ESTABLISHMENT OF OPERATIONAL GUIDELINES FOR TEXAS COASTAL ZONE MANAGEMENT

Interim Report on

BIOLOGICAL USES CRITERIA

Prepared by

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CHAPTER I

INTRODUCTION

The purpose of this interdisciplinary project is to formulate the criteria for coastal zone use and development. The portion assigned to our group is to develop Biological Use Criteria. Biological Use Criteria are defined here as the environmental quality which will permit natural communities of flora and fauna and the natural productivity of the Texas bays and estuaries, including their shoreline areas. Biological use then may be identified in terms of environmental quality where known inputs may cause changes in the natural balance of living systems. Such criteria are difficult to estimate or identify because of the diversity of communities and the continual natural variations in environmental conditions in our estuarine systems.

The runoff from land due to rainfall provides a continually varied input to the bay systems in proportion to area, chemistry, use of upland areas, as well as the circulation and mixing of the bays, which vary seasonally and with the occurrence of intense storms or periods of drought. Man has and will continue to change the physical and chemical configurations of estuarine environments as recreation and urban and industrial development have added to the demands on the water systems. Thus, it is immediately apparent that the current communities in our estuaries are those that have adapted to the constant long and short term cyclic changes.

The question then arises as to what baseline to use to establish biological use. We can use the relatively normal environments of parts of Corpus Christi Bay, the Laguna Madre and San Antonio Bay as baselines to compare with the highly developed Galveston Bay system. One can also compare the biological assemblages of Galveston Bay to see how they have changed with respect to man's input, and attempt to evaluate the current status with respect to the past.

Fortunately, as compared with other highly industrialized and urbanized areas such as the Hudson River estuary and Raritan Bay, our environment is generally still recreationally and esthetically sound. However, development is continuing at a rapid pace and some of our environments such as the coastal dunes are being exploited, which may endanger their protective role during storms. Other areas along the bays are being developed which will change the grass flats and other communities. However, at the same time that man is becoming more concerned with environmental change, there is a rapid movement of the population to the sea shore, bringing more rapid changes such as industrial complexes and the development of marinas and shoreline housing.

The procedure for the development of Coastal Zone Biological Use Criteria thus became quite clear. The biological parameters for community structure and water quality parameters must be identified with past changes, and a comparison of the more natural or undeveloped areas such as San Antonio Bay be made with developed areas such as Galveston Bay.

It was with this philosophy that the Biological Use Criteria program was established. This first year has been used to identify descriptive parameters. The second year will be used to relate these parameters to the development of values for the environment that can be used for the development of zoning and water quality criteria.

Acknowledgements

This first year's work was accomplished by a team of scientists and assistants who contributed to various apsects of the program. The Biotope descriptions were partially provided by Dr. Kennith Gordon who initiated the Biological Uses program as project coordinator. The artist's renditions were drawn by Marcia Kier. They were assisted by a large number of the scientific staff of the Marine Science Institute who provided continual guidance in the complex listing and renditions of the various environments. Dr. William Brogden provided the necessary input to implement the Environmental Data Management system, ENVIR. Dr. Joseph Ceck assisted by Barry Beitz, Michael Litwin, Richard Moore and Dinah Bowman created the life history data bank from a thorough literature search. Mrs. Dinah Bowman was responsible for the background of chemical criteria and comparison of the elements. Editing and overall attention to the details of the coordination of the project was provided by Dorothy Oppenheimer.

CHAPTER II

PROCEDURE AND SCOPE

This first year has been a challenge to regard the environment in a perspective that will allow for both communication between disparate academic fields and the evaluation of the extensive scientific literature available concerning discrete environmental parameters. Several concepts were established to identify and assess the natural parameters governing the biological assemblages of the coastal environment.

While many terms have been, and are being, used to describe the coastal environments, such as Coastal Zone, Wet Lands, Grassflats or Nursery Grounds, none of these have a well founded scientific definition such as is accorded ecological units such as the biomes or forest succession zones.

Thus the first accomplishment was to label the distinct assemblages of living organisms that exist in geographically distinct areas of the coastal bay and estuary systems of Texas. An old scientific term, BIOTOPE, was selected for coastal zone areas and 20 distinct zones such as the surf zone, shoreline dunes, salt water marshes, brackish water marshes and grassflats and oyster reefs, etc., were identified. The Biotopes, drawn in water colors by artist-naturalist Marcia Kier, accurately depict the major representative species of plants and animals and their geographic setting. A running description of the Biotopes was prepared by a team of biologists along with a list of species of organisms. An identifying overlay for each water color was added.
The first year Biotope preparation totaled 13 and the second year program will proceed to prepare the remaining seven Biotopes, for a total of 20.

Because of the variability of the environments of the Texas Coastal area it was assumed that the Biotope areas could undergo change during seasonal and yearly fluctuations of rainfall as well as due to man made changes. This required an additional description to show how change has occurred during the past. An historical account of the Aransas Pass area was developed to illustrate changes that had occurred during the past 100 years through search of old charts and published narratives. Such historical changes to the environment may thus shed some light on ecological changes.

Other environmental descriptions include a comprehensive inventory of life historyinformation concerning the organisms living in the bay and estuary systems. The fish were selected for the initial study and a life history inventory was established which related the presence of over two hundred species of fish to specific parts of the estuaries in terms of salinity, temperature, habitat and food preference.

The water was further identified by various chemical and physical parameters such as salinity, temperature, turbidity nutrients, primary productivity, etc. This information can then be used to evaluate the water quality with respect to the distribution of organisms present.

The results of the first year have been gratifying. The Biotope description lends itself to an accurate estimate of the extent of the various habitats and of the possible effects of changing habitats. It also allows for a description of changes that can be related to any part of the Texas estuary system and many other environments of the Gulf of Mexico. It is an accurate and adaptable biological description. The life history information allows the Biotope concept to be further impleted in terms of man's input, as compared to seasonal water quality changes. The physical-chemical evaluation provides a step further in the description of the total system.

While we are still in the initial stages of obtaining basic information for the various descriptions listed above, it becomes apparent that we can start to show the normal fluctuations within the bay systems and how the biological community responds. The chemical-physical criteria present today in the bays correlated with the Biotopes and life history information will allow a maxima and minima list to be prepared which we will call the preliminary BIOLOGICAL USE CRITERIA. Continually updated versions of this list will be used to quantitatively describe the quality of the coastal environment to aid decision makers. The Biotope information will tell immediately the changes that will occur to habitats when one Biotope is changed to another or eliminated.

Finally, in order to test our procedure, an environmental evaluation was outlined to show changes that might occur during the development of a deep water port at Harbor Island, Texas.

CHAPTER III

THE BIOTOPES OF THE TEXAS ESTUARY SYSTEM

The report "Biotopes of the Texas Coastal Zone: an Ecography" (Oppenheimer and Gordon, 1972) set forth a system of labeling environmental units in terms of both biotic and physical characteristics. Inherent in the definition of these units is the understanding that their utility will lie in assessing the biological impact of any proposed man-made change in the environment. This determination, it is hoped, will complement the physical assessments of any development made in terms of the Bureau of Economic Geology's Environmental Capability units (Fisher, et al., 1972).

An example of the application of the Biotope concept can be found in Chapter VI concerning a proposed development of the present facilities of Harbor Island into a deepwater port. For that section, pertinent Biotopes were delineated from aerial photography. Also included in Chapter VI are samples of the Biotope illustrations and key lists from the original report.

The Biotopes of Corpus Christi Bay were also identified and quantified in terms of their areal distribution. The enclosed map "Biotopes of Corpus Christi Bay" and Table III-1 are presented as a baseline for the areal quantification of the Biotopes in Corpus Christi, Nueces and Redfish Bays. Again, these measurements are intended to be of use in assessing the magnitude and results of proposed changes in terms of the biological parameters involved. Resource materials included aerial photography from NASA Manned Spacecraft Center Missions 84, 110 and 228, photomosaics belonging to the Bureau of Economic Geology, USGS maps of the Corpus Christi Bay area and oblique color aerial photographs taken in April 1973.

It is readily apparent from both the map and the table that the majority of the area of Corpus Christi Bay is covered by the Bay planktonic

Biotope. The other major entities are the Thalassia (grassflat), Spoil bank, Dune and barrier flat and Sand flat Biotopes.

While the sum of the areas covered by the Spartina (salt marsh) and Thalassia (grassflat) Biotopes are only about 40% as extensive as that of the Bay planktonic, they are both nearly twice as productive as the Bay planktonic (Odum & Odum, 1959, p. 72, 73). These energy relationships will be explored during the next year's efforts to define the quantities of organic matter produced.

Grateful thanks are extended to Drs. William Fisher and Robert Kier and Mr. Albert Erxleben of the Bureau of Economic Geology and Dr. Ralph Hunter of the Corpus Christi Office of the U.S.G.S. for their helpful advice and the use of their materials in the preparation of this map and to Ms. Judy Watson for her efforts in drafting it.

Table III - 1

BIOTOPE	ACRES	PERCENTAGE
Open beach	1,980	1.31
Dune and barrier flat	13,358	8.85
Spoil bank	13,327	8.83
Jetty and bulkhead	2,211	1.46
Oyster reef	760	0.50
Thalassia (Grass flat)	18,894	12.51
Spartina (Salt water marsh)	7,579	5.02
Juncus (Fresh water marsh)	411	0.27
Mudflat	604	0.40
Sandflat	7,348	4.87
Bluegreen algal flat	1,208	0.80
Hypersaline	3,033	2.01
Rivermouth	15,755	10.43
Bay planktonic	63,340	41.94
Channel	1,202	0.80
Sum	151,010	100.00

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U. S. Geological Survey 7½" Topographic Quadrangles for Texas: Aransas Pass, 1954; Corpus Christi, 1968; Crane Islands NW, 1968; Crane Islands SW, 1968; Estes, 1971; Oso Creek, 1968; Port Aransas, 1968; Port Ingleside, 1968; Portland, 1968.

CHAPTER IV

ENVIRONMENTAL DATA MANAGEMENT SYSTEM FOR ENVIRONMENTAL IDENTIFICATION

An environmental data management system called ENVIR has been developed by a team from the Gulf Universities Research Consortium. This system is being used to evaluate environmental parameters and aid in describing the living systems (Biotopes) of Corpus Christi Bay and related areas.

ENVIR is being used in this project for the development and management of three data banks. These banks consist of life history information, point measurements of biological, chemical and physical parameters, and commercial fish landings. Data sources are primarily published data and reports concerning the Corpus Christi Bay vicinity, with additional data from similar areas around the Gulf of Mexico. The following discussions will include descriptions of each data bank format, sample output and a discussion of the kind of problem or description that can be illuminated using each bank.

A. Life History Data Bank

The life history bank is being initially developed for fish species and includes such diverse information as species lists for entire bay systems, individual species reactions to salinity, temperature or toxic chemicals, distribution in Biotopes and economic significance, will be used to identify the populations relating to environmental parameters and changes.

Table IV A 1 is the format in which information is coded. The flexibility of the system is such that each data bank can be controlled by a specifically tailored set of instructions such as Table IV A 1. As can be seen, information concerning the environmental and temporal ranges of an organism can be coded, as well as its reactions to various parameters, its importance to man and its place in a community. Naturally, not all of these entries are made for every organism. It will be seen from the following illustrations that questions may be directed with reference to bay system, Biotope or particular environmental conditions. Presently, there are 2500 entries in this bank. The present inventory of species is about 200. Limited time and funds will not permit expansion of the information coded beyond the items listed in Table IV A 1.

Table IV A 2 is a portion of the reply to a request to print out trophic level, genus, species, common name, life stage, Biotope and reference for species occurring in the local bay systems. The punctuation of such queries is the agent which establishes the ordering of the responses. Table IV A 3 is a segment of the reply to a similar query asking for Biotope organisms found there, bay system and reference. Table IV A 4 shows the responses to salinity and temperature reported for the genus Paralichthys in the local bay systems.

Table IV A 5 addresses another aspect. It is the reply to a query to identify local, commercially important organisms with an upper temperature limit of between 30° and 32°C. Depending on temperature and location parameters, such an analysis could be of value in discussions of power plant siting in the Corpus Christi vicinity. Follow up analyses could include investigation of temperature requirements for organisms that are food items for other important organisms which are not shown to be affected by projected temperature changes. Table IV A 6 lists known food items for the organisms from Table IV A 5.

The Life History bank can be used as well in conjunction with the point measurement bank which will be discussed in Section IV B. Such a combination of data will be of use in the determination of water quality criteria.

B. Biological-Chemical-Physical Point Measurement Data Bank

The descriptors of the point measurement bank are designed to record individual measurements such as might be taken serially on a cruise or along a transect. Table IV B 1 shows the sequence of these descriptors. Physical and chemical sample data, as well as biota collected, can be entered. This bank will provide the investigator with the ability to pinpoint environmental parameters of any bay system. From such a data assembly, isopleths can be drawn for a parameter at a given time, or changes in a parameter at one location with respect to time can be graphed. Figure IV B 1 shows such a graph for nitrate data from Trinity Bay for the period 1968-1972 (Oppenheimer and Brogden) and Table IV B 2 gives pertinent statistics for nitrates and phosphorous found in both Galveston and Trinity Bays during that time.

Data from Corpus Christi Bay and adjacent waters is still being collected. Upon release from the Texas Water Development Board, this data, consisting of physical and chemical measurements and plankton and benthos samples will be coded into a bank similar to that already extant for Galveston Bay.

C. Commercial Landings Data Bank

Commercial catch data, reported by the National Marine Fisheries Service, has been entered into this bank. Table IV C 1 is the 1971 annual summary for the Corpus Christi Bay vicinity. In addition, monthly summaries by bay system and species are on hand. Table IV C 2 shows monthly catch information for 1967 for red drum in Corpus Christi Bay.

This data can be used to augment our understanding of seasonal abundance of the reported organisms in conjunction with the Life History bank. Also, it is hoped that this information will be of use to the economics part of the project.

Information from the data banks should provide baselines for evaluating environmental impacts. When interpreted in terms of the Biotopes, the results of proposed alterations can be forecast as changes from one Biotope to another. The coastal zone management decision makers can then evaluate part of the problems of any proposed activities in terms of such changes.

TABLE IV A 1

Descriptors for the Life History Data Bank

NUMBER	NAME	TYPE	EXAMPLE
*1	Class	Name	Chondrichthyes
*2	Family	"	Carcharinidae
*3	Genus	"	Carcharhinus
*4	Species	"	Leucas
5	Common Name	"	Bull Shark
*6	Life Stage	"	Adult
*7	Motility	"	Nektonic
8	Biotope	"	Open Bay
9	Bottom Type	"	Mud + Sand
10	Bay System	Name	Aransas Bay
11-22	Jan -- Dec	Name	"P" or "A" (for presence during month in specific Bay, Biotope, etc.)
23	Start Year	Order	1941
24	End Year	"	1942
25	Parameter	Name	Salinity
26	Units	"	0. PPT
27	Limit Type	Name	Lethal
28	Upper Limit	Order	10
29	Lower Limit	Order	400
30	Commercial	Name	Direct
31	Sports	"	Bait
32	Other Imp	"	Forage
33	Trophic Level	"	Omnivore
34	Diet Sig	"	Major
35	Food Item	Name	Anchoa
*36	Reference	Order	1
37	Ref Remark	Name	Catch Statistics
*38	Coded By	Name	Cech
*39	Batch	Order	1
*40	Sheet	Order	96

*These descriptors should be filled for each entry.

Table IV A 2

QUERY--SHOW: TROPHIC LEVEL, (GENUS, SPECIES, COMMON NAME), (LIFE STAGE, BIOTOPE, REFERENCE) FOR SPECIES WITH BAY SYSTEM ARANSAS OR ARANSAS BAY OR COPANO-ARANSAS OR COPANO BAY OR BAFFIN BAY OR BAFFIN-ALAZAN OR CORPUS CHRISTI PASS OR LAGUNA MADRE OR UPPER LAGUNA MADRE OR LYDIA ANN CHANNEL OR REDFISH BAY AND TROPHIC LEVEL, CARNIVORE AND NOT (BIOTOPE, UNKNOWN)*

REPLY--

CARNIVORE

ALBULA	VULPES	BONEFISH
LARVA	CHANNEL	41
ANCHOA	MITCHILLI	BAY ANCHOVY
LARVA	OPEN BAY	41
SPAWNING ADULT	OPEN BAY	41
CYNOSCION	NEBULOSUS	SPOTTED SEATROUT
ADULT	GRASS FLAT	1
ADULT	HYPERSALINE	3
ADULT	SYPERSALINE	4
ADULT	SHALLOW BAY	1
DASYATIS	AMERICANA	SOUTHERN STINGRAY
ADULT	OPEN BAY	1
DASYATIS	SABINA	ATLANTIC STINGRAY
ADULT	OPEN BAY	1
ELOPS	SAURUS	LADYFISH
NEKTONIC	OPEN BAY	1
GALEICHTHYS	FELIS	SEA CATFISH
ADULT	OPEN BAY	1
LEIOSTOMUS	XANTHURUS	SPOT
ADULT	SHALLOW BAY	1
JUVENILE	GRASS FLAT	1
JUVENILE	HYPERSALINE	7
JUVENILE	SHALLOW BAY	1
LOBOTES	SURINAMENSIS	TRIPLETAIL
ADULT	OPEN BAY	1
MENTICIRRHUS	AMERICANUS	SOUTHERN KINGFISH
ADULT	SHALLOW BAY	1
PARALICHTHYS	LETHOSTIGMA	SOUTHERN FLOUNDER
JUV + ADULT	OPEN BAY	1
JUV + ADULT	SHALLOW BAY	1
POGONIAS	CROMIS	BLACK DRUM
ADULT	GRASS FLAT	1
ADULT	SHALLOW BAY	1
SCIAENOPS	OCELLATA	RED DRUM
ADULT	GRASS FLAT	1
ADULT	SHALLOW BAY	1
JUVENILE	GRASS FLAT	1
JUVENILE	SHALLOW BAY	1
SPHYRNA	TIBURO	BONNETHEAD
JUVENILE	OPEN BAY	41

Table IV A 3

QUERY--SHOW: BIOTOPE, (GENUS, SPECIES, COMMON NAME, LIFE STAGE, BAY SYSTEM, REFERENCE) FOR SPECIES WITH BIOTOPE, GRASSFLAT AND BAY SYSTEM, ARANSAS BAY OR COPANO BAY OR COPANO-ARANSAS OR LAGUNA MADRE OR REDFISH BAY*

REPLY--

GRASS FLAT

CALLINECTES	SAPIDUS	BLUE CRAB	JUV + ADULT	REDFISH BAY	39
CYNOSCION	NEBULOSUS	SPOTTED SEATROUT	ADULT	COPANO-ARANSAS	1
CYNOSCION	NEBULOSUS	SPOTTED SEATROUT	JUVENILE	LAGUNA MADRE	8
CYNOSCION	NEBULOSUS	SPOTTED SEATROUT	JUVENILE	REDFISH BAY	36
CYPRINODON	VARIEGATUS	SHEEPSHEAD MINNOW	JUV + ADULT	REDFISH BAY	36
CYPRINODON	VARIEGATUS	SHEEPSHEAD MINNOW	JUV + ADULT	REDFISH BAY	39
FUNDULUS	SIMILIS	LONGNOSE KILLIFISH	JUV + ADULT	REDFISH BAY	36
GALEICHTHYS	FELIS	SEA CATFISH	JUV + ADULT	REDFISH BAY	36
GERRES	CINEREUS	YELLOWFIN MOJARRA	JUV + ADULT	REDFISH BAY	36
GOBIOSOMA	BOSCI	NAKED GOBY	JUV + ADULT	ARANSAS BAY	1
GOBIOSOMA	BOSCI	NAKED GOBY	JUV + ADULT	COPANO BAY	1
GOBIOSOMA	ROBUSTUM	CODE GOBY	JUV + ADULT	REDFISH BAY	39
HYPORHAMPHUS	UNIFASCIATUS	HALFBEAK	JUV + ADULT	REDFISH BAY	36
LAGODON	RHOMBOIDES	PINFISH	JUVENILE	REDFISH BAY	36
LAGODON	RHOMBOIDES	PINFISH	JUV + ADULT	REDFISH BAY	39
LEIOSTOMUS	XANTHURUS	SPOT	JUVENILE	COPANO-ARANSAS	1
LEIOSTOMUS	XANTHURUS	SPOT	JUVENILE	REDFISH BAY	36
LEIOSTOMUS	XANTHURUS	SPOT	JUV + ADULT	REDFISH BAY	39
LUCANIA	PARVA	RAINWATER KILLIFISH	JUV + ADULT	REDFISH BAY	39
MENIDIA	BERYLLINA	TIDEWATER SILVERSIDE	JUV + ADULT	REDFISH BAY	36
MENIDIA	BERYLLINA	TIDEWATER SILVERSIDE	JUV + ADULT	REDFISH BAY	39
MICROPOGON	UNDULATUS	ATLANTIC CROAKER	JUVENILE	REDFISH BAY	36
MUGIL	CEPHALUS	STRIPED MULLET	JUV + ADULT	REDFISH BAY	28
MUGIL	CEPHALUS	STRIPED MULLET	JUV + ADULT	REDFISH BAY	36
MUGIL	CUREMA	WHITE MULLET	JUV + ADULT	REDFISH BAY	28
NEOPANOPE	TEXANA	MUD CRAB	---	REDFISH BAY	39
OPSANUS	BETA	GULF TOADFISH	JUV + ADULT	REDFISH BAY	36
ORIHOPRISTIS	CHYRSOPTERA	PIGFISH	JUVENILE	REDFISH BAY	36
PALAEMONETES	PUGIO	GRASS SHRIMP	JUV + ADULT	REDFISH BAY	39
PARALICHTHYS	LETHOSTIGMA	SOUTHERN FLOUNDER	JUV + ADULT	REDFISH BAY	36
PENAEUS	DUORARUM	PINK SHRIMP	JUV + ADULT	REDFISH BAY	39
POGONIAS	CROMIS	BLACK DRUM	ADULT	COPANO-ARANSAS	1
POGONIAS	CROMIS	BLACK DRUM	JUVENILE	REDFISH BAY	36

Table IV A 4

QUERY--SHOW: (GENUS, SPECIES, COMMON NAME), (BAY SYSTEM, REFERENCE), (PARAMETER, LIMIT TYPE, LOWER LIMIT, UPPER LIMIT, UNITS) FOR SPECIES WITH GENUS. PARALICHTHYS AND PARAMETER, SALINITY OR TEMP AND BAY SYSTEM, ARANSAS BAY OR COPANO BAY OR UPPER LAGUNA MADRE*

