146	1.081			3.863	1.288	1.288
BBY		1.930	1.396	1.109	.575	2.853		6.849	3.234	1.986

Table 24. Continued.

	LW08	LW10	LE11	MEAN	SE	AN01	AN03	RB07	MEAN	SE
ULP			2.524	.841	.841	2.625	1.458		1.361	.759
ABS	1.600	2.625		1.408	.764			49.540	16.513	16.513
NAP							2.051		.684	.684
ASS										
FISH	186.615	1.562	12.241	66.806	59.984			2.430	.810	.810
JCK		1.773		.591	.591					
DOWN	53.101	11.895	4.039	23.012	15.215		2.524	9.064	3.863	2.701
CAD										
FISH	181.050	816.035	138.355	378.480	219.124	91.346	37.776	3.546	44.223	25.550
	50.286	8.937	145.152	68.125	40.321	10.646	24.792	103.968	46.469	29.038
ULL										
RRAC	1.773	2.117		1.297	.656			2.430	.810	.810
CKF	6.951	19.523	8.948	11.807	3.901	2.430	8.510	27.703	12.881	7.616
NER	1.773	2.117	17.895	7.262	5.318	7.714	3.367	15.006	8.696	3.396
GUNN										
SANDL			6.898	2.299	2.299	293.963	4.233		99.399	97.290
TERF	1900.779	540.019	529.728	990.175	455.312	320.428	593.063	102.859	338.783	141.807
EARBN										
SEARB	13.749	9.475	17.398	13.541	2.290	6.152	2.524	178.628	62.435	58.106
FLND	1.727	1.312	1.526	1.522	.120	10.509	1.727		4.079	3.254
KE	81.572	95.576	44.466	73.871	15.248	51.664	22.259	102.174	58.699	23.336
FLND	17.268	6.350	4.971	9.530	3.890	3.947	2.051	6.180	4.059	1.193
DOWPN	38.750	164.301	88.393	97.148	36.507	153.047	46.466	91.591	97.035	30.887
FLND	13.195	224.429	551.878	263.167	156.706	279.856	265.315	563.701	369.624	97.129
UFFER										

Table 25. Fish abundance at Borrow Pit stations compared with channel stations, by rank.

	LW08	LW10	LE11	MEAN	AN01	AN03	RB07	MEANS
DGF	15	19	18	20	24	13		23
KATE								
ATE			24	29.5	21.5			29
KATE			26.5	33	26			34
TURG		25.5		31.5				
EEL							25	36
EEL							23.5	34
ERRG	2	1	4	1	8	4	1	4
VIFE	3	2	1	2	1	1	4	1
SHAD	4	5	7	6	12	5	9	10
MENHD	19	18	24	21	5	11		7
HERRG	24	24	28.5	24		17		28
HERR								
SEF					18.5			26
HAKE	14	10	8	11	10	8	15	13
HAKE	17	11	15	13	11	23	13	16
HAKE	26	8	12	12	17		12	17
NETF								
ILVER	19	16	10	14	25	14		24
TICKL								
HORSE							23.5	34
EFISH	19		22	23			19	27
BBY		23	28.5	28	20		17	22

Table 25. Continued.

	LW08	LW10	LE11	MEAN	AN01	AN03	RB07	MEANS
ULP			24	29.5	21.5	24		25
ABS	25	20		26			10	14
NAP						20.5		32
ASS								
ISH	5	27	16	10			21.5	30.5
JCK		25.5		31.5				
OWN	8	13	21	15		18.5	16	21
CAD								
FISH	6	3	6	4	7	7	20	12	
	9	15	5	9	13	9	5	11
ULL								
RRAC	21.5	21.5		27			21.5	30.5
CKF	16	12	17	17	23	12	11	15
NER	21.5	21.5	13	19	15	16	14	18
GUNN								
SANDL			19	22	3	15		5
TERF	1	4	3	3	2	2	6	3
EARBN								
SEARB	12	14	14	16	16	18.5	3	8
FLND	23	28	26.5	25	14	22		19
KE	7	9	11	8	9	10	7	9
FLND	11	17	20	18	18.5	20.5	18	20
DOWPN	10	7	9	7	6	6	8	6
FLND	13	6	2	5	4	3	2	2
UFFER								

Table 26. Diversity parameters for Borrow Pit stations and for channel stations.

	LW08	LW10	LE11	MEAN	SE	AN01	AN03	RB07	MEAN	SE
PUE	4642.620	7535.248	3438.848	5205.572	1215.568	3601.902	1855.234	2076.057	2511.064	549.131
P	26.000	28.000	29.000	27.667	.882	26.000	24.000	25.000	25.000	.577
	1.772	1.710	2.065	1.849	.109	1.668	1.817	2.195	1.893	.157
D	4.027	3.549	4.982	4.186	.421	2.901	4.226	5.892	4.340	.865
	2.961	3.024	3.439	3.141	.150	3.053	3.056	3.142	3.218	.023
	.752	.718	.799	.756	.024	.655	.763	.830	.749	.051

abundant species as dominants, seven species are dominants on average in both the Pit and in the channel stations, they include the three river herrings, the flounders, fluke, windowpane and winterflounders, and butterfish. Weakfish and scup which are dominant in the Pits were also near dominants in the channels ranking twelfth and eleventh, respectively, Atlantic menhaden and striped searobin were ranked seventh and eight respectively in the channel average catches but these relatively high catches were due to large catches of juvenile menhaden at AN01 only and large catches of newly metanorphosed searobin during summer at RB07 only, otherwise the catches of these species were not high in the channels.

The different diversity parameters for the fish populations caught at the three channel stations, together with the values for the Pit stations are summarized in Table 26. There were twice as many fish caught on average in the Pit stations as in the channels, with about the same numbers of species. The different diversity indices were all very similar for both Pit and channel stations.

Conclusions from comparison with channel stations

The comparisons of catches between the Pit stations and the channel stations closest to them showed close similarities in species composition, dominance and diversity, although fish were about twice as abundant on average in the Pit. This similarity between the fish communities in the Borrow Pits and the communities at all of the channel stations is clearly demonstrated by the results of the classification and cluster analysis (Figures 9 and 10), in which all three Pit stations were included in group 2 together with all of the channel stations. (AN01, AN03, AS01, AS03, RB06, RB07, IR06, IR07) in the survey area.

Barcode in front

DUE DATE