REPLY--

PARALICHTHYS ALBIGUTTA		GULF FLOUNDER				
ARANSAS BAY	1					
SALINITY		OCCURRENCE	96	352	0.1 PPT	
SALINITY		PREFERENCE	250	---	0.1 PPT	
TEMP		OCCURRENCE	154	303	0.1C	
UPPER LAGUNA MADRE	51					
SALINITY		OCCURRENCE	200	600	0.1 PPT	
SALINITY		OPTIMUM	---	450	0.1 PPT	
PARALICHTHYS LETHOSTIGMA		SOUTHERN FLOUNDER				
ARANSAS BAY	1					
SALINITY		OCCURRENCE	20	362	0.1 PPT	
SALINITY		OCCURRENCE	196	300	0.1 PPT	
SALINITY		PREFERENCE	---	250	0.1 PPT	
TEMP		OCCURRENCE	99	305	0.1C	
TEMP		OCCURRENCE	145	216	0.1C	
COPANO BAY	1					
SALINITY		OCCURRENCE	20	362	0.1 PPT	
SALINITY		PREFERENCE	---	250	0.1 PPT	
TEMP		OCCURRENCE	99	305	0.1C	
UPPER LAGUNA MADRE	51					
SALINITY		OCCURRENCE	200	600	0.1 PPT	
SALINITY		OPTIMUM	---	450	0.1 PPT	

Table IV A 5

QUERY--SHOW: (GENUS, SPECIES), (LIMIT TYPE, UPPER LIMIT, UNITS, BIOTOPE, BAY SYSTEM) FOR SPECIES WITH COMMERCIAL, DIRECT OR DIRECT + INDIRECT AND PARAMETER, TEMP AND UPPER LIMIT, FROM 3ØØ TO 32Ø AND BAY SYSTEM, ARANSAS BAY OR ARANSAS OR COPANO BAY OR COPANO-ARANSAS*

REPLY--

MENTICIRRHUS	AMERICANUS			
OCCURRENCE	3Ø5	Ø.1 C	SHALLOW BAY	ARANSAS BAY
PARALICHTHYS	LETHOSTIGMA			
OCCURRENCE	3Ø5	Ø.1 C	OPEN BAY	ARANSAS BAY
OCCURRENCE	3Ø5	Ø.1 C	SHALLOW BAY	ARANSAS BAY
OCCURRENCE	3Ø5	Ø.1 C	SHALLOW BAY	COPANO BAY
POGONIAS	CROMIS			
OCCURRENCE	3Ø7	Ø.1 C	GRASS FLAT	COPANO-ARANSAS
OCCURRENCE	3Ø7	Ø.1 C	SHALLOW BAY	COPANO-ARANSAS
SCIAENOPS	OCELLATA			
OCCURRENCE	32Ø	Ø.1 C	GRASS FLAT	COPANO-ARANSAS
OCCURRENCE	32Ø	Ø.1 C	SHALLOW BAY	COPANO-ARANSAS

Table IV A 6

QUERY--SHOW: (FOOD ITEM, DIET SIG, GENUS) FOR SPECIES WITH GENUS, MENTICIRRHUS OR PARALICHTHYS OR POGONIAS OR SCIAENOPS AND NOT (DIET SIG, UNKNOWN)*

REPLY--

AMPHIPODS	MAJOR	POGONIAS
ANCHOA	MAJOR	PARALICHTHYS
ANOMALOCARDIA	MAJOR	POGONIAS
CALLINECTES	MAJOR	SCIAENOPS
CRABS	MAJOR	PARALICHTHYS
CRUSTACEANS	MAJOR	POGONIAS
FISH	MAJOR	PARALICHTHYS
FISH	MINOR	SCIAENOPS
GOBIOSOMA	MAJOR	POGONIAS
MICROPOGON	MAJOR	PARALICHTHYS
MOLLUSCANS	MAJOR	POGONIAS
MUD CRABS	MAJOR	SCIAENOPS
MUD CRABS	MINOR	POGONIAS
RANGIA	MAJOR	PARALICHTHYS
RANGIA	MAJOR	POGONIAS
RAZOR CLAMS	MAJOR	MENTICIRRHUS

TABLE IV B 1

Descriptors for the Biological-Chemical-Physical Point Measurement Data Bank

NUMBER	NAME	TYPE
1	Station	Name
2	Line	Order
3	Site	"
*4	Year	"
*5	Month	"
*6	Day	"
*7	Time	"
8	Depth	Order
9	Agency	Name
10	Cruise	"
*11	Parameter	"
*12	Units	Name
*13	Value	Order
14	Phase	Name
15	Comments	"
16	Method	Name
17	Haul Time	Order
18	Genus	Name
19	Species	"
20	Common Name	"
21	Life Stage	Name
*22	Latitude	Order
*23	Longitude	"
*24	Batch	"
*25	Sheet	Order

*Required entries

Table IV B 2

Nitrate and total Phosphorous values for the Galveston Bay System, 1968-1972.
(Oppenheimer and Brogden)

	Nitrate, ppm.			Phosphorous, ppm.		
	Min.	Max.	Mean	Min.	Max.	Mean
Trinity Bay	0	1.9	.28	0	2.0	0.49
Galveston Bay	0	7.8	.18	0	4.2	0.55
East Bay	0	0.4	.11	0	0.9	0.27
West Bay	0	0.8	.11	0	1.7	0.18

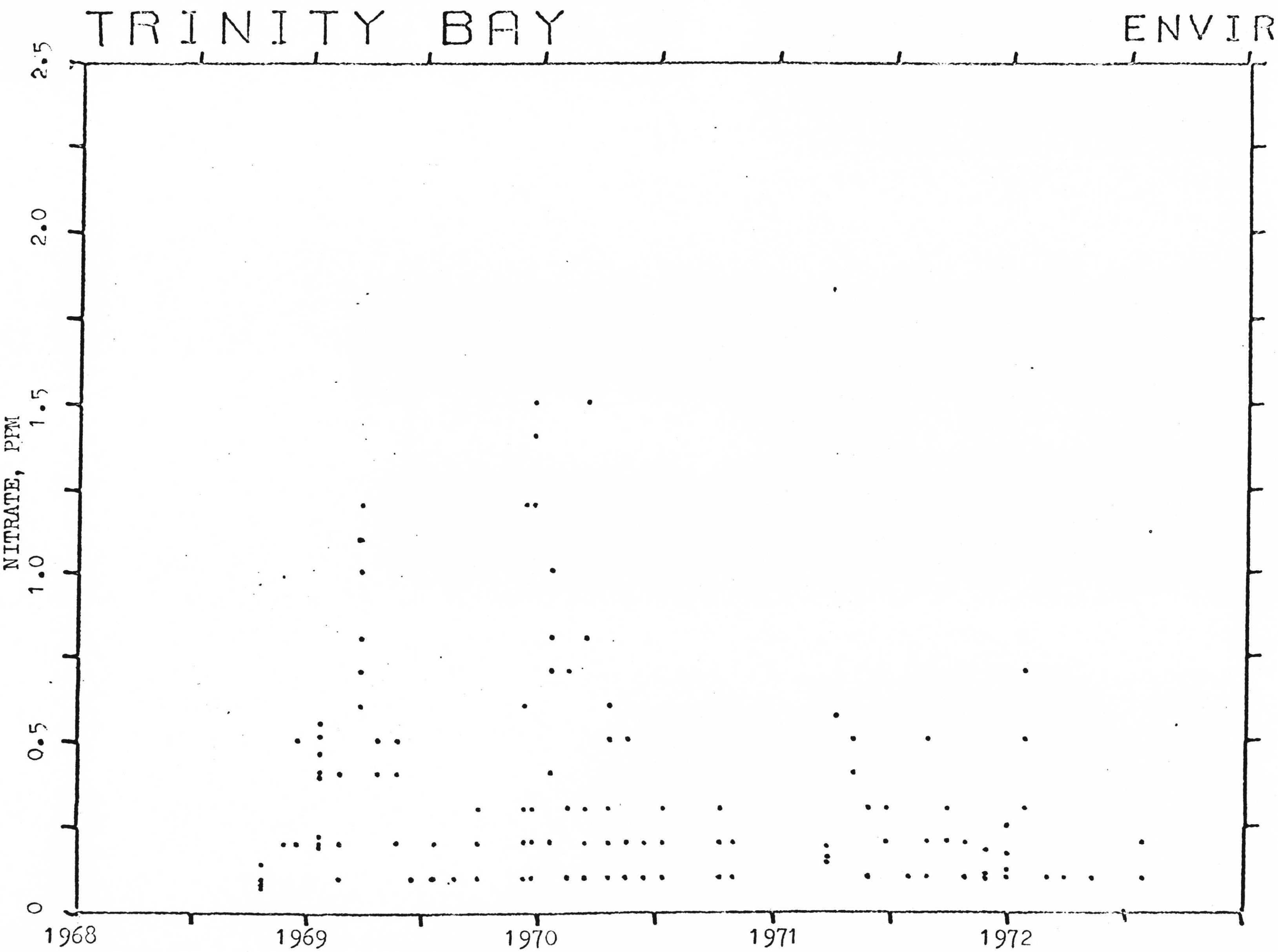

FIGURE IV B 1. SURFACE NITRATE CONCENTRATIONS, TRINITY BAY, TEXAS, 1968-1972.

TABLE IV C 1

1971 Annual Summary of Commercial Catches by Bay System and Species for the Corpus Christi Vicinity[1]

SPECIES	CORPUS CHRISTI AND NUECES BAYS		BAFFIN BAY AND UPPER LAGUNA MADRE		ARANSAS AND COPANO BAYS	
FISH	POUNDS	DOLLARS	POUNDS	DOLLARS	POUNDS	DOLLARS
CROAKER	2,600	143	7,100	344	1,000	57
DRUM:						
BLACK	63,100	6,189	547,900	55,811	114,000	11,737
RED (REDFISH)	72,600	17,342	545,400	139,241	222,200	52,247
FLOUNDERS	5,300	1,316	18,100	4,987	32,700	7,999
MULLET	5,000	202	4,700	235	31,600	1,347
SEA CATFISH	900	82	400	41	3,400	412
SEA TROUT, SPOTTED	42,400	10,157	377,500	94,078	181,000	43,800
SHEEPHEAD	6,900	477	33,600	1,925	23,800	1,601
UNCLASSIFIED:						
FOR FOOD	-	-	-	-	-	-
FOR BAIT, REDUCTION AND ANIMAL FOOD	17,500	677	-	-	16,400	656
TOTAL FISH	216,300	36,585	1,534,700	296,662	626,100	119,856
SHELLFISH, ET AL.						
CRABS, BLUE	100,500	10,049	200	24	591,800	58,116
OYSTER MEATS	-	-	-	-	30,000	12,925
SHRIMP (HEADS-ON):						
BROWN AND PINK	19,300	3,945	-	-	78,900	14,987
WHITE	84,100	59,607	-	-	343,800	232,292
TOTAL SHELLFISH	203,900	73,601	200	24	1,044,500	318,320
GRAND TOTAL	420,400	110,259	1,535,700	297,060	1,670,600	438,176

[1]National Marine Fisheries Service Data.

Table IV C 2

Monthly catch statistics for 1967 for red drum (common name coded 1082) from Corpus Christi Bay (bay system coded 0201). Data from National Marine Fisheries Service annual summaries.

QUERY--SHOW: YR, (MO, POUNDS, VALUE, COUNTY) FOR SP WITH BAY SYSTEM, Ø2Ø1 AND YR, 1967 AND COMMON NAME, 1Ø82* [1]

REPLY--1967

1	1Ø	26	6Ø
2	4	12	6Ø
4	96	259	1Ø
5	12	36	6Ø
6	Ø	2	6Ø
6	22	55	8Ø
7	124	31Ø	8Ø
8	3	11	13Ø
8	43	1Ø7	8Ø
9	12	37	13Ø
9	2Ø	5Ø	12Ø
9	35	87	8Ø
11	291	583	4Ø
12	1Ø	26	13Ø
12	2ØØ	5ØØ	4Ø

[1] National Marine Fisheries Service Data.

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Oppenheimer, C. H. Jr., and W. B. Brogden. 1973. Galveston Bay Toxicity Studies. In preparation.

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CHAPTER V

WATER QUALITY CRITERIA

The first year's scope was to derive the background and techniques to develop a series of water quality criteria to supplement those published in 1967 by the Texas Water Quality Board (TWQB, 1967) and in 1968 by the Federal Water Pollution Control Administration (FWPCA, 1968). These criteria were to augment previous standards by presenting upper and lower limits for materials released into the Corpus Christi estuarine area that are omitted in more general standards. In addition, these criteria were to be expressed with reference to the salinity of the receiving waters; fresh-brackish, marine and hypersaline levels. Table V 1 derived from a wide source of literature provides an example of guidelines for water quality. This should be considered only a research list relating to the characteristics of Texas Bay System which will be modified and upgraded next year.

Development of water quality criteria has been continuously confused by the discovery of naturally occurring concentrations of materials exceeding those specified. To put such differences in perspective, Table VI 1 has been constructed to show, from the literature, the general comparison of elements in natural systems. From such data, realistic values can be approached in developing criteria for marine environments. In addition, local data for physical-chemical content of various estuaries is being compiled in ENVIR to monitor background levels. In this way, supplementary information concerning both biological reactions to specific chemical substances and ambient concentrations of these substances will become available through the ENVIR data banks.

Table IV A 5 shows an example from the life history bank and Figure IV B 1, an example from the point measurement bank.

Table V 2 is a summary of a preliminary calculation of residence time for total organic carbon in Corpus Christi Bay. Presently, the major source of organic carbon in the bay is from primary productivity, with about one percent from runoff and municipal and industrial sources. These calculations assume a homogenous mixing throughout the bay which is probably not the case. Realistic considerations should include local concentrations of effluent materials in such areas as the Ship Channel and along La Quinta Channel. This information is the first step in assessing the energy transferred through each Biotope, which is one of the goals for year two.

Figure V 1 illustrates the annual fluctuation of water temperature at Port Aransas, Texas taken from the Marine Science Institute pier. Surface water temperatures were monitored continuously from 1967 to 1970 in the Aransas Pass. Annual ranges averaged 35°F; monthly ranges, 12°F; and daily, 4°F (E.W. Behrens, unpublished data). The annual range was approximately 40°F to 75°F.

TABLE V 1

BIOLOGICAL USE CRITERIA

	Threshold Limits in H_2O* (May be integrated with dilution in specific cases)
Salinity	± 10% of maximum and minimum over 5 year avg.
Sulfates	10% above maximum average for 5 years
Dissolved Solids	± 10% of maximum and minimum over 5 year avg.
BOD-organic carbon	Not to exceed 10% over grass primary productivity as related to specific area on a monthly basis.
NO_3^-	Maximum average values for bay or region area as measured in past years
NO_2^-	
NH_4^+	
O_2	Minimum 40% saturation.
pH	6.5 - 8.5 for salinities >15 ppt, 5.5 - 10.5 for salinities <15 ppt
Coliforms	10,000/100ml
Temperature	4^o - September-May; 1.5^o - June-August. Maximum above daytime high temp as averaged from area of input.
Toxicants	(See specific compounds)
Solids & Turbidity	5000 mg/l and 24 hr settling rate to 16 Jackson Units
Radio nuclides:	
Strontium	10 pc/l
Gross Beta	1000 pc/l
Radium	3 pc/l
Color	No restriction except due to chemical composition
Taste & Odor	Organoleptical absent *in situ*
Acids & Alkalies	See pH
Phenols	1.0 mg/l - except in areas with normal high polyphenols, then at maximum observed values
Alkyl-Aryl Sulfonates	1.0 mg/l
Pesticide**	10 µg/l
Oil	No visible sheen
Detergents, cationic	1 µg/l
Organic Mercurial**	1 mg/l
Cyanide	.02 mg/l
H_2S	.50 mg/l

*At this time no allowance is made for zones of higher output near effluent. Values are given for environmental water content.

**To be individually treated at a later date.

Biological Use Criteria (Cont.)

Trace Elements:#

	mg/l*	mg/l**
Mercury	.00003	.01
Copper	.003	.01
Lead	.00003	.05
Nickel	.0054	.05
Zinc	.01	5.00
Chromium	.00005	1.00
Cadmium	.08	.10
Arsenic	.003	1.00
Silver	.0003	.01
Vanadium	.002	1.00
Fluorine	1.30	10.00
Manganese	.002	.10
Cobalt	.0005	.01
Beryllium	.0000006	.001
Selenium	.004	.01
Yttrium	.0003	.01
Antimony	.0005	.01
Boron	4.60	10.00

*mg/l - normal oceanic seawater
**mg/l - upper threshold limits

#Evidence is accumulating that in seawater - estuarine environments that free ions or for some organic metallic compounds are the predominating toxic agent and are rapidly chelated or adsorbed.

Table V 2

SAMPLE CALCULATION OF RESIDENCE TIME FOR ORGANIC CARBON IN CORPUS CHRISTI BAY

DAILY AVERAGE TOC INPUT[1]	1.38×10^3 lb C/day
DAILY AVERAGE PRODUCTIVITY[2]	2.45×10^6 lb C/day
STANDING CROP[3]	1.95×10^7 lb C

$$\text{RESIDENCE TIME} = \frac{\text{STANDING CROP}}{\text{INPUT + PRODUCTIVITY}}$$

$$\text{RESIDENCE TIME} = \frac{1.95 \times 10^7 \text{ lb}}{2.49 \times 10^6 \text{ lb/day}} = 7.83 \text{ days}$$

1. J. S. SHERMAN, PERSONAL COMMUNICATIONS
2. ODUM, 1959.
3. MAURER, 1971; REIMERS, 1968; WILSON, 1963

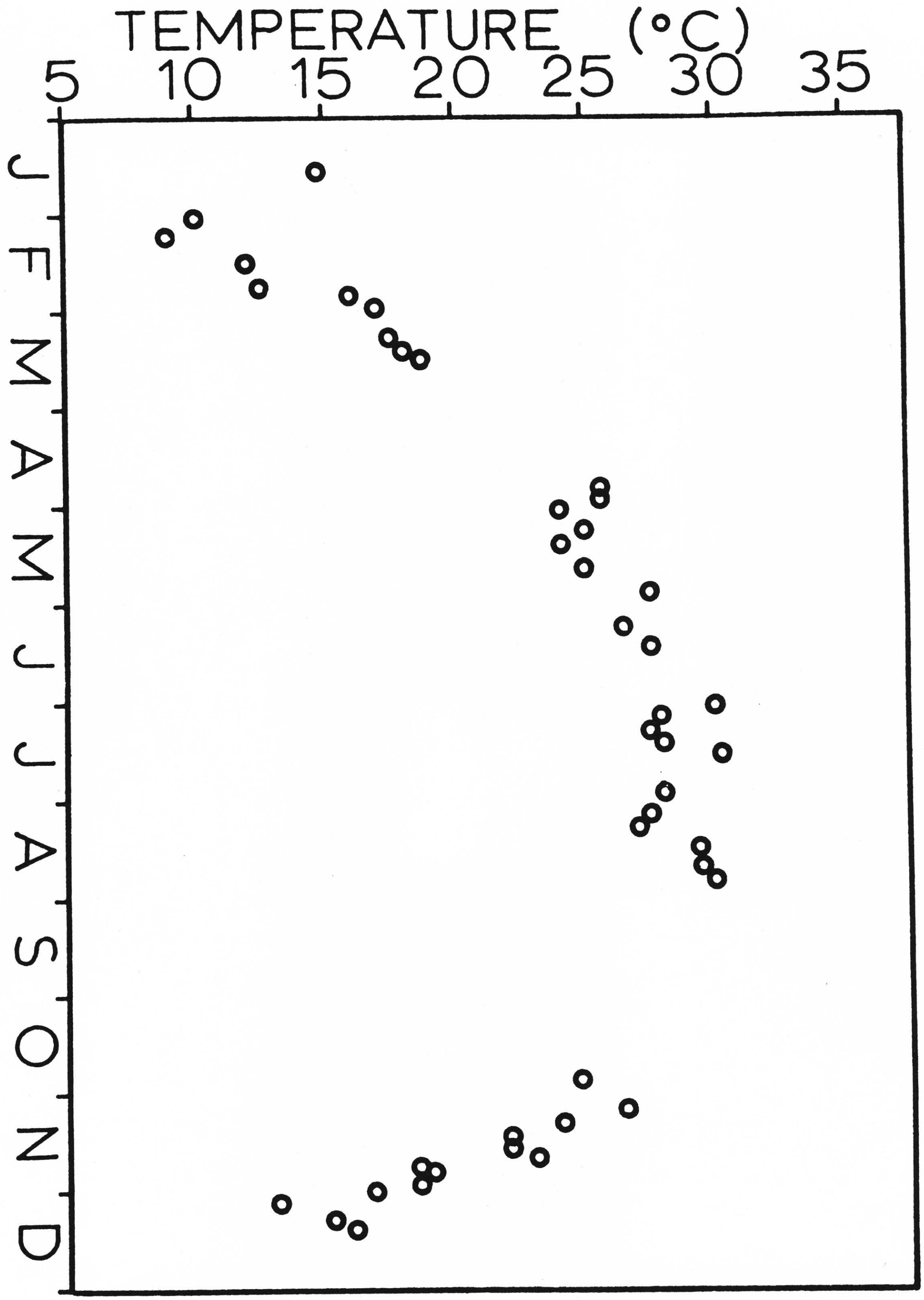

Figure V 1

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CHAPTER VI

APPLICATION OF BIOLOGICAL USE CRITERIA TO BAY AND ESTUARINE MANAGEMENT AND USE

If we assume that esthetic and biological environmental aspects will be the guiding constraints to the eventual development of our bays and estuaries, then the identification of effects of change to natural communities may control economic considerations and urban, industrial and recreational development.

Thus it appears that the identification of Biological Use Criteria in conjunction with Land Use Criteria will provide the guidelines for economic or waste disposal criteria. Once the scope of development is identified then input into the bays by man's activities may be considered. The location and development of urban and industrial complexes can be identified in terms of land or estuarine change. Modification of the land or water systems for transportation, raw materials for industry, cooling water, etc. in turn can be regulated by understanding their impact on the system in terms of land or bay modification or esthetic or biological change.

The following application of the Biotopes, Life History information and water quality criteria as applied to a proposed development of a deep water port at Harbor Island, Texas may serve as an example of the integration of this project with the other projects of the interdisciplinary program.

To show the changes that have been imposed on the environment during man's past activities, we have made a historical survey of environmental changes as documented in the literature and in the archives of the Corps of Engineers and NOAA. A thorough search was made and extracts prepared to show the sequence of man's development and their expected environmental changes to the Corpus Christi Bay environment and especially to the Port Aransas area of Harbor Island.

After the historical inventory was made, we approached the harbor development in terms of the environmental matrix outlined on the first report of the interdisciplinary team titled "A Conceptual Report on the Management of Bays and Estuaries" referenced in this report. The Biotope concept, life history data and water quality data were applied to the problem of environmental change due to harbor development. Water quality criteria were evaluated in the matrix as a result of the information in the various ENVIR data systems banks. The result is a comprehensive summary evaluation of the impact of the development on the ecology of the area.

The following is divided into two parts: (1) the historical environmental changes, and (2) the ecological impact of the Harbor development.

THE DEVELOPMENT OF HARBOR ISLAND

Historical Changes and Status of Its Environmental Surroundings

Harbor Island (Fig. 3) is located in the semi-arid environment of the South Texas Coast. It is opposite an inlet through the barrier island that separates Corpus Christi and Aransas Bays from the Gulf of Mexico. Harbor Island is typical of the inlet deltas which form as a result of river and tidal water flows between the lagoons and the Gulf of Mexico. The tides have usually one cycle in 24 hrs and an average amplitude of one ft. Due to the relatively low river flow and the small tidal amplitude, the inlet delta is extensive and has a low profile above the mean sea level. The sediments ranging from silt to shell are stabilized by plants and marine grasses. Periodic high intensity storms and accompanying high tides have continually changed the shape and form of the delta.

The historical development of the barrier islands of the Texas Coast has been described by Price (1947), Castanares and Phleger (1969), the U.S. Department of the Interior (1954), Ippen (1966) and Zenkovich (1967). It is generally concluded that these barrier islands are a result of the lowering of the sea-level between 5,000 and 9,000 years ago. During the evolution of the barrier islands and their lagoons, inlet deltas such as Harbor Island were formed.

Harbor Island is first shown in the 1833 chart (Fig. 4) by Captain Monroe of the ship Amos Wright (Kennedy, 1841), who named the area Curlew Island. This area, as shown by early charts, was probably similar to the present area to the northeast of the old lighthouse with Spartina grass flats and mangroves covered by water during high tides, and cut by numerous tidal channels. The first U.S. chart, in 1851 (Fig. 5), was the result of a survey made to position a lighthouse and shows the extent of the deltaic flats. Figure 6, chart of 1875 shows the lighthouse in place and channel depths. The chart of 1884 (Fig. 7) shows the early general morphology of the area. These charts indicate that the area of the present day Corpus Christi Ship Channel in the vicinity of west Harbor Island, was then a tidal mudflat with oyster reefs on the northern side of what was later to be called Turtle Cove. This shallow mud flat was undoubtedly deepened by periodic storms to increase flow between the pass and Corpus Christi Bay. However, this area was not deep enough for continual small boat passage. Early records, as far back as the Spanish colonization of 1520 (Walton, 1949), indicate that the route to the Nueces River for ships was across the Aransas Pass Bar to Aransas Bay and then southwestward through Corpus Christi Bayou and Redfish Bay to Corpus Christi Bay. This route was enhanced by the Morris and Cummings Cut through Redfish Bay in the 1860's, which allowed continuous shipping by vessels of approximately 6 foot draft. In addition, because of the predominately southeasterly winds, this route was favorable for sailing. This route was used until 1908 (Fig. 8), after which the Corpus Christi Ship Channel was cut through Turtle Cove to a depth of 8½ feet (Fig. 9, 1913).

As the area adjacent to the Aransas Pass developed, the need of water transportation resulted in the stepwise development of the facilities

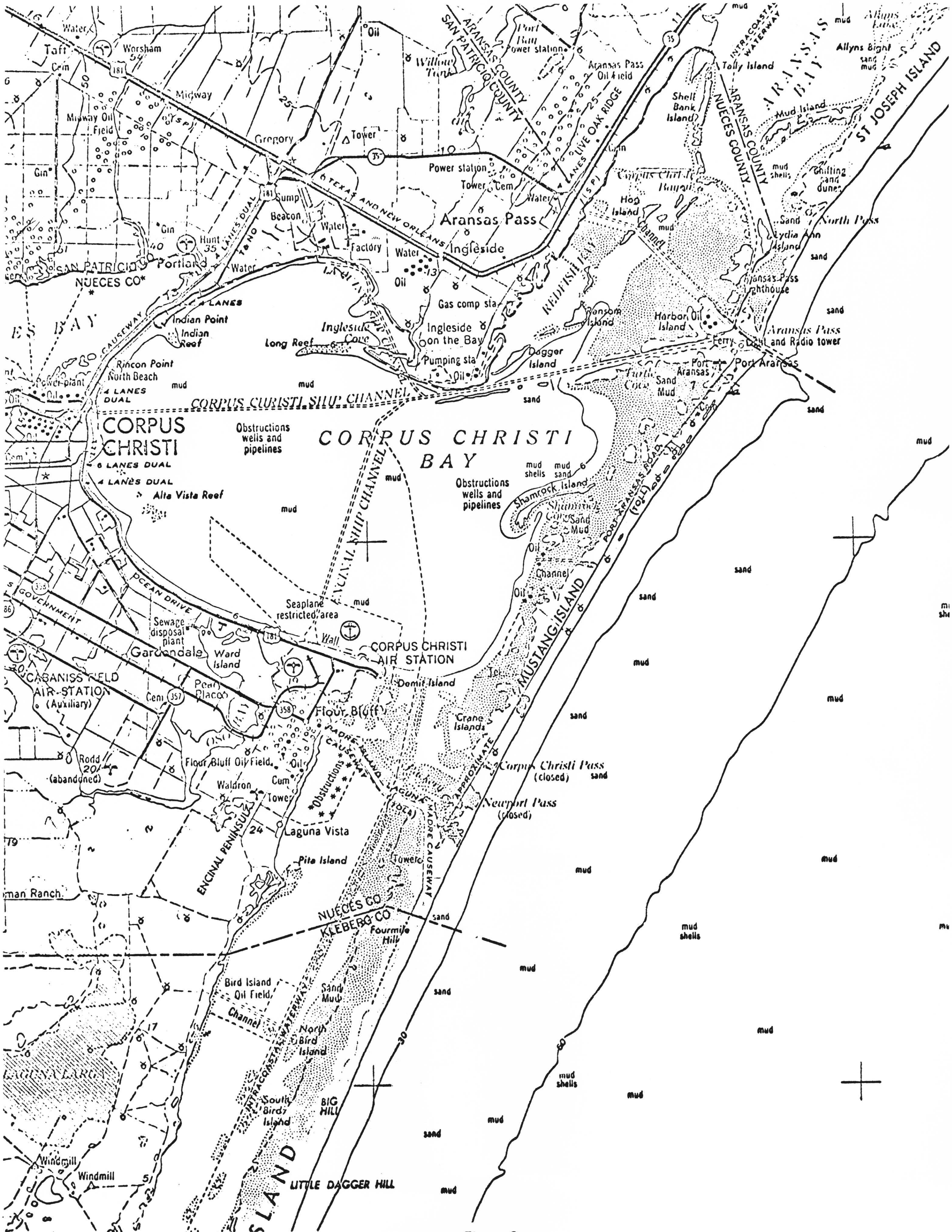

Taft
Worsham
Midway
Midway Oil Field
Gregory
Tower
Power station
Aransas Pass
Ingleside
Portland
SAN PATRICIO
NUECES CO
Indian Point
Indian Reef
Rincon Point
North Beach
Ingleside Cove
Long Reef
Ingleside on the Bay
Pumping sta
Gas comp sta
SAN PATRICIO COUNTY
ARANSAS COUNTY
NUECES COUNTY
Aransas Pass Oil Field
LIVE OAK RIDGE
INTRACOASTAL WATERWAY
Tally Island
Shell Bank Island
Allyns Bight
Mud Island
ARANSAS BAY
ST JOSEPH ISLAND
Shifting sand dunes
North Pass
Lydia Ann Island
Aransas Pass Lighthouse
Hog Island
Channel
REDFISH BAY
Ransom Island
Harbor Island
Dagger Island
Turtle Cove
Port Aransas
Aransas Pass
Coast Guard and Radio tower
CORPUS CHRISTI SHIP CHANNEL
CORPUS CHRISTI
Obstructions wells and pipelines
CORPUS CHRISTI BAY
6 LANES DUAL
4 LANES DUAL
Alta Vista Reef
Shamrock Island
Shamrock Cove
PORT ARANSAS ROAD
ENCINAL SHIP CHANNEL
OCEAN DRIVE
Seaplane restricted area
Wall
CORPUS CHRISTI AIR STATION
Sewage disposal plant
Gardendale
Ward Island
CABANISS FIELD AIR STATION (Auxiliary)
Pearl Placo
Flour Bluff
Flour Bluff Oil Field
Rodd (abandoned)
Waldron
Tower
Obstructions
Laguna Vista
Pita Island
ENCINAL PENINSULA
PADRE ISLAND CAUSEWAY
LAGUNA MADRE CAUSEWAY
MUSTANG ISLAND
Domit Island
Crane Islands
APPROXIMATE
Corpus Christi Pass (closed)
Newport Pass (closed)
NUECES CO
KLEBERG CO
Fourmile Hill
Bird Island Oil Field
North Bird Island
South Bird Island
BIG HILL
INTRACOASTAL WATERWAY
LITTLE DAGGER HILL
LAGUNA LARGA
Windmill
man Ranch
sand
mud
mud shells

Figure 3

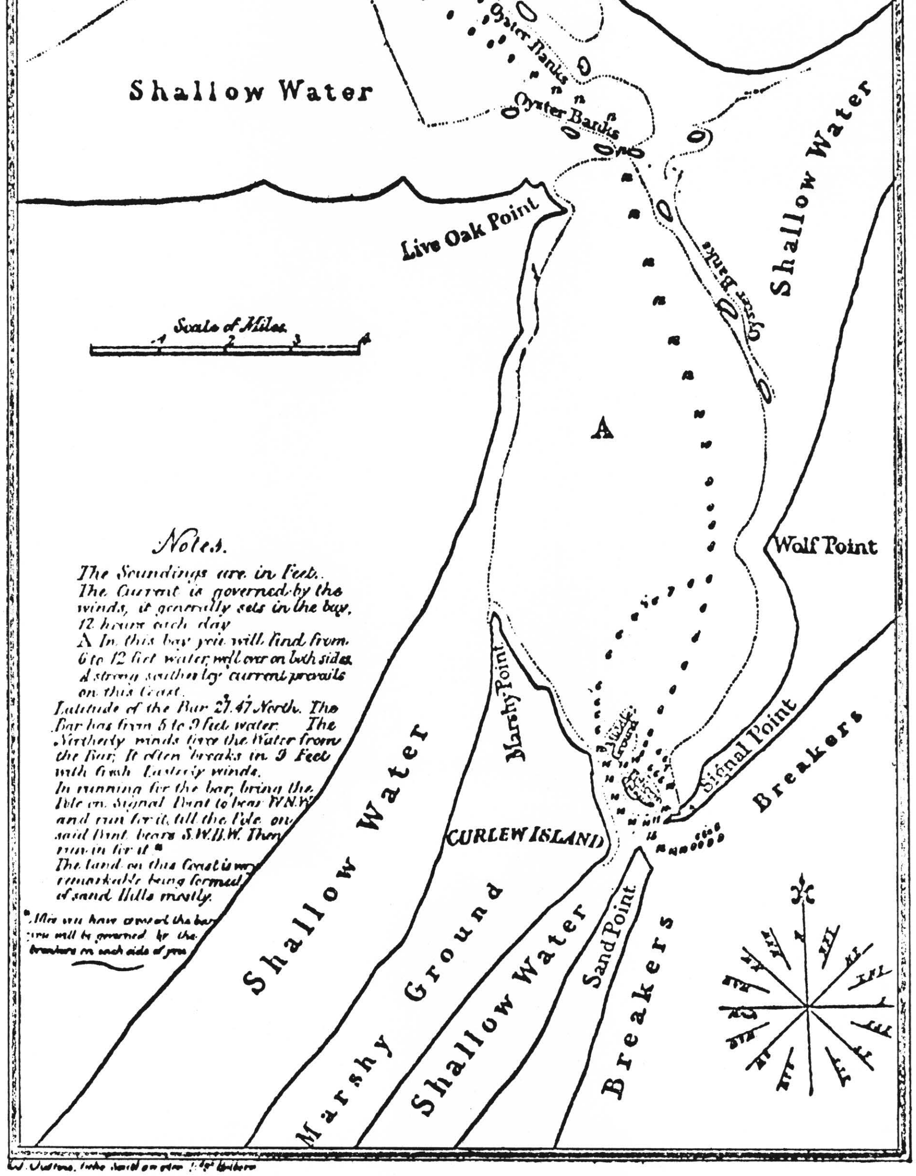

ARANZAS BAY,
as Surveyed by
Captn. Montee
of the "Amos Wright"
Copano Landing
Lagoon
Shallow Water
Oyster Banks
Oyster Banks
Live Oak Point
Shallow Water
Oyster Banks
Scale of Miles
1 2 3 4
A
Notes.
The Soundings are in Feet.
The Current is governed by the winds, it generally sets in the bay, 12 hours each day
Latitude of the Bar 27.47 North.
Wolf Point
Marshy Point
Signal Point
Breakers
CURLEW ISLAND
Shallow Water
Marshy Ground
Shallow Water
Sand Point
Breakers

Figure 4

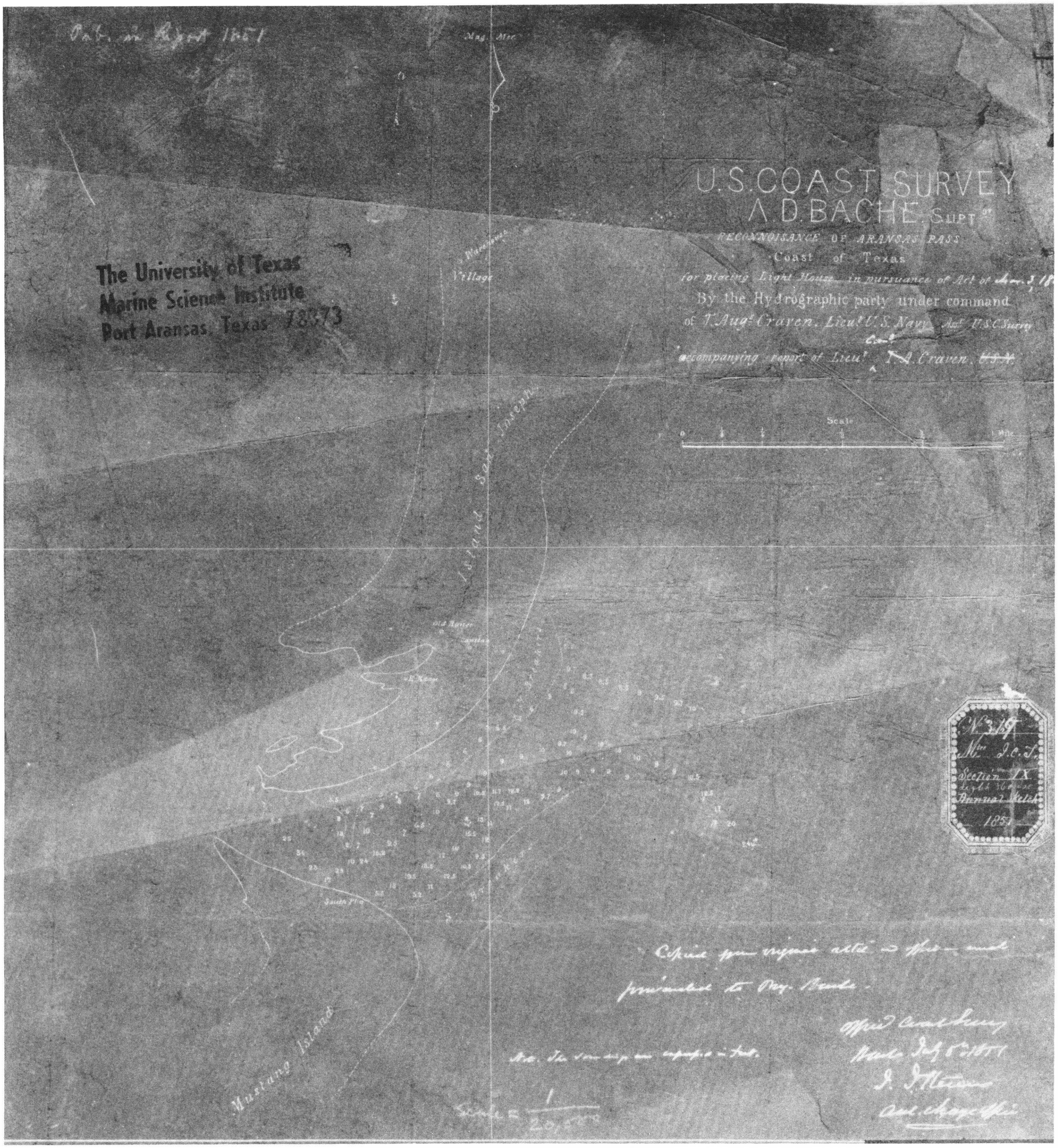
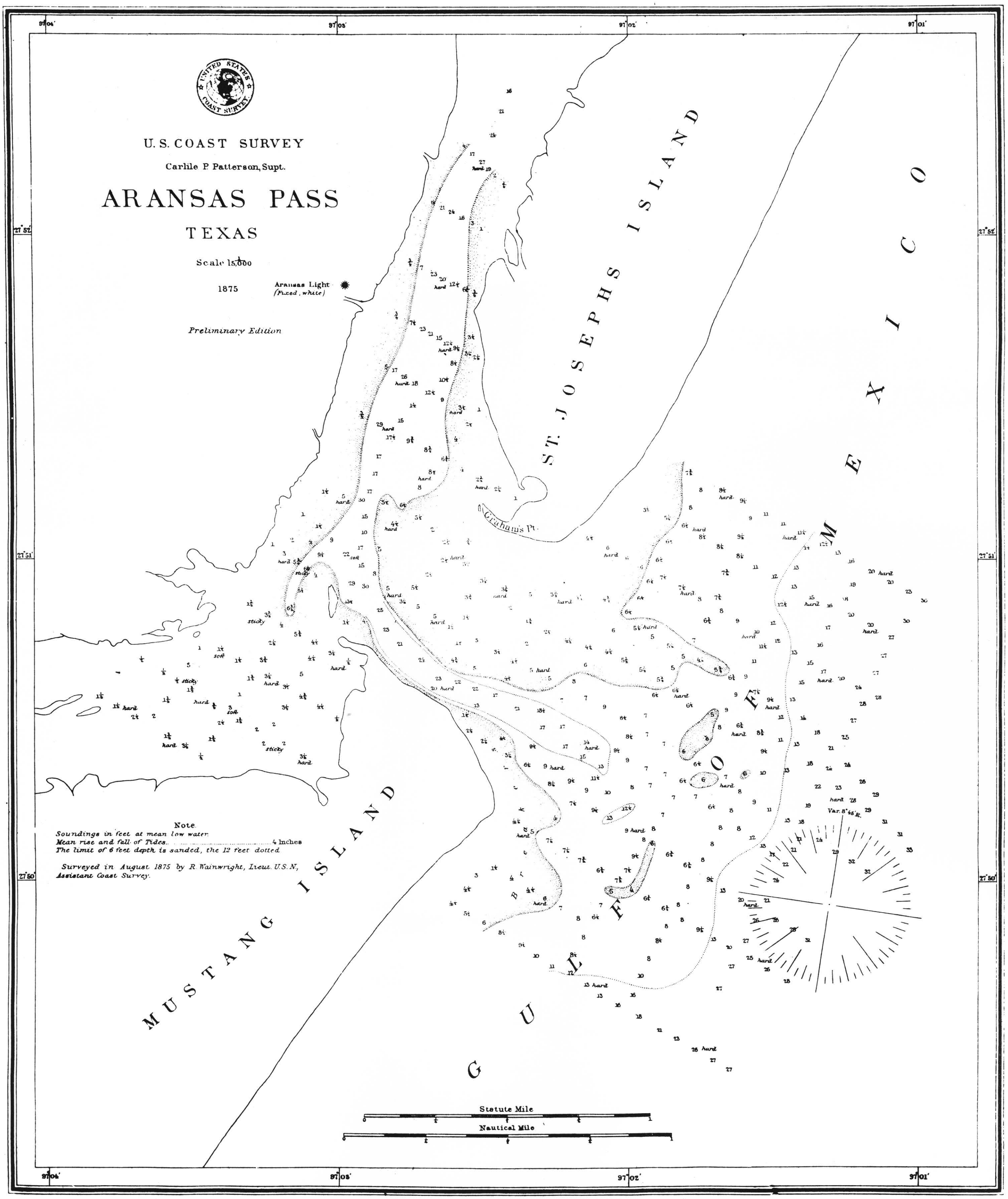

U.S. COAST SURVEY
A.D. BACHE, SUPT.
RECONNOISANCE OF ARANSAS PASS
Coast of Texas
By the Hydrographic party under command
Scale
The University of Texas
Marine Science Institute
Port Aransas, Texas 78373
Village
Mustang Island
1851

Figure 5



UNITED STATES COAST SURVEY
U.S. COAST SURVEY
Carlile P. Patterson, Supt.
ARANSAS PASS
TEXAS
1875
Aransas Light (Fixed, white)
Preliminary Edition
ST. JOSEPHS ISLAND
MUSTANG ISLAND
GULF OF MEXICO
Graham's Pt.
Note.
Soundings in feet at mean low water.
Mean rise and fall of Tides .... 4 Inches
The limit of 6 feet depth is sanded, the 12 feet dotted.
Surveyed in August 1875 by R. Wainwright, Lieut. U.S.N, Assistant Coast Survey.
Statute Mile
Nautical Mile
97°04'
97°03'
97°02'
97°01'
27°52'
27°51'
27°50'

Figure 6


Red Fish Cove
Dagger I.
SHOAL BAY
SHALLOW BAY
Ransom's Pt.
MUD FLATS
HARBOR ISLAND
Quarantine
Corpus Christi Bayou
Mud Island
Lydia Ann Island
Aransas
LIFE SAVING STATION
ARANSAS PASS
ISLAND
1st Jetty 1887

Figure 7


Mud Island
Corpus Christi Bayou
Quarantine
Aransas Pass
SHALLOW BAY
SHOAL BAY
Ransom's Pt.
Red Fish Cove
Dagger I.
MUD FLATS
HARBOR I.
Lydia Ann I.
ST. JOSEPHS ISLAND
Tarpon Club House
Tarpon
ARANSAS PASS
Shamrock Pt.
SHAMROCK COVE
ISLAND

Figure 8


ARANSAS PASS
Mud Island
Corpus Christi Bayou
Quarantine
DREDGED TO 8½ FT
DREDGED TO 8½ FEET
SHOAL BAY
HARBOR I.
Lydia Ann I.
ST. JOSEPHS ISLAND
LIGHT
Ransom's Pt.
MUD FLATS
Red Fish Cove
Dagger I.
Turtle Cove
LIFE SAV. STA.
Tarpon
ARANSAS PASS
SHAMROCK COVE
Shamrock Pt.

Figure 9

in the Port Aransas area. Before maintenance of the Aransas Bar was begun, larger vessels could not enter the Harbor Island area through the Aransas Pass except at those times when the offshore bar was deepened by storm erosion and the deeper draft vessels could enter the Pass only as far as Lydia Ann Channel, although the early charts indicated depths as great as 42 feet behind the bar near Harbor Island. This same area currently has depths up to 68 feet. The U.S. Rivers and Harbors Act of March 3, 1879 indicated government interest in improving the port facilities by appropriating $135,000. A small community developed on both St. Joseph Island and Mustang Island, which catered to these vessels and provided the facilities to offload their cargoes to barges and smaller vessels that could navigate the shallow passes to Corpus Christi Bay.

The variability of the barrier island as it was subjected to storms and accompanying water energies can be shown by the historical records of the location of the entrance of Aransas Pass from the Gulf. In 1883, the pass was located, according to Armstrong Price (personal communication), at approximately the position of Lydia Ann Island, as shown by Monroe's Chart (Fig. 4). In 1851, at the time the lighthouse was being established, the pass had moved to the southwest approximately two miles (Fig. 5). The lighthouse was initially constructed opposite the pass. During the time between 1851 and 1885 the pass moved to approximately its present position. Some believe the great storm of 1875 was responsible for this change. This hurricane also destroyed the St. Joseph Island settlement at Heath's Wharf, sometimes called Tarpon Club, which had a population of approximately 400. The docks where the larger vessels were berthed were also destroyed. The 1900 chart and the 1908 chart (Fig. 8) show Tarpon on Mustang Island, whereas in the 1860's records show what might be inferred to be developed community plots opposite the present location of Lydia Ann Island. The resident population in the early 1900's was approximately 1200 or the same as the present day resident population.

Accounts of such changes and of boat activities have been recorded in the Mercer family logs. These logs graphically detailed life in the Aransas Pass area during the early days. Such items as snow at Port Aransas in 1873, the 1875 hurricane, a drought in 1877, and hail large enough to break glass in 1878 were listed among the accounts.

The importance of water transportation and the agonistic effect of nature on the shifting sands dictated that stability of the bar channel was desired. Entries in the Mercer log showed that the bar shifted so often that even the pilots, who formed their association in the 1880's, as well as the Aransas Life Saving Service, often had to lead the vessels through the bar with small boats sounding ahead.

The first attempts to stabilize the Pass entrance started in the 1860's by private individuals, using brush and lime rock from Rockport and the Laguna Madre. The Rivers and Harbors Act of 1879 funded the construction of the south jetty which is shown on the charts of 1884 and 1887 (Figs. 7 and 10). This was called the Mansfield Jetty and was later replaced by the present south jetty. Remains of the Mansfield Jetty existed until 1930, when they were removed.

Var'n 1886 8°10' E. Annual decrease 2½'
SHALLOW BAY
SHOAL BAY
MUD FLATS
HARBOR I.
Corpus Christi Bayou
Quarantine
Aransas
ST. JOSEPH'S ISLAND
ARANSAS PASS
Morris and Cummings Cut. 8 feet deep
Ransom's Pt.
Red Fish Cove
Dagger I.
SHAMROCK COVE
Shamrock Pt.

Figure 10

It is very difficult to estimate from existing literature when development of the area now called Harbor Island began. The construction of piers, bulkheads and dredge fill emplacement probably was started by the Spanish in the 1500's but did not reach significant proportions until the development and construction of the jetties in the latter 1800's. The 1879 Rivers and Harbors Act provided for both channel dredging and the construction of jetties. Following this authorization, dredged sediment materials were used to fill both the Port Aransas area and Harbor Island. In 1909 a channel connecting Turtle Cove and Corpus Christi Bay was dredged to 8½ ft., initiating the present development of the Corpus Christi Ship Channel. Material removed in deepening the channel was subsequently placed on Harbor Island and along the Channel. In 1912, a railroad was completed between Aransas Pass and Harbor Island, and port facilities were constructed on the island, Figure 11 (Schmidt, 1968). Also during this construction period, beginning in 1909, the Aransas Pass Channel and Dock Company dredged the Aransas Pass Channel and material from the channel was placed along the south side to provide, with appropriate wooden bridges and trestles, the foundation for the railroad. The Harbor Island facilities served the area as a major port for this area until the great storm of 1919 destroyed most of the dock and warehouses and the railroad. Following this catastrophy, the U.S. Army Corps of Engineers abandoned Harbor Island as the major port in favor of Corpus Christi. The Harbor Island railroad operated until the 1930's when the railbed was converted to auto transportation. Presently Texas Highway 361 follows alongside the former railroad embankment (Figs. 12-15).

With the deepening of the channel across Aransas Pass bar and the construction of the Ship Channel to Corpus Christi, the bay system has been drastically altered. Some environmental effects may include protection for fish during temperature and salinity transitions due to the increased water depths and greater chances of successful migration for adult and larval fish and larval shellfish during their movements between the Gulf and the Bays as well as modification of the terrain. The imposition of a system of islands resulting from the disposal of dredged material may have limited the effect of enhanced circulation by imposing a physical barrier. The Morris and Cummings Cut increased the water circulation between Aransas, Redfish and Corpus Christi Bays. Prior to this first bay bottom alteration, the Bays were subject to wide fluctuations in water movement. During the past, channels were alternately closed or opened, the existing channels were deepened and new passes were created depending on the frequency of major storms and subsequent sand movement and deposition during periods of normal weather patterns. At times of high rainfall the Bays were fresh for long periods of time and at times of drought, high salinities prevailed. The Spanish, for example, reported the harvesting of salt in Nueces Bay in the 1500's. The literature abounds with descriptions of fish kills during droughts that are similar to those which occurred in the Laguna Madre and Baffin Bay before the Intracoastal Canal and Mansfield Pass were dredged. During fresh water periods Nueces Bay had extensive oyster beds over which the present Nueces Bay Causeway passes. The opening, between Nueces and Corpus Christi Bays, was shallow enough for wagons to ford at low tide. Oyster shell has been extensively harvested from Nueces Bay during the past years, resulting in a general deepening of the area. One can postulate that Nueces Bay was a shallow, very muddy bay receiving the soils and remains of plants and animals from the extensive land drainage through the Nueces River.

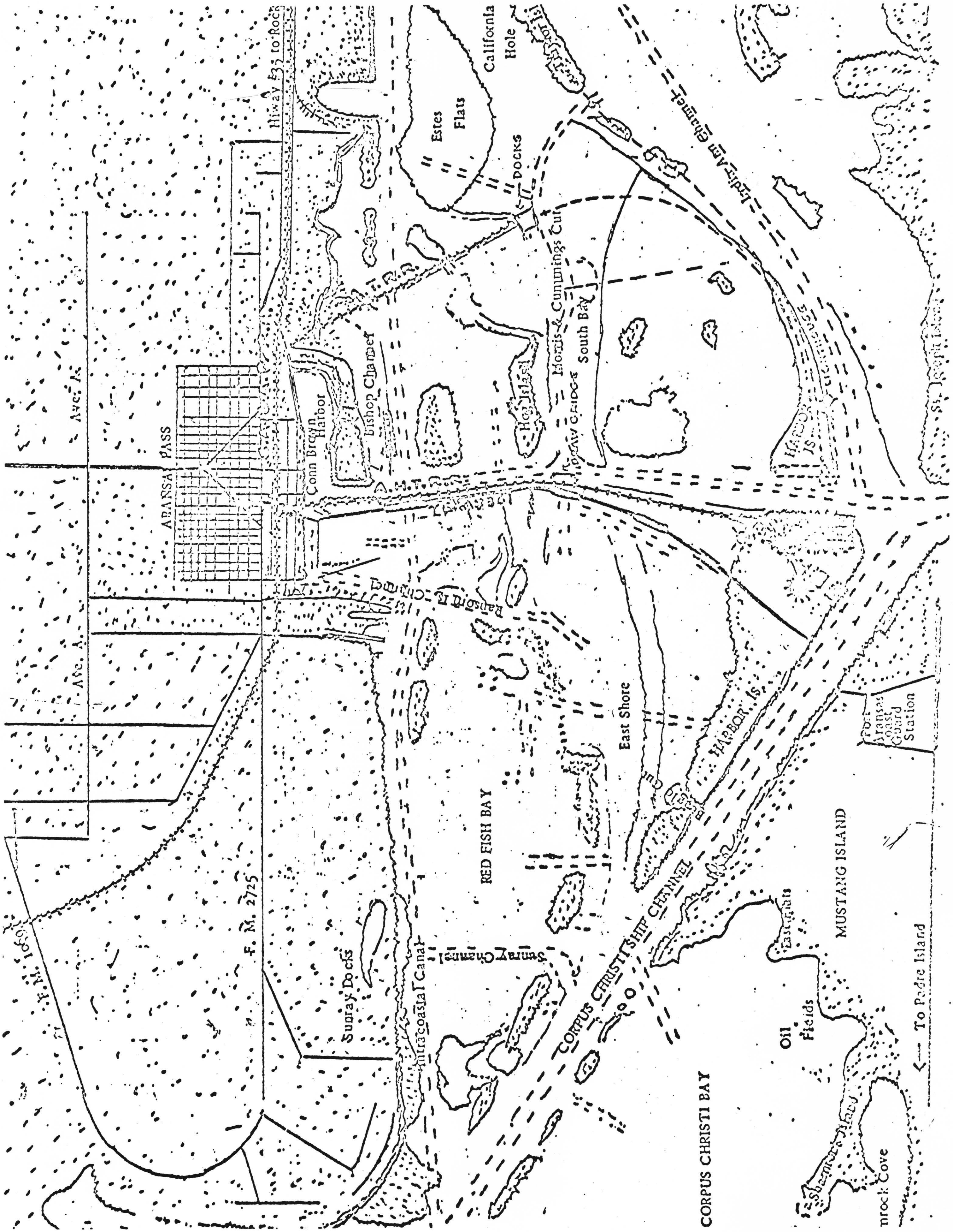

California Hole
Estes Flats
DOCKS
Morris & Cummings Cut
South Bay
Hog Island
Bishop Channel
Conn Brown Harbor
ARANSAS PASS
Ave. A
East Shore
RED FISH BAY
HARBOR IS.
Port Aransas Coast Guard Station
MUSTANG ISLAND
CORPUS CHRISTI SHIP CHANNEL
Sunray Channel
Sunray Docks
Intracoastal Canal
F. M. 1069
F. M. 2725
Oil Fields
CORPUS CHRISTI BAY
To Padre Island

Figure 11

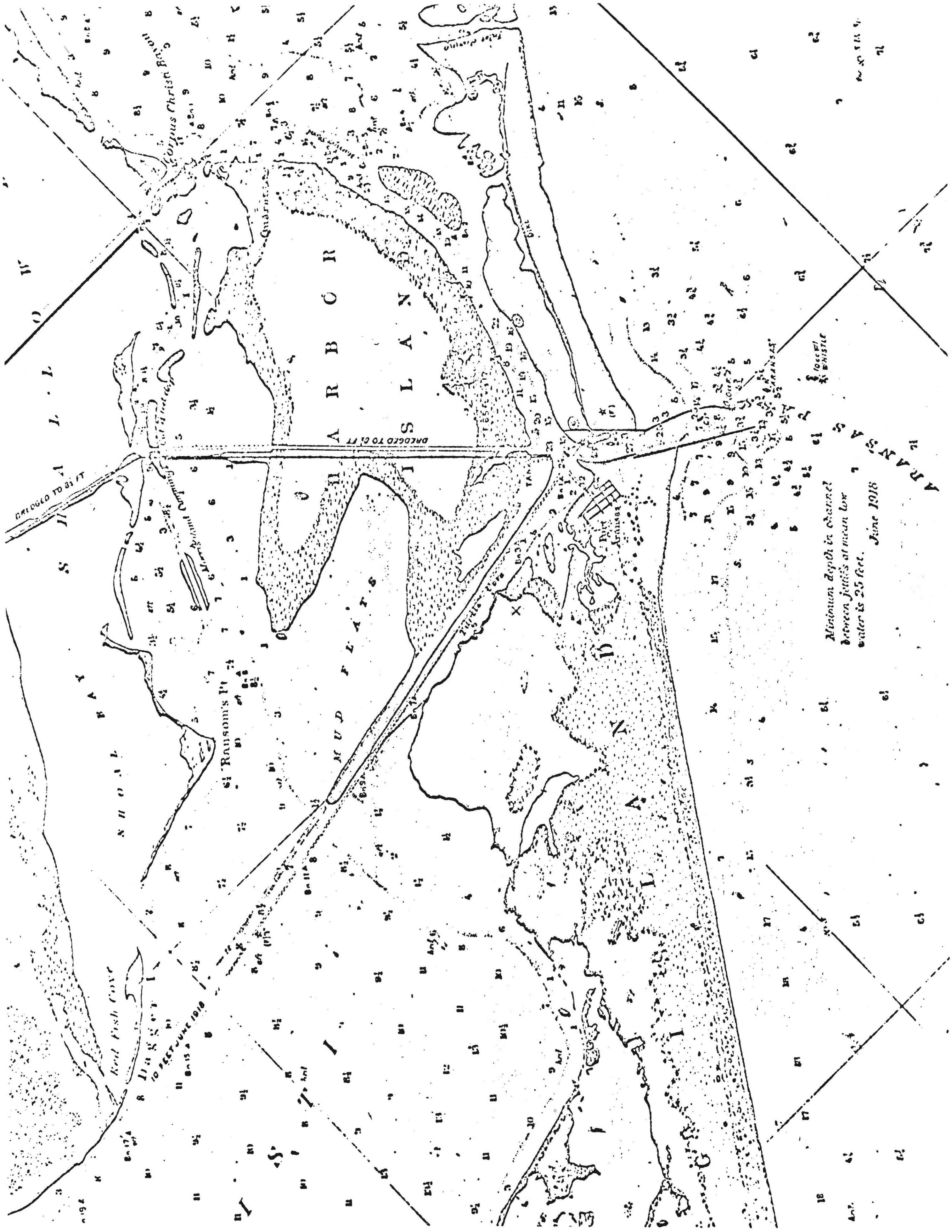

Corpus Christi Bayou
DREDGED TO 8½ FT
DREDGED TO 21 FT
Ransom's Pt
MUD FLATS
SHOAL BAY
Red Fish Cove
Port Aransas
ARANSAS
Minimum depth in channel between jetties at mean low water is 25 feet.
June 1918

Figure 12

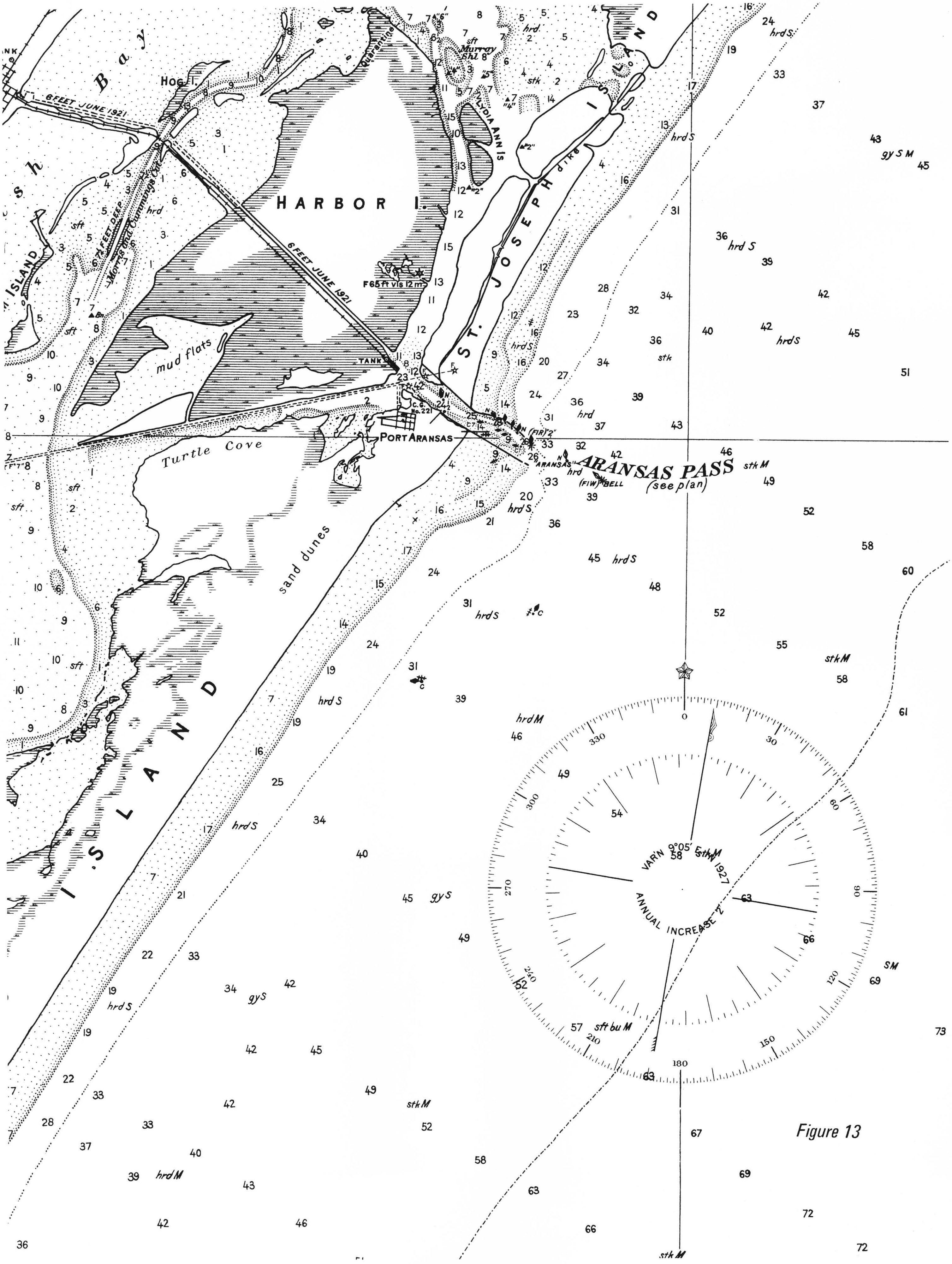

Bay
HOG I.
HARBOR I.
6 FEET JUNE 1921
7 FEET DEEP
Quarantine
Murray Shl.
LYDIA ANN IS.
ST. JOSEPH ISLAND
dike
F 65 ft vis 12 m
mud flats
TANK
PORT ARANSAS
C.G. No. 221
Turtle Cove
ARANSAS PASS
(see plan)
(FIW) BELL
sand dunes
ISLAND
VAR'N 9°05' E 1927
ANNUAL INCREASE 2'

Figure 13

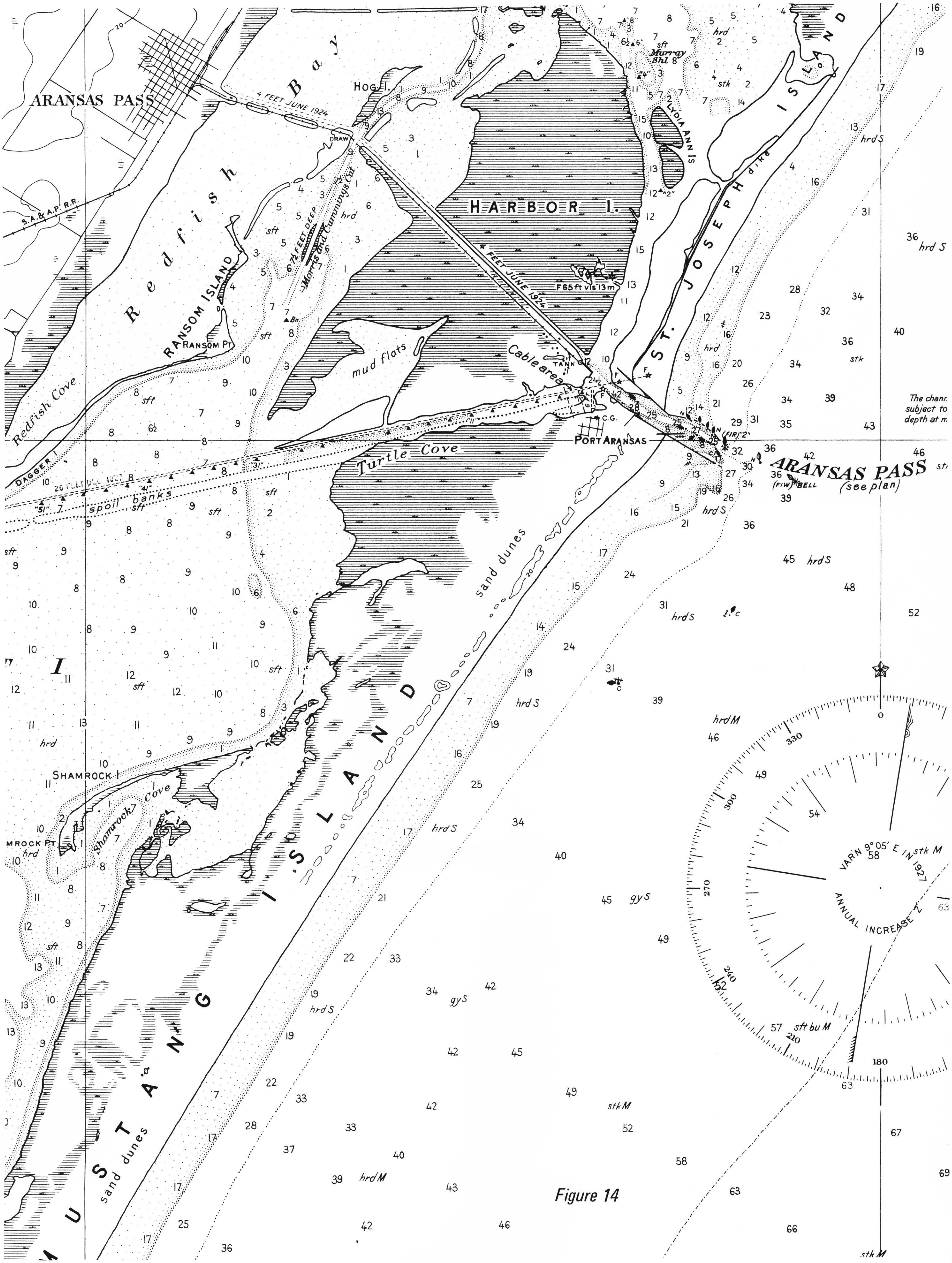

ARANSAS PASS
Redfish Bay
HOG I.
4 FEET JUNE 1924
DRAW
S.A.& A.P. R.R.
RANSOM ISLAND
RANSOM PT
Redfish Cove
DAGGER I.
Morris and Cummings Cut
6½ FEET DEEP
HARBOR I.
FEET JUNE 1924
F 65 ft vis 13 m
mud flats
Cable area
TANK
C.G.
PORT ARANSAS
Turtle Cove
spoil banks
Murray Shl
LYDIA ANN IS
ST. JOSEPH ISLAND
dike
ARANSAS PASS
(see plan)
BELL
sand dunes
MUSTANG ISLAND
SHAMROCK I
Shamrock Cove
VAR'N 9° 05' E IN 1927
ANNUAL INCREASE 2'
The chann. subject to depth at m

Figure 14

ARANSAS PASS
TANK
Hog I
ARANSAS CHANNEL
The project depth is 12 feet.
For controlling depths see charts 523 or 892.
(use chart 892)
Lydia Ann Channel
Lydia Ann I
ST. JOSEPH ISLAND
Redfish Bay
INTRACOASTAL WATERWAY
Redfish Cove
Dagger I
Ransom I
Ransom Pt
(use chart 893)
marsh
S.P.R.R.
Radio Tower
OVHD. PWR. CABS.
TOWER (Aband L.H.)
HARBOR I
Cable Area
Ferry
PORT ARANSAS
(use chart 523)
E Int 3sec 85ft 15M
R Bn 300
CUP
C.G. NO. 221
HORN
Fl 4sec 17ft "85"
Fl 38ft
E Int 6sec 78ft
ARANSAS PASS
(chart 523)
Disposal Area
ARANSAS PASS-CORPUS CHRISTI CHANNEL
The Project depth to Corpus Christi, Texas is 36 feet.
For controlling depths see chart 523.
Sand dunes
MUSTANG ISLAND
Shamrock I
Shamrock Pt
Shamrock Cove
PA wreck (23 ft rep)
"1" Fl 10sec WHISTLE Ra Ref
W Or Fl 4sec Priv maintd
Obstr Fish haven
Mast PA
Platforms (lighted)
HORN
MAGNETIC
VAR 8°45'E (1965)
ANNUAL DECREASE 1'

Figure 15

During the period of the 1880's, with the development of the Aransas Pass area, the Corpus Christi Ship Channel and the construction of the jetties at Aransas Pass and the port facilities at Harbor Island, the circulation of the bays was extensively altered. Because of the former restrictions in circulation, long term salinity variations influenced changes in the animal and plant populations. Archaeologists following the transitions in shell middens in Ingleside report alternate layers of oysters and conch which indicate changes between relatively fresh and saline waters due to long term climatic variations. The deeper passes provided protection for fish during temperature and salinity transitions. The passes provided easier access for both adult and larval fish and shellfish as they migrated to the open Gulf to spawn and returned to the productive bays to grow.

Since their origin, the Texas Bays have been muddy water systems and highly productive in numbers and types of biological organisms. Because they partially entrapped the nutrients and organic material introduced from the uplands as well as providing sites for deposition of the weathered soils and clays from upland drainage, there resulted shallow, muddy bottom grass flats which offer protection and forage to many species, including the young of many commercially important species. The tides and slope of the sediment is advantageous for the typical marine grasses found in the area. The turbid waters, which exclude attached grasses in water depths of greater than three to five feet, sustain a wide variety of planktonic algae as the basis of the food chain in this environment.

There are very few areas remaining that are representative of the original grass flat environments. A recent aerial survey of the bay revealed a few areas such as Redfish Bay, between the city of Aransas Pass and Lydia Ann Channel and north of the Highway 361, to be relatively unchanged grass flats and mangrove islands; the latter disappear in times of high salinity as in the 1945-50 period. The bay side of Mustang Island from Shamrock Cove to the new Corpus Christi Fish Pass has had little man-made change. Most of the remainder of the bay margin area has been changed in some manner by man in attempts to stabilize and develop the valuable lands adjacent to natural water environments or to exploit mineral resources. Most of the west shore of Corpus Christi Bay has been bulkheaded or stabilized from erosion by waves. The Ingleside area is being altered by industrial and urban development, while the Intracoastal Waterway development between Aransas Pass and Ingleside has extensively altered that area.

Man's Past Effect on the Ecology of the Area

Through agricultural, industrial, urban and recreational development, man has markedly changed the configuration of the bay and, as nature has in the past, has changed the biota of the bay. This is especially true of the development of Harbor Island. Dredging and filling operations documented as early as 1880 have already changed large portions of Harbor Island and Port Aransas. Sediment from the first cut of the Corpus Christi Channel was deposited on Harbor Island (Figs. 8 and 9). Comparison of recent photographs to the charts of 1884 and 1887 indicate substantial increases in the elevation of the land in the area. The positioning of the jetties has altered deposition of sand and shell by changing the action of the long shore currents. The deepening and extension of the channels has provided a larger capacity for water exchange between the bays and the Gulf. Such development, accompanied by other bay bottom and peripheral alteration, and by a change in water flow from the Nueces River, has increased the stability of the salinity of the bay and enhanced flushing and productivity in the Gulf adjacent to the pass. Prior to these changes, as reported in various literature, the bays were subject to sudden drastic changes in salinity and temperature. Fish kills due to both drought-induced high salinities and freezing were frequently reported. Then as man changed the water stability, reports of fish kills due to hypersalinity or freezing temperatures decreased and for the past several years have not been extensively reported.

A review of the literature of the area reveals no significant change in the total biological productivity although such information is not extensive. Some biological changes have occurred and some fish like the tarpon have not been as abundant as in the past. There is a recent trend that indicates that the white shrimp are declining and are being replaced by the brown shrimp. Larger redfish are less abundant, although this may be due to changes in fishing such as the use of troutlines, which are more efficient for catching the larger redfish. Oysters are not as abundant as in the early 1900's, but such changes could be natural due to long term cycles of salinity changes or due to predators. Oysters are still found in Corpus Christi Bay by the Nueces Causeway, and near Flour Bluff. The tarpon have disappeared for some years but this year's catch indicates that they may be increasing again.

While it is very easy to use historical evidence to show that our coastal environment is or has been changing, it is very difficult to show the degree that man may be responsible, except of course for the physical changes due to dredging and bulkheading or filling waterfront property. The bay waters normally receive in the past and present a multitude of organic and inorganic chemicals through land drainage and erosion and undergo continual change. These include heavy metals, plant nutrients, and organic molecules of extensive variety. After all, most industrial chemicals have had an origin or were discovered in living systems and natural environments for example hydrocarbons that comprise about 1% of most dry protoplasm. Complex polyphenols are common in woody plants. Antibiotics and toxic material such as neurotoxins of red tide and jellyfish are produced by living organisms. Alcohols, fatty acids, gases, proteins, and vitamins are normally produced. Heavy metals, such as cobalt, mercury, titanium, and lead have been a part of the normal water chemical composition and many are vital to healthy protoplasm, as shown in Table 1. Of course there are extremes, and an excess of almost any chemical can be equally destructive to living populations as can be a lack or deficiency. The chemical values for organisms are shown alongside those of open sea water. Such mineral composition ranges may be considered to be normal to the total environment.

What then constitutes an environmental balance? Perhaps, because of the extreme complexity and interdependence of environmental factors, one can look at variations in some end product as an indicator of change. If, for instance, man relates the state of the environment in part to the presence or absence of commercial and sport fishing, we may make certain extrapolations. For example, most sport fish depend on a migration between

TABLE 1

Comparative Values of Elements in the Environment*

	Element	Seawater Range (mg/l)	Earth Crust Average (ppm)	Marine Organisms Range (ppm)	Land Organisms Range (ppm)
H	Hydrogen	108,000	1,400	41,000 - 52,000	55,000 - 70,000
He	Helium	.0000069 - .000005	.008		
Li	Lithium	.18 - .1	20	1 - 5	.02 - .1
Be	Beryllium	.0000005 - .0000006	2.8	.001	.1 - .0003
B	Boron	4.7 - 4.6	10	20 - 120	50 - .5
C	Carbon	28	200	345 - 100,000	280,000 - 465,000
N	Nitrogen	0.5	510	15,000 - 75,000	30,000 - 100,000
O	Oxygen	857,000	464,000	400,000 - 470,000	186,000 - 410,000
F	Fluorine	1.4 - 1.3	625	2 - 4.5	.5 - 1,500
Ne	Neon	.00014	.005		
Na	Sodium	10,769 - 10,293	23,600	4,000 - 48,000	4,000 - 1,200
Mg	Magnesium	1,350 - 1,262	23,300	5,000 - 5,200	1,000 - 3,200
Al	Aluminum	1.9 - .01	82,000	10 - 60	.5 - 4,000
Si	Silicon	4 - .02	281,500	70 - 20,000	120 - 6,000
P	Phosphorus	.1 - .07	1,050	3,500 - 18,000	2,300 - 44,000
S	Sulphur	901 - 884	260	5,000 - 19,000	3,400 - 5,000
Cl	Chlorine	19,353 - 18,550	130	47,000 - 90,000	2,000 - 2,800
Ar	Argon	.6	3.5		.75 (Mammalian Blood)
K	Potassium	387 - 376	20,900	5,000 - 52,000	7,400 - 1,400
Ca	Calcium	408 - 389	41,500	1,500 - 300,000	200 - 260,000
Sc	Scandium	.00004 - .000004	22		.008 - .00006
Ti	Titanium	.00002 - .001	5,700	.2 - 80	.2 - 1
V	Vanadium	.002 - .0003	135	.14 - 2	1.6 - .15
Cr	Chromium	.00025 - .00005	100	1 - .2 (108)	.23 - .075
Mn	Manganese	.01 - .002	950	1 - 60	.2 - 630
Fe	Iron	.15 - .001 (10^{-9})	56,300	400 - 700	140 - 160
Co	Cobalt	.0001 - .0007	25	.5 - 5	.5 - .03
Ni	Nickel	.006 - .0001	75	.4 - 25	.8 - 3
Cu	Copper	.01 - .0005	55	4 - 50	2.4 - 14
Zn	Zinc	.021 - .005	70	6 - 1500	100 - 160
Ga	Gallium	.000007 - .0005	15	.5	.006 - .06
Ge	Germanium	.00007 - .00006	5.4	.3	
As	Arsenic	.03 - .0003	1.8	.3 - 150	.2
Se	Selenium	.006 - .00009	.05	.8	.2 - 1.7
Br	Bromine	66 - 65	2.5	60 - 1,000	6 - 15
Kr	Krypton	.0025 - .0003	.0001		
Rb	Rubidium	.2 - .12	90	20 - 7.4	17 - 20
Sr	Strontium	13 - 8.1	375	20 - 1400	14 - 26
Y	Yttrium	.0003	33	.1 - .2	.04 - .6
Zr	Zirconium	2.2 X 10^{-5}	165	.1 - 20	.3 - .64
Nb	Niobium	.00002 - .00001	20	.001 - 300	.3
Mo	Molybdenum	.01 - .0003	1.5	2.5 - .45	.9 - .2
Tc	Technetium				
Ru	Ruthenium		.001 - .01		.002 - .005
Rh	Rhodium		.0 - .005		
Pd	Palladium		.01		.002
Ag	Silver	.0003 - .00004	.07	11 - .25	.8 - .006
Cd	Cadmium	.00001 - .00011	.2	3 - .15	.6 - .5
In	Indium	< .02	.05 - 1		.016
Sn	Tin	.003 - .0008	2	.2 - 20	.15 - .3
Sb	Antimony	.00033 - .0005	.2	.2	.006 - .06
Te	Tellurium		.001 - .01		.02 - 25
I	Iodine	.06 - .05	.5	1 - 1500	.42 - .43
Xe	Xenon	.000052 - .0001	.00003		
Cs	Cesium	.002 - .00005	2	.07	.2 - .064
Ba	Barium	.06 - .01	425	30 - .2	(4000) 14 - .75
La	Lanthanum	.0003 - 1.2 X 10^{-5}	30	.1 - 10	.0001 - .085
Ce	Cerium	.0004 - 5.2 X 10^{-6}	60		320 - .03
Pr	Praseodymium	2.6 X 10^{-6}	8.2	.5 - 5	46
Nd	Neodymium	9.2 X 10^{-6}	28	.5 - 5	460
Pm	Promethium				
Sm	Samarium	1.7 X 10^{-6}	6	.04 - .08	.01 - .0055
Eu	Europium	4.6 X 10^{-7}	1.2	.06 - .01	.021 - .00012
Gd	Gadolinium	2.4 X 10^{-6}	5.4	.06	70
Tb	Terbium		.9	.006 - .01	.0015 - .0004
Dy	Dysprosium	2.9 X 10^{-6}	3		.02 - .01
Ho	Holmium	8.8 X 10^{-7}	1.2	.005 - .01	.5 - 16
Er	Erbium	2.4 X 10^{-6}	2.8	.04 - .02	2 - 46
Tm	Thulium	5.2 X 10^{-7}	.5		.0015 - .00004
Yb	Ytterbium	2.0 X 10^{-6}	3.4	.02	.00012 - .0015
Lu	Lutetium	4.8 X 10^{-7}	.5	.003	4.5 - .00012
Hf	Hafnium	8 X 10^{-6}	3.2	< .4	.04 - .01
Ta	Tantalum	2.5 X 10^{-6}	2	410	
W	Tungsten	.00012	1.5	.0005 - .05	.005 - .07
Re	Rhenium		.005 - .001	.014 - .0005	
Os	Osmium		.0015 - .005		
Ir	Iridium		.001		.00002 - .02
Pt	Platinum		.005 - .01		.002
Au	Gold	.000015 - .000004	.004	.012 - .0003	.04 - .00023
Hg	Mercury	.0003 - .00003	.08	.03	.046 - .015
Tl	Thallium	< .00001	.5		.4
Pb	Lead	.006 - .00003	13	.5 - 8.4	2 - 2.7
Bi	Bismuth	.000017 - .0002	.17	.3 - 0.4	.06 - .004
Po	Polonium		2 X 10^{-10}	15 - 17**	.1 - 600**
At	Astatine				
Rn	Radon	6 X 10^{16} - 0.6 X 10^{-15}	4 X 10^{-13}		
Fr	Francium				
Ra	Radium	3 X 10^{10} - 2 X 10^{-11}	9 X 10^{-7}	.7 - 15 X 10^{-8}	10^{-9} - 7 X 10^{-9}
Ac	Actinium		5.5 X 10^{-10}		
Th	Thorium	<.0005 - .00005	8.3	.003 - .03	.003 - .1
Pa	Protactinium	2.4 X 10^{-11} - 2.0 X 10^{-9}	1.4 X 10^{-6}		
U	Uranium	.015 - .00015	2.7	.004 - 3.2	.038 - .013
Np	Neptunium				
Pu	Plutonium				.07 - 6.8**
Am	Americium				
Cm	Curium		.0001		
Bk	Berkelium				
Cf	Californium				
Es	Einsteinium				
Fm	Fermium				
Md	Mendelevium				

* Taken from various authors listed in bibliography

** Disintegrations $sec.^{-1}$ kg^{-1}

proper spawning areas in the Gulf and nursery grounds in the bays. During their growth, they require various parts of the food chain which are dependent on other water systems. Thus, from the continued presence of fish one may presume that all of the complex pieces of the life puzzle are present to sustain the fish satisfactorily. Some scientists prefer to place this in terms of organic carbon-fish ratios. If the carbon production, plus the import of carbon from land, is inadequate, then the entire food chain will vary and the end result of fish will change in kind and quantity.

We can make another presumption. That is, that natural fluctuations in certain living populations do take place as is indicated in the current transition in which in the Gulf white shrimp are declining and being replaced by an increase in brown shrimp. However, the total population of shrimp may be on the increase, as this 1972 year catch has been reported by the National Marine Fisheries to be of record size. Thus we do have long period as well as seasonal changes that may affect the balance of populations but in most instances the scientist is confronted by so many environmental variables that it is impossible to point to cause and effect such as when he tried to identify subtle changes such as the change in relative abundance of shrimp species.

Figure 16 describes estuarine relationships between environmental limits of optima and minima and how factors might interrelate. The variables

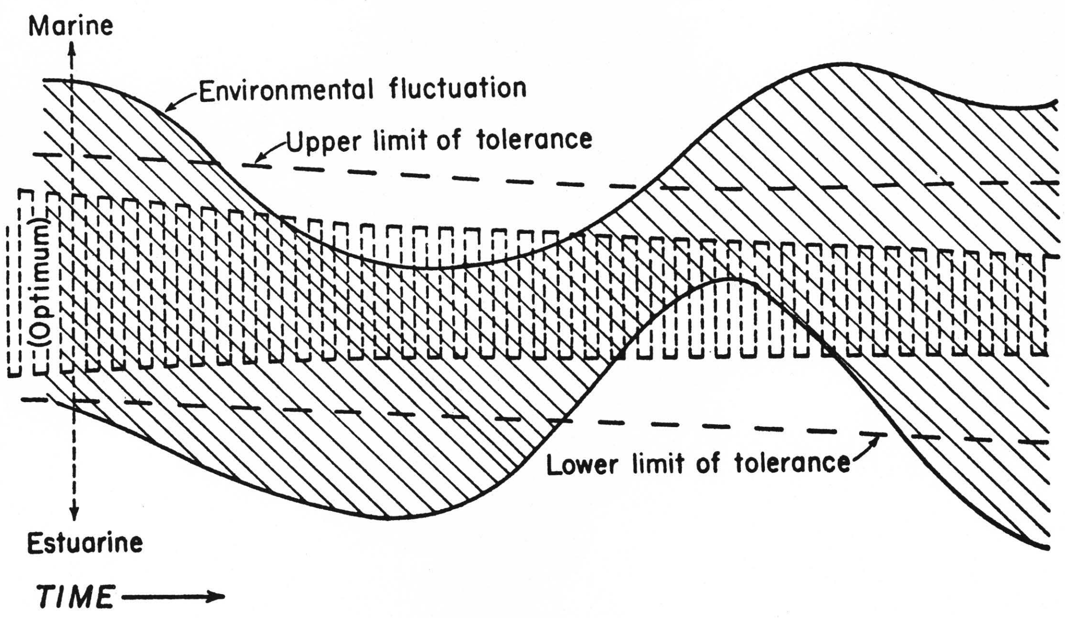


Figure 16. Diagram showing suggested relationship between optima, range of tolerance, and range of environmental fluctuation in an estuarine environment, trending in this case toward narrowed optimum by inspection.

From Hedgpeth (1953)

might include temperature, salinity or turbulence and may vary cyclically on a seasonal basis or at odd intervals with events like hurricanes. This is an example of normal environmental constraints on living populations.

Figure 16 is descriptive of some discrete location at some period of time between seasonal, annual storms and hurricanes, or rainfall and drought, and some organism which is influenced by some environmental parameter such as temperature, salinity, wind and storms. The graph shows that in a fluctuating environment such as the Texas Bay systems, an organism may not be able to tolerate the extreme conditions. The organism may be shown to have an optimum situation and upper and lower limits of tolerance which may be exceeded by the environmental change. Thus in hot or cold weather organisms will seek deeper or more favorable water areas and cannot be found on the flats.

The organism can respond to this by one of two methods. If the organism is capable of movement it can avoid the area of extremes and follow the more stable water environment. Perhaps this is the reason for the winter Gulf life cycle for most commercial fish and crustaceans; that is, they have learned that the bays may have extreme temperature and salinity changes during the winter, and thus they move out of the bays into the more stable Gulf waters where they mature sexually and spawn. The larvae then move back into the bays in the more warm summer temperatures.

If the organisms are sessile, or bottom dwelling, they may not be able to respond to environmental extremes by movement to more stable areas. These organisms can adapt to the situation through the development of reproductive modes having large amounts of sperm and eggs which are spread throughout the bay system and where a certain percentage find a favorable environmental site even under extreme environmental changes.

Through the above two mechanisms living organisms have been able to survive in the highly changing estuarine environment whereas those which were not able to cope with the environment no longer exist in the area.

Large environmental fluctuations over short or long time periods may then change the biological assemblage of the environment through natural events. The resulting rise and fall of living species in the Texas Bays may be very difficult to distinguish from that due to man-made environmental changes that fall above or below the tolerance of some species of living organism.

While one can visualize through Fig. 16 that populations may rise and fall in the transitional environment such as we have in Texas Bays, we must also consider the concept of Vernadsky of the Conservation of the Biosphere, which states that the total amount of living substance on earth has neither increased or decreased during all the geological epochs known to us. It has also preserved its basic chemical composition throughout time. The large scope of living organisms will allow the rise and fall of species while maintaining a constant biomass over a substantial area as in the Texas Bay System. Thus the environment becomes very specific for individual organisms and any change in the environment seriously affects this specificity.

If there is some general agreement that the total biomass of the bays has not declined and that in general most of the pertinent species of living organisms, as evidenced by past reports, has not markedly changed, then it is logical to assume that the extensive changes to the bay system by man have not up to this point been destructive. For the sake of argument, we are discussing only total biomass and not the esthetic changes to the shoreline that may be more pertinent to some.

If the development of Harbor Island and the deepening and stabilizing of the channel at Aransas Pass has indeed increased the stability of the bay waters by increasing circulation between the bay and Gulf, then one can assume that further deepening and enlarging of the pass may be more stabilizing to the bay system. This may be increasingly necessary to provide a more adequate flushing of the inevitable waste of man and uplands which will enter the bay as it has in the past through runoff. Also, as the human community increases, even though industrial wastes are recycled, man will inevitably contribute his personal wastes of carbon, nitrogen and phosphorus to the bay waters. In some ways this may counteract the changes in normal fertility of the bay as river flow is decreased by the development of dams and entrapment basins for man's water needs. Some feel that dams and their containment of water will curtail the natural nutrients to the bay. However, recycling of that same water through a metropolitan sewage system to the bays could be programmed through scientific information to provide a balance between the water flow and the addition of sewage waste. In terms of carbon, sewage or river water addition to the bays as balanced by plant photosynthesis could produce a larger yield of fish for the commercial and sport fisherman. Thus, through judicial scientific planning man can increase the sport and commercial fish and shellfish yield of the bay in biological parameters. Such action, supplemented by the increase in circulation and additional cross section of water area in the channel, may be highly favorable to the system and may indeed counteract the inevitable development of the shore line and its loss of the productive exposed marsh grasses.

Such knowledge must be used in conjunction with a loss of natural environments to determine whether new environments can be cultivated or initiated or whether the total area will tolerate such changes. This concept is discussed later in the impact section.

To put this in graphical terms, the scientist can show the way to sensible development of the bays. This development, attended by the establishment of parks and preserves, will allow the esthetic development of marinas as well as the preservation of natural habitats and still keep the biological productivity of the bay at some near natural balance.

Impact of Harbor Island Development on the Ecology of the Area

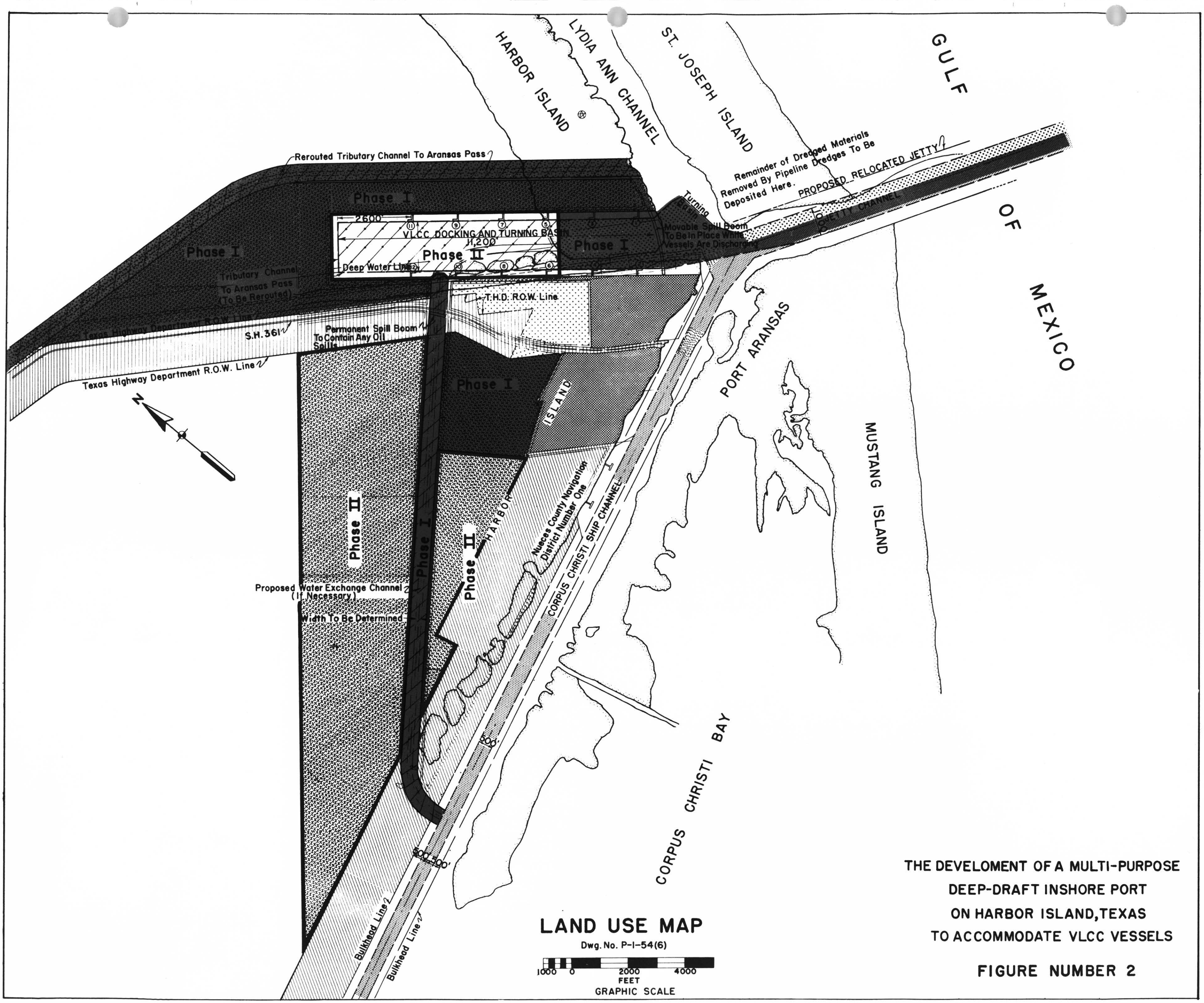
Navigation District No. 1, the local Port Authority of Nueces County, has proposed to enlarge the existing port facilities in the vicinity of Harbor Island, Texas to provide an onshore deep water port to accommodate VLCC vessels of 275,000 to 300,000 DWT capacity. Preliminary plans for the proposed port expansion are presented in Figure 2, which can be compared to the present facility in Figure 1. The proposed development of Harbor Island to accommodate VLCCs is to be accomplished in two phases. The two phases are shown in Figure 2 with phase I outlined in blue and phase II in black. The following discussion of environmental effects will relate primarily to phase II. Phase I development will obviously cause less environmental changes and in most instances will relate to a percent of the environmental effects of phase II. The proposal will include raising the elevation of land adjacent to the VLCC docking basin with natural sediment material from the enlarged basin, the widening of the Ship Channel, in phase II the relocation of the north jetty, and the extension of both jetties and deepening of the out bar and jetty channels to 72 feet for an approximate distance of 7.5 miles seaward from the coast. The VLCC docking basin will be located north of the existing oil tanks, and the Aransas Pass Tributary channel will be relocated to the north of the tanker basin and enter Lydia Ann Channel to the south of the Lighthouse. The area outlined in Figure 2 will be filled to an approximate elevation of 20 feet to provide flood protection from future storms. The dredged sediment will be placed either in dyked enclosures as outlined by the harbor boundaries or will be disposed offshore in deep water.

A circulation channel is being planned to prevent the harbor from becoming stagnate. The channel is situated so that each change of tide will flush through the channel, thus replenishing the water in the harbor and will dilute any material that may be accidentally or inadvertently released. If the circulation channel was not included, the depth, dead end, and naturally productive water would allow the basin water to go anaerobic in the warm summer months. This anaerobic water could then affect larvae and other living organisms passing in migration near the Harbor entrance or entering the Harbor.

While most of the dredged sediment will be placed in the dyked areas of the harbor boundaries the spoil from the approximately 9 miles of channel to the 72 foot contour will be disposed of offshore. Such material has been placed by existing and past dredging and channel maintenance and the spoil placed approximately 3 miles offshore. No data have been obtained to determine the effects of this spoil emplacement during the past years. The proposed deepening of the channel to 72 feet for a distance of 9½ miles offshore will produce considerable more dredged material than past activities. It is difficult to establish the effect of the proposed emplacement because of the lack of past data or information. Therefore we propose that a research project be established to determine the effects of past dredging activities in the area and to determine the place, effect and the type of disposal of dredged sediments that would provide the least impact on the environment. One such type of disposal or emplacement might be in the form of an artificial reef where the material is placed in deep water in a single mound. Other disposal methods may be suggested during and after the research project.

AN AERIAL VIEW OF HARBOR ISLAND AND PORT ARANSAS, TEXAS, showing the location of the PROPOSED MULTI-PURPOSE DEEP-DRAFT INSHORE PORT ON HARBOR ISLAND. (Photo Dec., 1972)

FIGURE I.



LAND USE MAP

Dwg. No. P-1-54(6)

1000 0 2000 4000
FEET
GRAPHIC SCALE

THE DEVELOMENT OF A MULTI-PURPOSE DEEP-DRAFT INSHORE PORT ON HARBOR ISLAND, TEXAS TO ACCOMMODATE VLCC VESSELS

FIGURE NUMBER 2

The dredged material will consist of ancient sediments of approximately 40 percent Pleistocene clay and 60 percent silt, sand and shell.

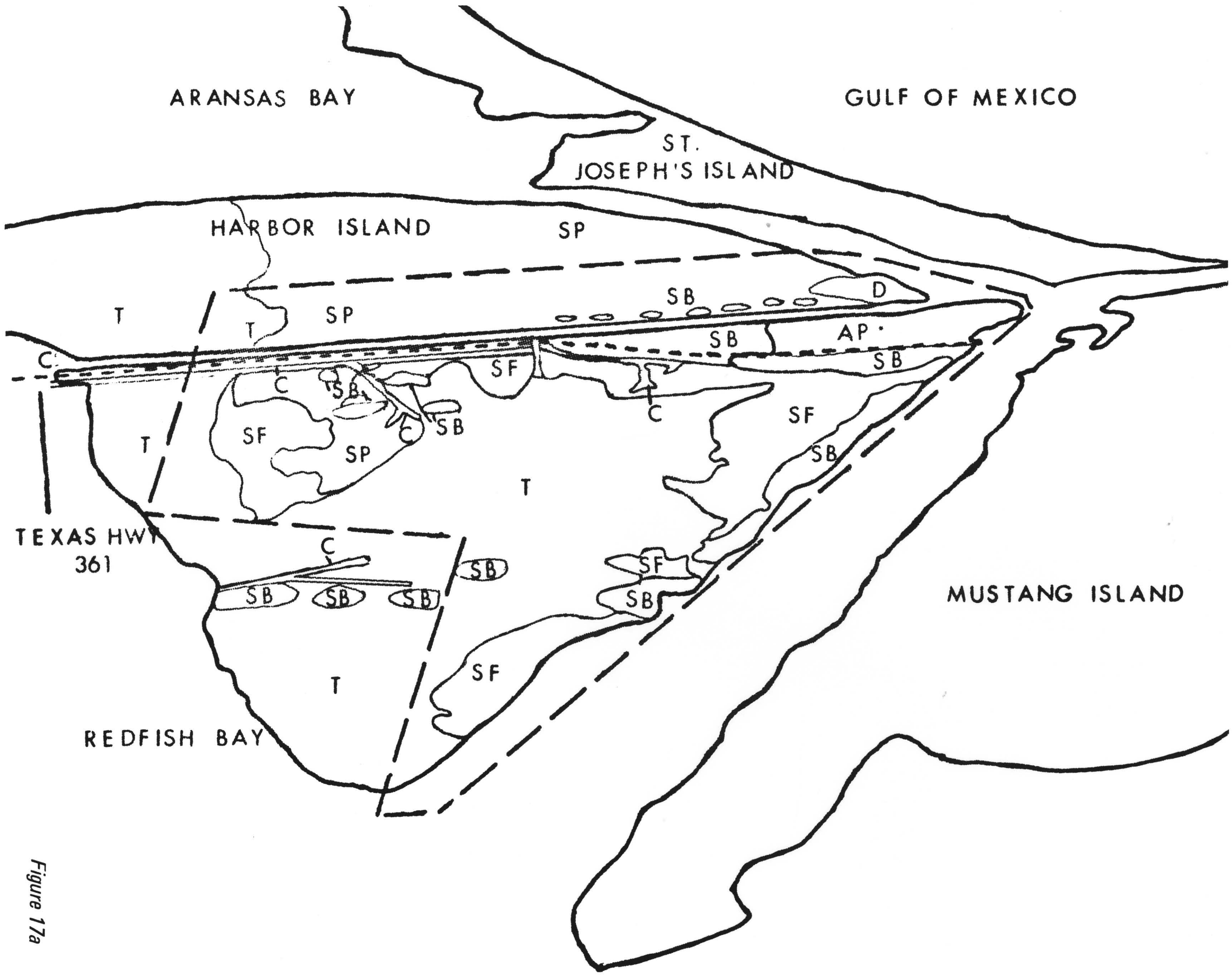
The Port Facility will be designed to accommodate all sewage effluent and other commodities from vessels at the Port, except for uncontrollable or accidental discharge. Spill booms will be provided to contain any accidental oil spills. Sewage and bilge disposal will be provided for vessels.as well as harbor facilities and the vessels. Only cooling water discharge from the vessels will be permitted in the VLCC basin. All solid waste from the shore facilities and vessels will be collected and disposed of by approved procedures. Procedures for loading and offloading of cargo will be established and monitored to assure compliance with all applicable rules and regulations of Federal, State and other authorities having jurisdiction. Operations will be secured during hurricane or major storm warnings. Appropriate safety procedures will be established to provide maximum protection for the environment and man.

Mechanical safeguards against accidental release of materials during Port operations will include: (1) spill booms maintained across the entrance to the Harbor and circulation channel at all times, except when vessels are entering or leaving; (2) the Corpus Christi Oil Spill Association, of which the Navigation District is a member, will provide equipment and manpower to remove either surface films or floating liquids; and (3) mechanical equipment will be available to remove from the surface of the Harbor any large floating objects or other materials that may accumulate during tidal action and current movements.

While in port, the vessels will be under the jurisdiction of the Navigation District's Harbor Master and Environmental Control Officer, and the U.S. Coast Guard.

Initially, only two or three docks will be required. To develop this Phase I of the project, approximately 8.92×10^7cy of material will be dredged and deposited on 1065 acres of land. Should twelve docks ultimately be required, the channel and basin dredging necessary for these docks will produce approximately 95.6×10^6cy of fill material. An estimate of the area (in acres) of these various types of environments which would be altered has been made. The acreages affected with completion of phase II are shown in Table 2 and in Figure 17. The environmental units to be disrupted during these operations have been identified according to the Biotope classification of Oppenheimer and Gordon (1972). Figures 18-23 are artist's renditions of the biological assemblages found within these biotopes.

The cross sections of the present Aransas Pass Channel and the proposed modifications show a cross-sectional area of approximately 40,000 ft^2. With a 600 ft. bottom and 72 ft. depth, the area will be approximately 69,000 ft^2 and with the 1000 ft. bottom and wider jetties, 105,000 ft^2. Estimates of the significance of the average tidal wedge in Corpus Christi Bay have been made (Ned Smith personal communication) and indicate that water entering through Aransas Pass at the start of an average tide will reach past Ingleside into Corpus Christi Bay.



ARANSAS BAY
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ST. JOSEPH'S ISLAND
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Figure 17a

Figure 17 Oblique photograph of Harbor Island area, Port Aransas, Texas.

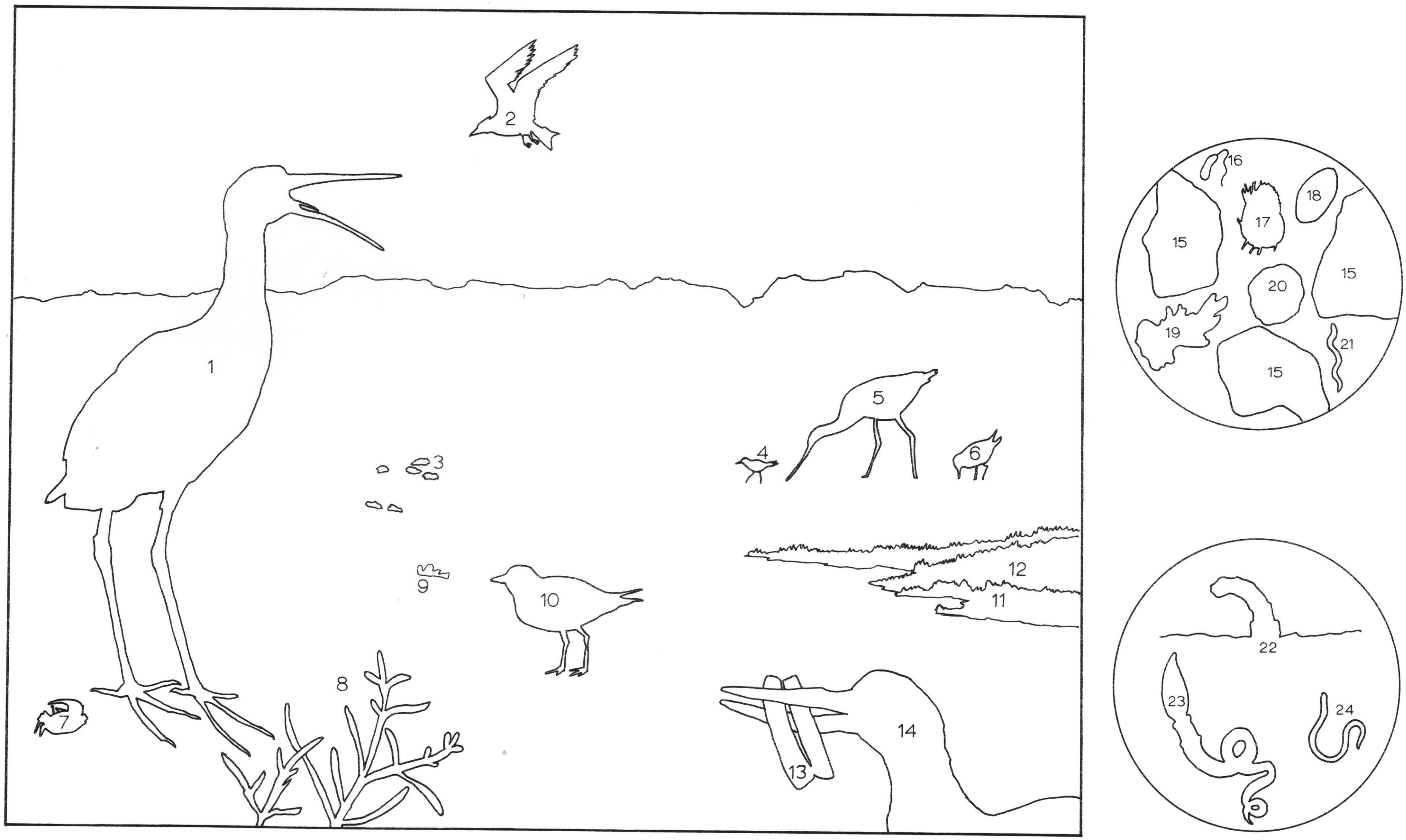

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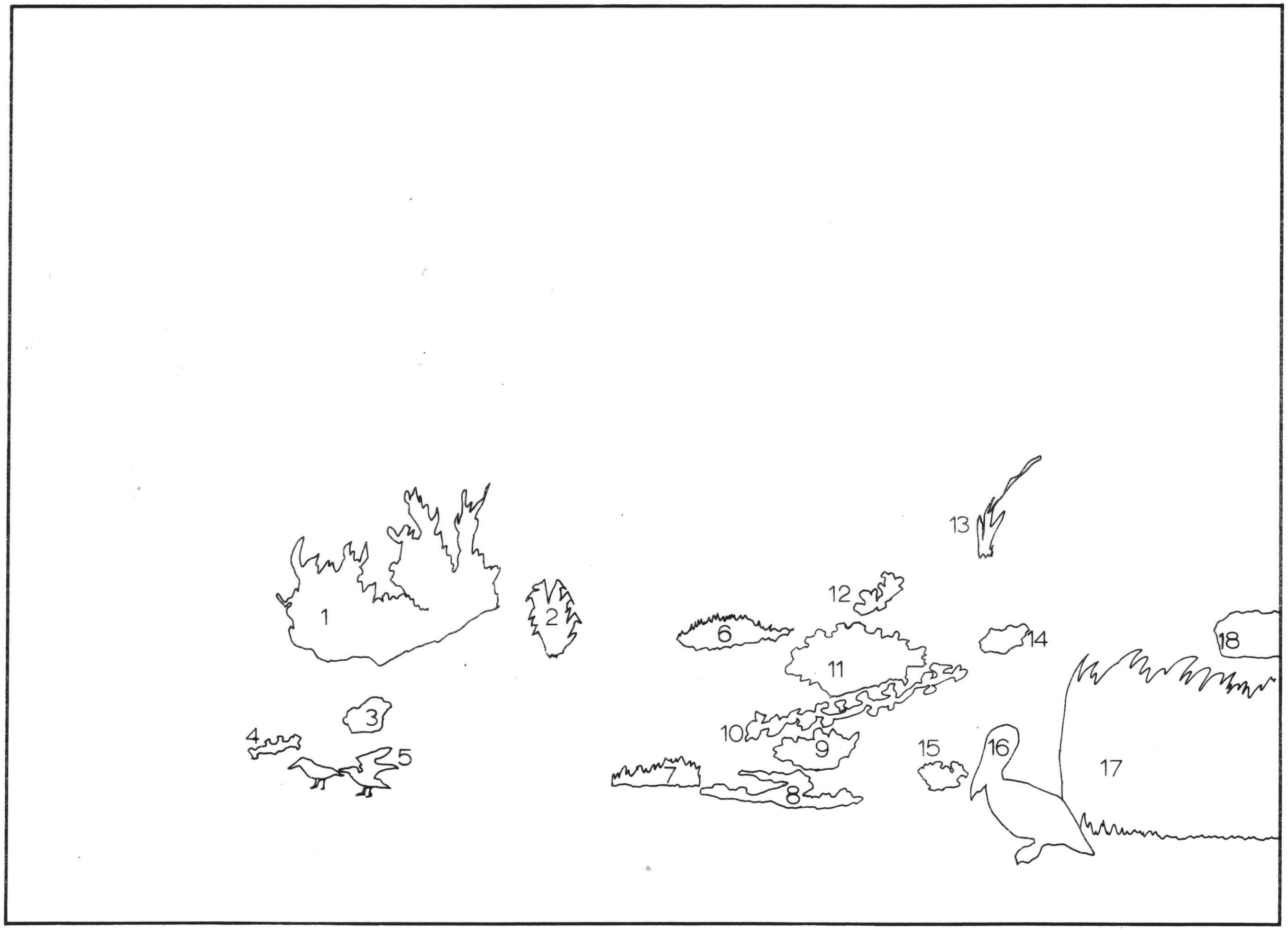
Figure 18

SAND FLAT

1. *Totanus melanoleucus* - Greater yellowlegs
2. *Hydroprogne caspia* - Caspian tern
3. *Uca pugnax* - Fiddler crab
4. *Crocethia alba* - Sanderling
5. *Recurvirostra americana* - Avocet
6. *Arenaria interpres* - Ruddy turnstone
7. *Uca pugnax* - Fiddler crab
8. *Salicornia bigelovii* - Glasswort
9. *Crassostrea virginica* - Oyster
10. *Charadrius semipalmatus* - Semipalmated plover
11. *Distichlis spicata* - Saltgrass
12. *Salicornia perennis* - Glasswort
13. *Ensis minor* - Razor clam
14. *Haematopus palliatus* - Oystercatcher
15. Sand grains, microscopic view
16. *Desulfovibrio desulfuricans* - Sulfur bacterium
17. *Euplotes* sp. - Protozoan
18. *Navicula punctigera* - Diatom
19. *Amoeba* sp. - Protozoan
20. *Chroococcus* sp. - Blue-green alga
21. *Beggiatoa* sp. - Sulfur bacterium
22. *Clymenella torquata* - Polychaete
23. *Saccoglossus* sp. - Protochordate
24. Nematode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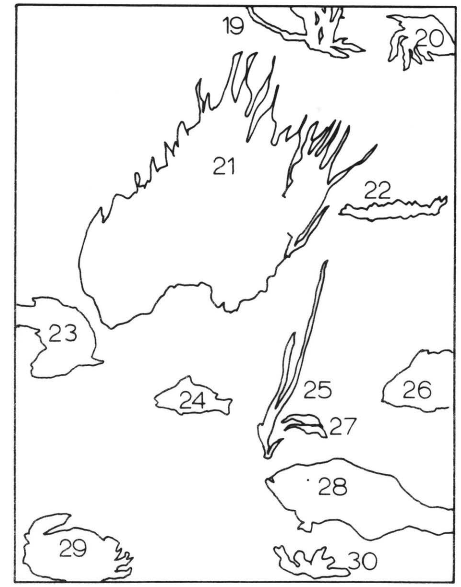
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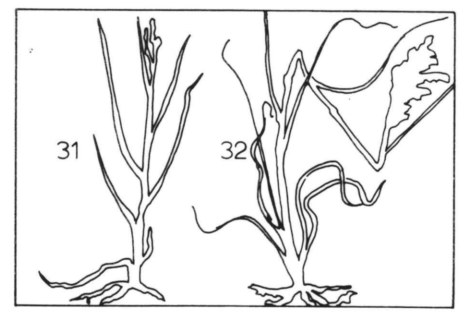
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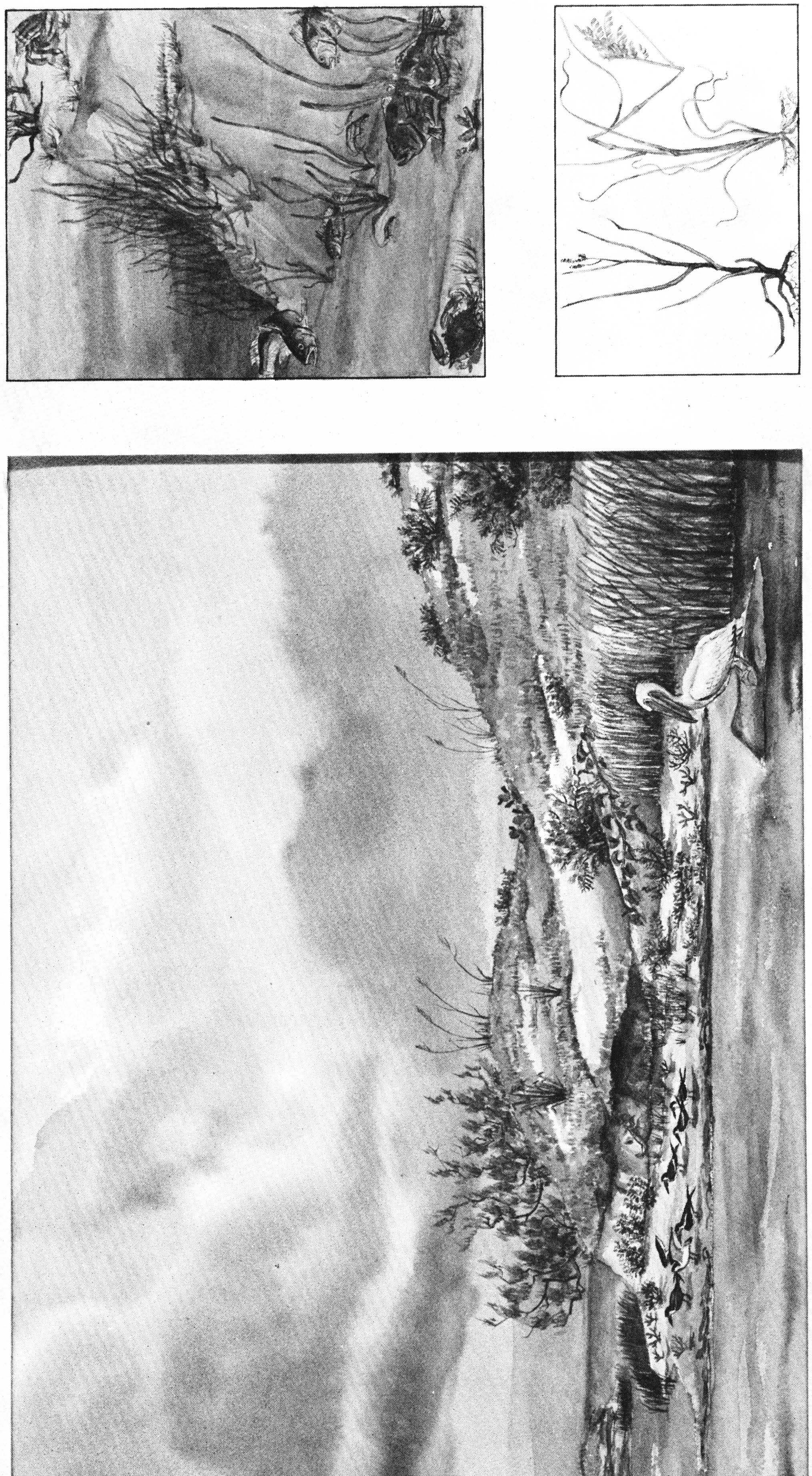
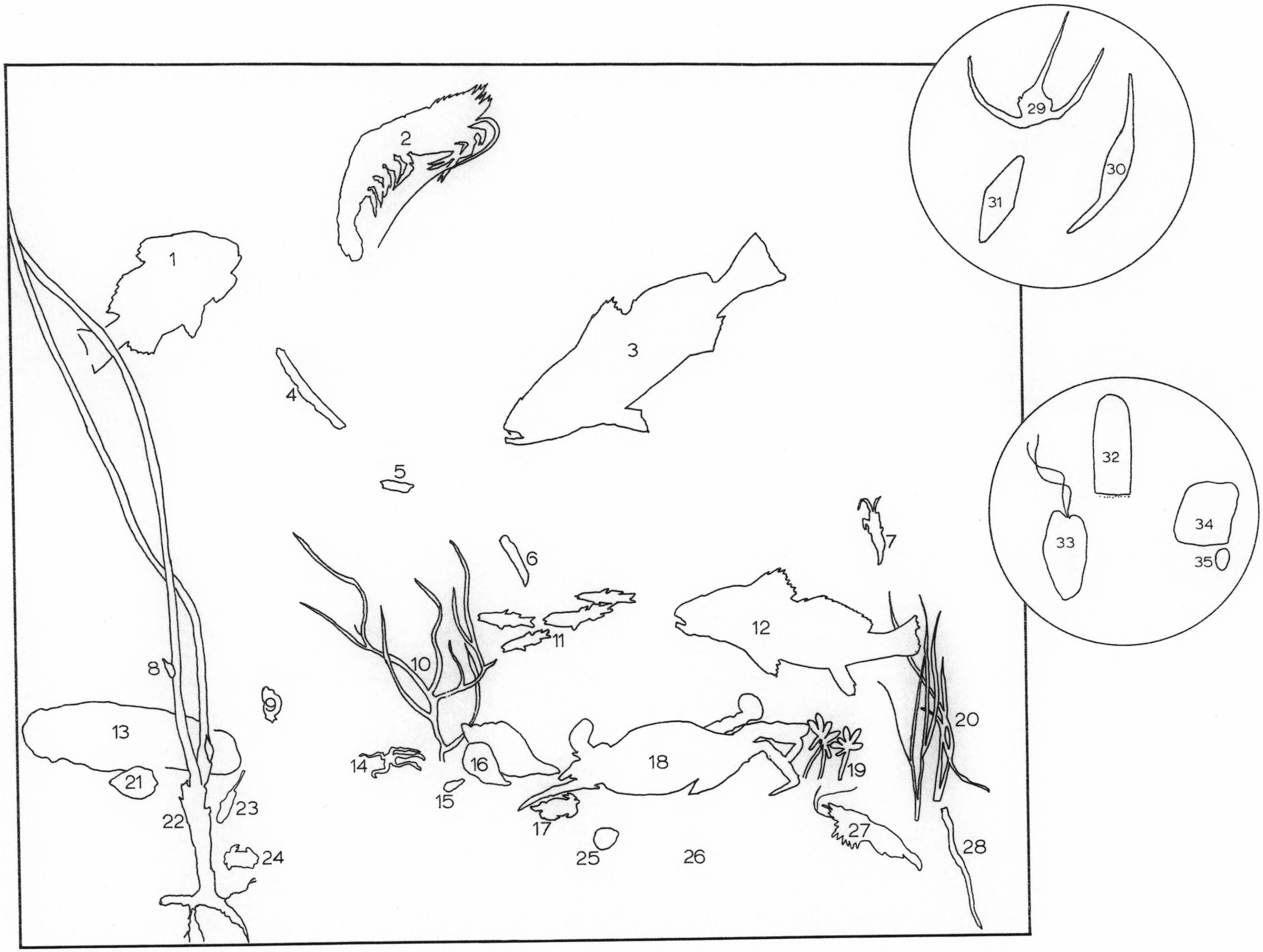


Figure 19

SPOIL BANK

1. Tamarix gallica - Salt cedar
2. Andropogon scoparius littoralis - Seacoast bluestem
3. Senecio sp. - Groundsel
4. Salicornia sp. - Glasswort
5. Rynchops nigra - Black skimmer
6. Spartina patens - Marshhay cordgrass
7. Distichlis spicata - Salt grass
8. Sesuvium portulacastrum - Sea purslane
9. Baptisia laevicaulis - Whitestem wild indigo
10. Ipomoea pes-caprae - Goatfoot morning glory
11. Prosopis glandulosa - Honey mesquite
12. Opuntia compressa - Low prickly pear
13. Uniola paniculata - Sea oats
14. Senecio sp. - Groundsel
15. Salicornia bigelovii - Saltwort
16. Pelecanus erythrorhynchus - White pelican
17. Spartina alterniflora - Smooth cordgrass
18. Gaillardia pulchella - Indian blanket
19. Spartina alterniflora - Smooth cordgrass
20. Clibanarius vittatus - Hermit crab
21. Diplanthera wrightii - Shoalgrass
22. Diplanthera wrightii - Shoalgrass (sprouts)
23. Cynoscion arenarius - Sand trout
24. Micropogon undulatus - Croaker
25. Thalassia testudinum - Turtle grass
26. Pogonias cromis - Black drum
27. Penaeus aztecus - Brown shrimp
28. Paralichthys lethostigma - Flounder
29. Callinectes sapidus - Blue crab
30. Crassostrea virginica - American oyster
31. Spartina spartinae - Gulf cordgrass
32. Uniola paniculata - Sea oats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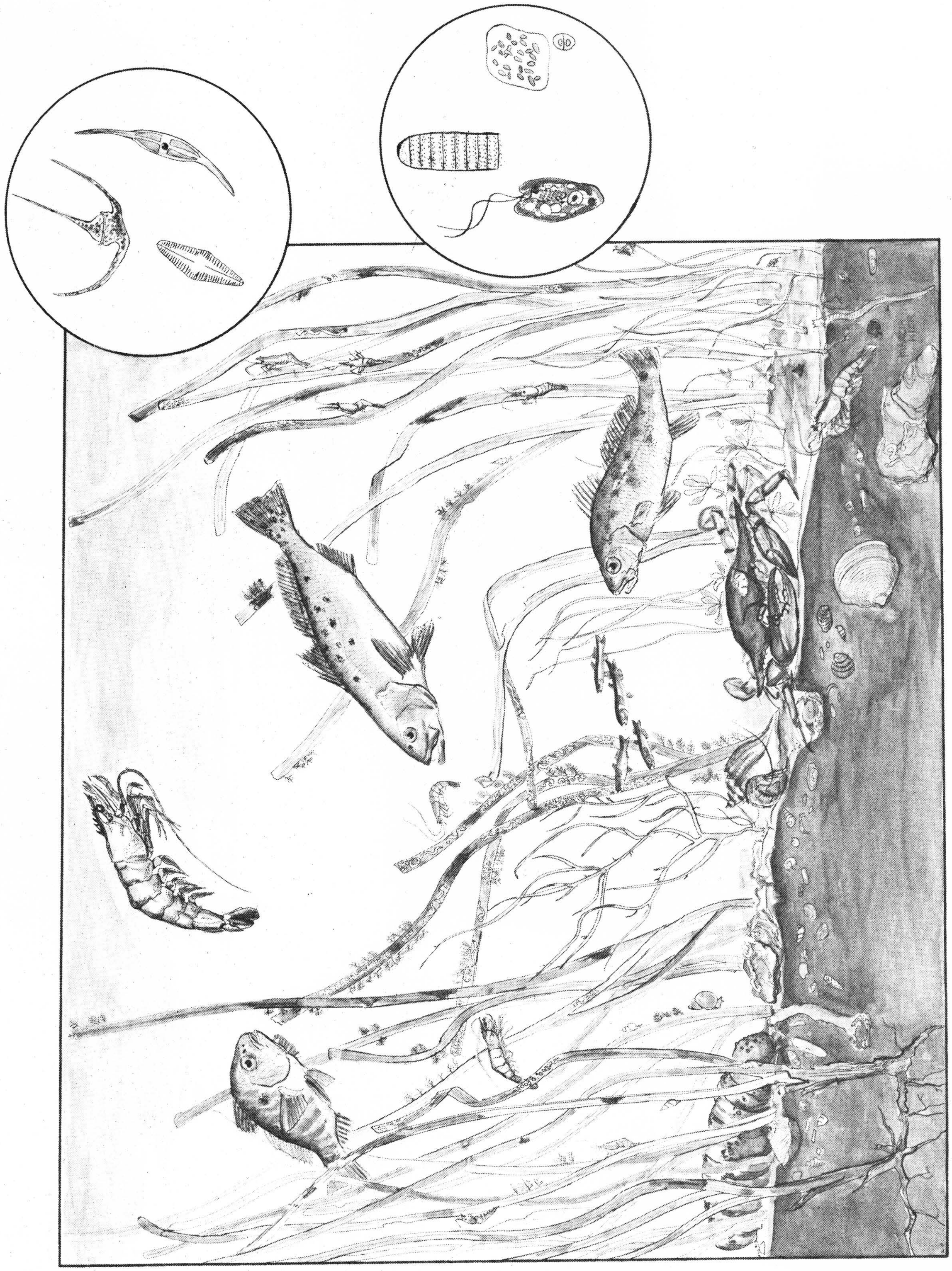
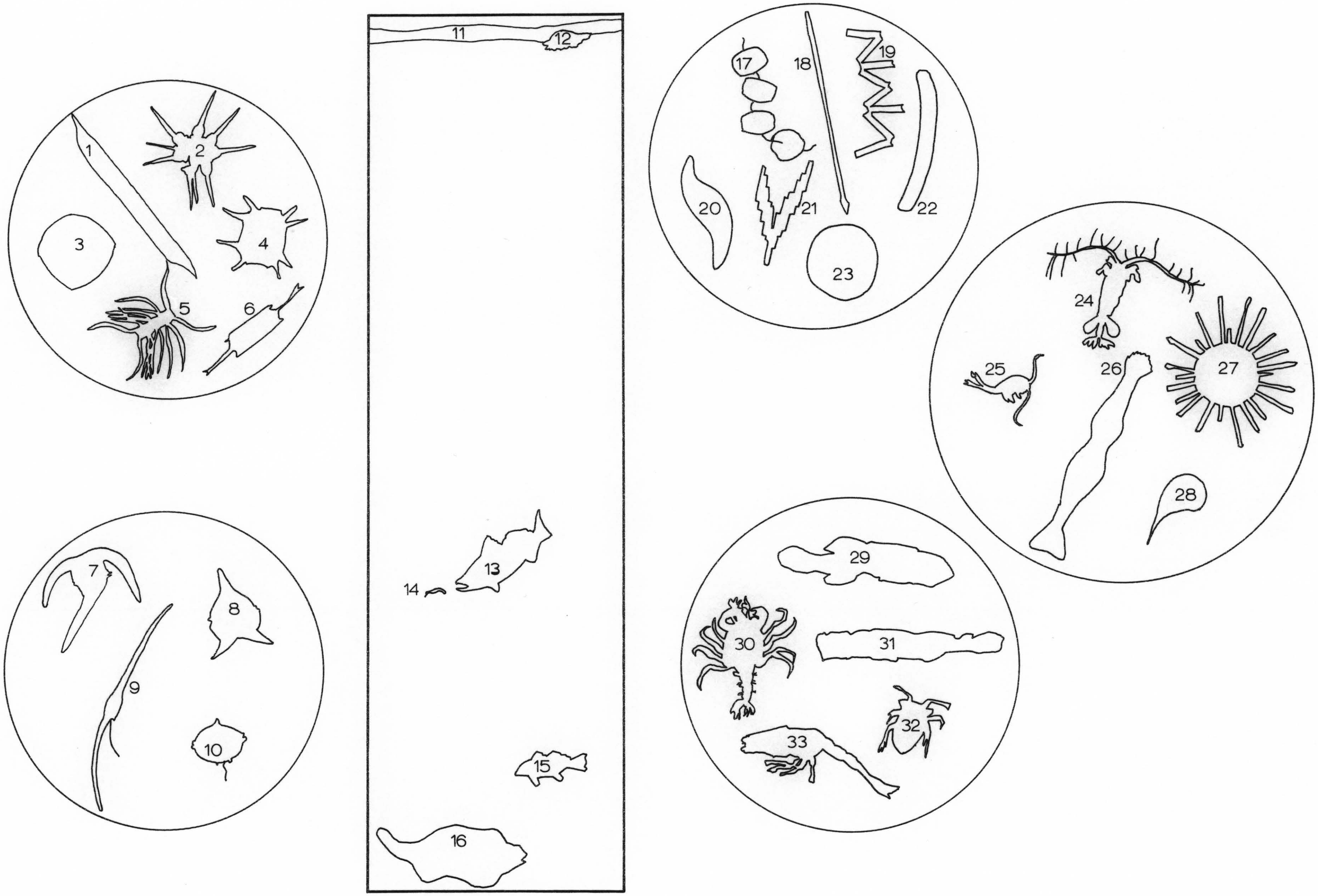


Figure 20

THALASSIA GRASSFLAT

1. Lagodon rhomboides - Pinfish
2. Penaeus aztecus - Brown shrimp
3. Cynoscion nebulosus - Spotted sea trout
4. Hydrozoan
5. Spirorbus sp. - Serpulid worm
6. Spirorbus sp. - Serpulid worm
7. Palaemonetes vulgaris - Grass shrimp
8. Cerithidea pliculosa - Horn shell
9. Neritina reclivata - Olive nerite
10. Gracilaria sp. - Red alga
11. Minidea beryllina - Tidewater silverside
12. Sciaenops ocellata - Juvenile redfish
13. Thyone sp. - Sea cucumber
14. Ophiothrix sp. - Brittle star
15. Odostomia gibbosa - Small gastropod
16. Clibanarius vittatus - Hermit crab
17. Neopanope texana - Mud crab
18. Callinectes sapidus - Blue crab
19. Halophila engelmannii - Sea grass
20. Halodule wrightii - Shoal grass
21. Phacoides pectinatus - Lucina clam
22. Thalassia testudinum - Turtle grass
23. Ensis minor - Razor clam
24. Rhitropanopeus harrisii - Burrowing crab
25. Chione cancellata - Venus clam
26. Phacoides pectinatus - Lucina clam
27. Penaeus duorarum - Pink shrimp
28. Phascolosoma gouldii - Mud worm
29. Ceratium sp. - Dinoflagellate
30. Nitzschia sp. - Diatom
31. Cymbella sp. - Diatom
32. Oscillatoria sp. - Blue-green alga
33. Dunaliella paupera - Saline euglenoid
34. Microcystis sp. (colony) - Green alga
35. Microcystis sp. (individual) - Green algae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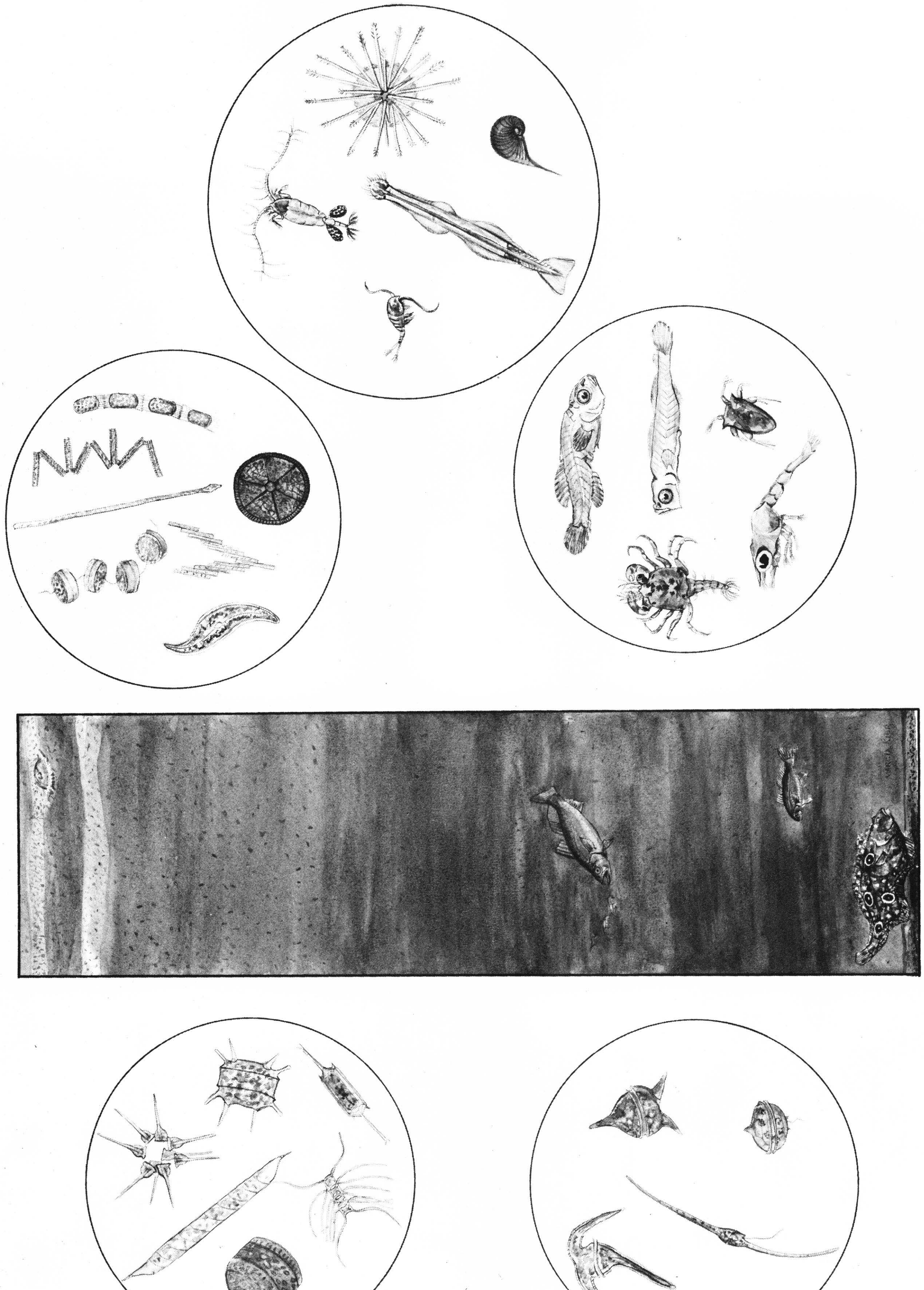

Figure 21

BAY PLANKTONIC

1. *Rhizosolenia styliformis* - Diatom
2. *Asterionella japonica* - Diatom
3. *Coscinodiscus radiatus* - Diatom
4. *Biddulphia mobiliensis* - Diatom
5. *Chaetoceros affinis* - Dinoflagellate
6. *Ditylum brightwellii* - Dinoflagellate
7. *Ceratium tripos* - Dinoflagellate
8. *Peridinium oceanicum* - Dinoflagellate
9. *Ceratium fusus* - Dinoflagellate
10. *Peridinium ornatum* - Dinoflagellate
11. Plankton bloom
12. *Aurelia aurelia* - Jellyfish
13. *Cynoscion arenarius* - Sand trout
14. *Penaeus aztecus* - Brown shrimp
15. *Leiostomus xanthurus* - Spot
16. *Ancylopsetta quadrocellatus* - Flounder
17. *Thalassiosira decipiens* - Diatom
18. *Thalassiothrix longissima* - Diatom
19. *Thalassionema nitzschioides* - Diatom
20. *Gyrosigma* sp. - Diatom
21. *Nitzschia paradoxia* - Diatom
22. *Skeletonema costatum* - Diatom
23. *Actinoptychus undulatus* - Diatom
24. *Calanus* sp. - Copepod
25. *Candacea* sp. - Copepod
26. *Sagitta macrocephla* - Arrow worm
27. *Aulacantha scolymantha* - Siliculose amoeba
28. Foraminifera
29. Larva of *Orthopristis chrysoptera* - Pigfish
30. Megalops stage of *Carcinus maenus* - Crab
31. Larva of *Lagodon rhomboides* - Pinfish
32. Nauplius of *Balanus* - Barnacle
33. Zoea stage of *Pagurus* - Hermit crab

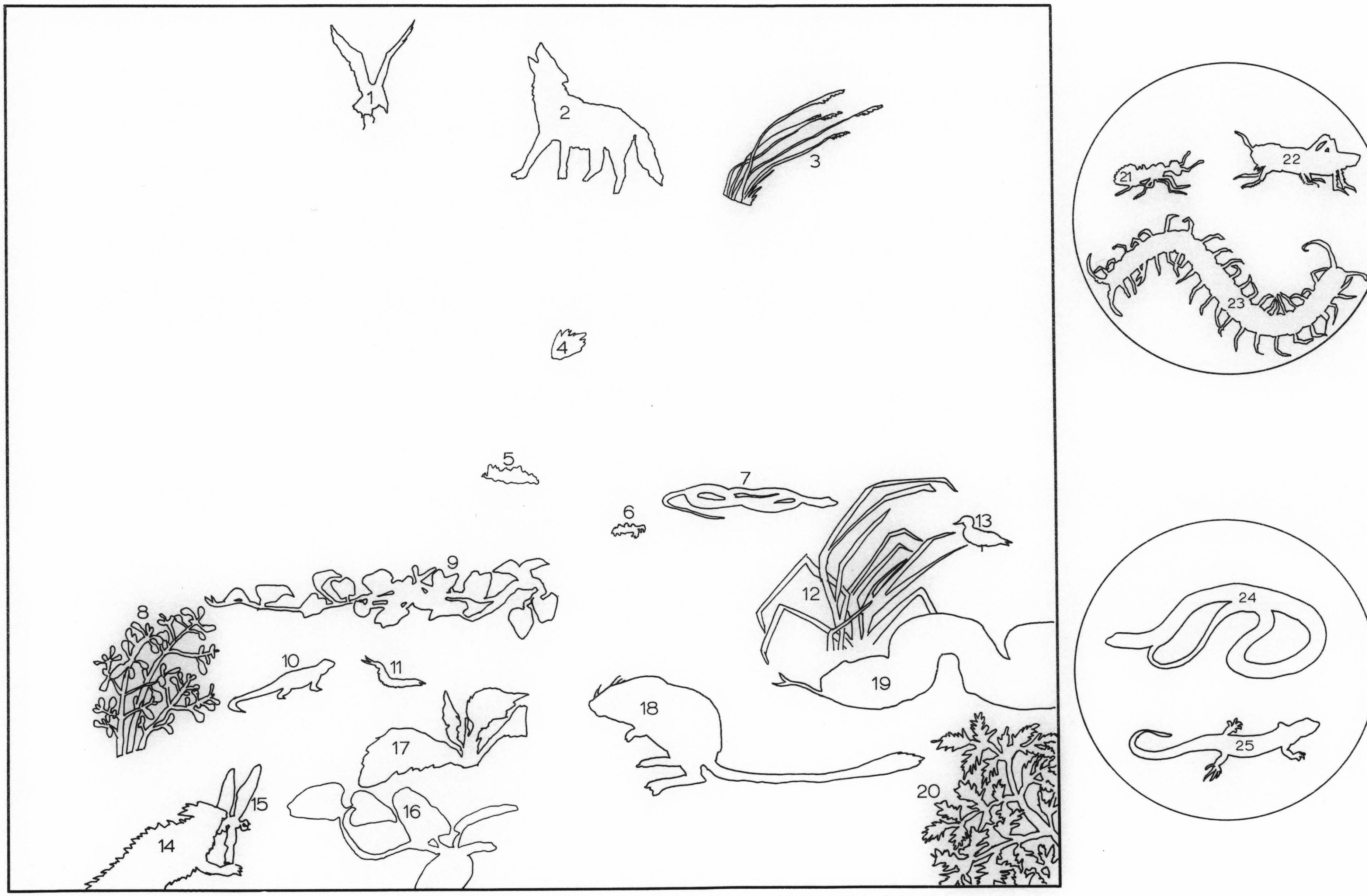
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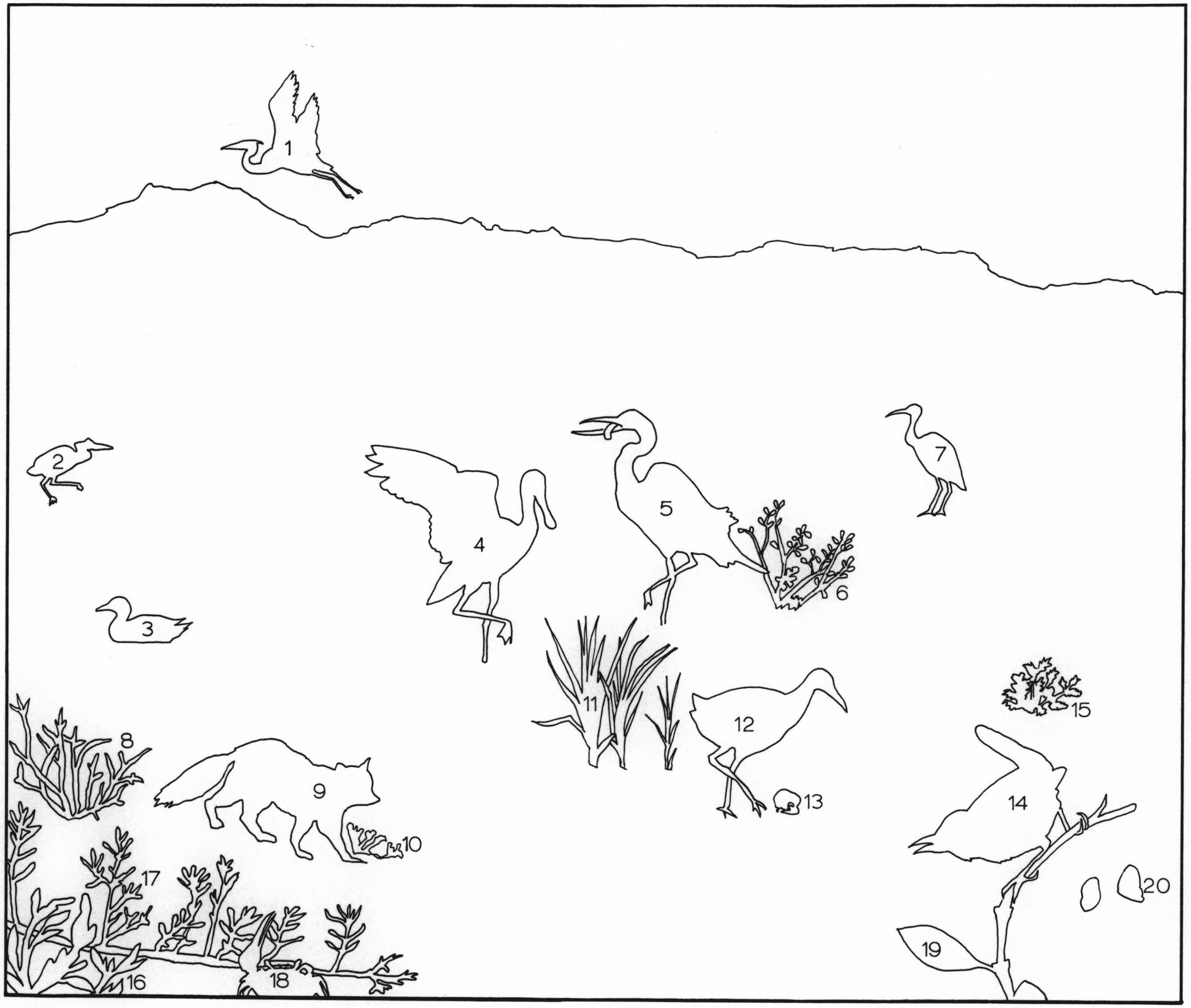
Figure 22

DUNE AND BARRIER FLAT

1. Larus atricilla - Laughing gull
2. Canis latrans - Coyote
3. Uniola paniculata - Sea oats
4. Andropogon littoralis - Seashore bluestem
5. Cenchrus incertus - Sand burr
6. Ocypode quadrata - Ghost crab
7. Masticophis flagellum testaceus - Western coachwhip
8. Croton punctatus - Beach tea
9. Ipomoea pes-caprae - Goatfoot morning glory
10. Holbrookia propinqua - Keeled earless lizard
11. Scolopendra sp. - Centipede
12. Panicum amarum - Bitter panicum
13. Crocethia alba - Sanderling
14. Phrynosoma cornutum - Texas horned lizard
15. Anax junius - Dragonfly
16. Ipomoea stolonifera - Morning glory
17. Helianthus annuus - Sunflower
18. Dipodomys ordii - Kangaroo rat
19. Crotalus atrox - Western diamondback rattlesnake
20. Helianthus sp. - Sunflower
21. Monomorium minimum - Little black ant
22. Schistocerea americana - Grasshopper
23. Scolopendra sp. - Centipede
24. Ophisaurus attenuatus - Glass lizard
25. Eumeces fasciatus - blue-tailed skink



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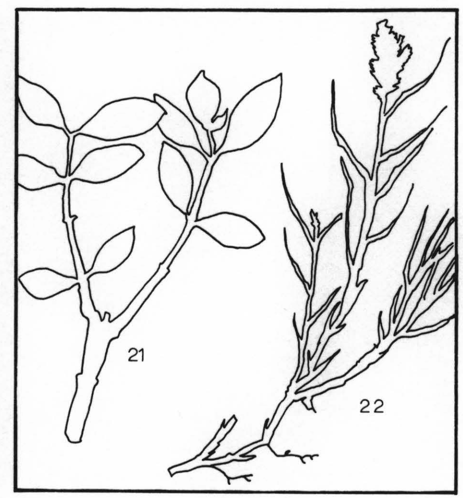

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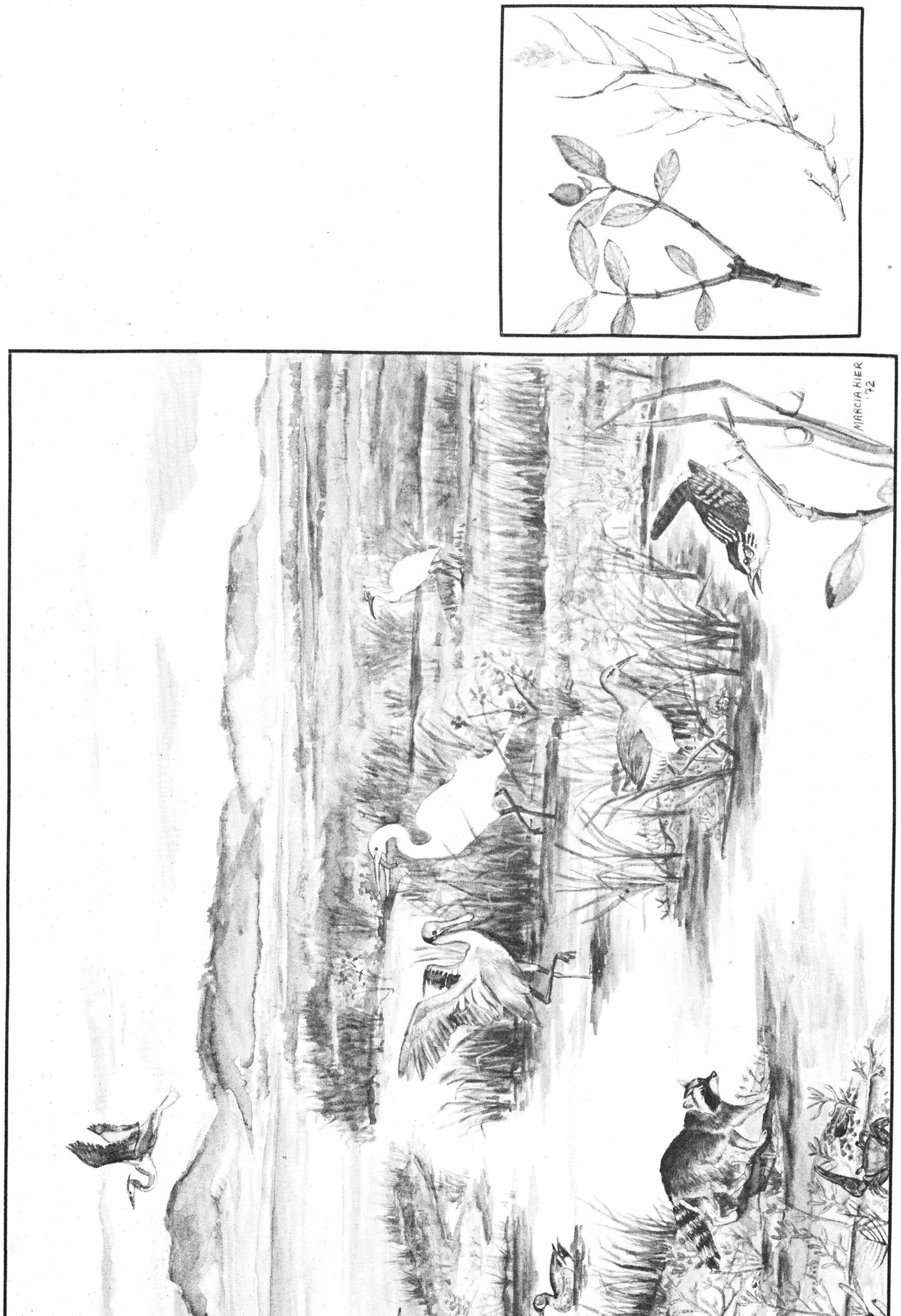

Figure 23

SPARTINA (SALT WATER MARSH)

1. Ardea herodias - Great blue heron
2. Butorides virescens - Green heron
3. Anas discors - Blue-winged teal
4. Ajaia ajaja - Roseate spoonbill
5. Casmerodius albus - Common egret
6. Avicennia germinans - Black mangrove
7. Eudocimus albus - White ibis
8. Salicornia bigelovii - Glasswort
9. Procyon lotor - Raccoon
10. Distichlis spicata - Saltgrass
11. Spartina alterniflora - Smooth cordgrass
12. Rallus longirostris - Clapper rail
13. Pagurus sp. - Hermit crab
14. Telmatodytes pulustris - Longbilled marsh wren
15. Croton punctatus - Beach tea
16. Sesuvium portulacastrum - Sea purslane
17. Batis maritima - Salt wort
18. Uca pugnax - Fiddler crab
19. Avicennia germinans - Black mangrove
20. Littorina irrorata - Periwinkle
21. Avicennia germinans - Black mangrove
22. Distichlis spicata - Saltgrass

TABLE 2

Land use changes in Acres of Biotopes for Phase I and Phase II development.

Symbol	Biotope	Phase I: Changed to Industrial Acres	Phase I: Changed to Channel or Basin Acres	Phase II: Changed to Industrial Acres	Phase II: Changed to Channel or Basin Acres
SF	Sand Flat	147	7	590	20
SB	Spoil Bank	30	67	297	6
T	Thalassia	574	201	1067	0
C	Channel	110	163	73	0
D	Dune	10	23	0	0
SP	Spartina	709	180	73	98
	Totals	1580	641	2100	124

Biological Impact

Dredging operations during construction and maintenance will be conducted using all precautions to keep the turbidity to an insignificant level. Dredged material will consist almost entirely of ancient Pleistocene clays and sands, shells and silt deposits which have not been exposed to man's recent activities. Cronin, Gunter and Hopkins (1971) indicate that moderate increased turbidity results in inconsequential effects on the environment. This statement should apply to the present proposed operation in view of the geographic location, large water movement and natural storm-caused turbidity of the water. All dredged material will be placed in dyked areas and as much runoff from the dredge discharge as is practical will be placed in rapidly mixing water areas.

According to Ketchum (1972, p. 128) the following criteria for selecting a specific port site are: (1) available real estate; (2) adequate submarine foundations; (3) suitable bottom material for channel dredging, submarine pipeline burial and minimum sedimentation; (4) anchor-holding capacity of the bottom; (5) adequate shelter; (6) minimum environmental impact; (7) minimum environmental risk to marine and coastal life if accidents occur; and (8) minimum secondary environmental impacts on shore and hinderland areas.

The Harbor Island site may be examined in view of the above criteria. Cargo and oil handling facilities have been in existence in the proposed port area since 1912. Most of the area has been modified by man over the past 100 years. A large portion of the area required is either owned by oil companies or Nueces County Navigation District No. 1, which is a political subdivision of the State. The channel is not new but it is proposed to be enlarged and deepened in virgin sediment with all material within practical limits being used for fill. Pipelines, water transportation (Gulf Intracoastal Canal) and highway transportation are immediately available and in operation, but will require increased capabilities of pipelines. Shelter will be provided by increasing the elevation of the land to 20 feet and constructing hurricane resistant facilities. Harbor Island is an area where large water movement exists which will facilitate subsequent dilution of by-products from either the construction or operation of the proposed Port Facilities.

Environmental Impact

The following discussion of environmental impact is given with the stipulation that (1) the engineering design of the Port Facilities will incorporate all proven innovations that will, to the extent possible, alleviate operational and accidental events that may harm the environment; (2) the design of the Port Facilities will include existing technological controls that will allow safe operation of the Port within the environmental impact guidelines and statements; and (3) that as new proven technological safeguards for environmental control become available they will be incorporated in the port facilities.

The guidelines also are designed to assume that an Environmental Control Officer will be assigned to these operations. He will be responsible at all times for supervision of all activities in the Harbor area and can initiate cleanup procedures at any time for environmental safety. This officer will have the authority to recommend to the Coast Guard that the port be closed at any time the environment may be endangered by accidental events or other events that occur.

Loss of Natural Environment

The area to be developed has been identified in terms of "biotopes" (Oppenheimer and Gordon, 1972) and presented in Table 2 in total acres involved and the percent of the area to be developed. The values were determined by both field examination and aerial photographic techniques. For convenience an overlay was prepared on an oblique aerial photograph as shown in Figure 17.

These biotope areas will be changed to industrial developed areas or channels.

Ecological Impact

The ecological impact will be described according to the following format (taken from Management of Bay and Estuarine Systems, 1972). Some instances will require overlapping descriptions. However, the graphical outline will provide the major significance of the port development to the area.

Table 3 is an impact chart showing the proposed activities identified with the Port development and a summary of the environmental changes produced.

TABLE 3
Environmental Impact Criteria

Activities / Environmental Changes To	Man: Recreation	Man: Archaeology	Man: Esthetics	Water Quality: Biological oxygen demand	Water Quality: Dissolved oxygen	Water Quality: Nutrients and dissolved salts	Water Quality: Pathogenic organisms	Water Quality: Floatables	Water Quality: Odors and Tastes	Water Quality: Color of water +	Water Quality: Suspended solids	Water Quality: Toxicity	Water Quality: Temperature	Air: Particulates	Air: Gases	Physical: Erosion and deposition	Physical: Subsidence	Physical: Hydraulics and current velocity	Physical: Hurricane effects	Biological: Photosynthesis	Biological: Consumers/food chain	Biological: Decomposition	Biological: Predation	Biological: Migration
Solid waste disposal	0		X	0	0	0	0	0	0	0	0			0	0					0	*#	*#		
" " accident	X		X	X	X	X	X	X	X	X	X			X	X				#	X	*X#	X		
Liquid waste disposal	0			0	0	0	0	0	0	0	0	0	0		0					0	*#	*#		
" " accident	X			X	X	X	X	X	X	X	X	X	X		X					X	*#	*#		
Gaseous waste disposal	0								0					0	0									
" " accident	X								X					X	X									
Dock construction																0		0	#					
Jetty construction																0		0						
Dredging, construction				X	X	X			X	X	X					*#		*#		X				*#
" maintenance				X		X			X	X	X					*#		*#		X				X
Sediment emplacement		0				#					X					0		0	#					
Rain runoff						#		X			M					X			X					
Shipping and docking	0																							
Utilities requirements			M																					
Commercial and sport fish							0	0													*#			*#
Recreation							0	0																
Hurricane effect						X					X					X		X						
Water exchange increase	#			#		#					M					*#		*#						
Pipelines transport															M									
Trucking															M									

No effect
0 Significant but controllable
X Temporary effect

* Significant long lasting negative change
\# Significant long lasting positive change
M Minor effect

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BIOTOPES OF CORPUS CHRISTI BAY
97°30'
25'
20'
97°15'
10'
5'
97°00'
50'
27° 45'
40'
35'
Aransas Pass
Ingleside
Portland
MUD ISLAND
ARANSAS BAY
Intracoastal Waterway
HARBOR ISLAND
Lydia Ann Is.
LYDIA ANN CHANNEL
SAN JOSE ISLAND
REDFISH BAY
La Quinta Channel
NUECES BAY
ARANSAS PASS CHANNEL
CORPUS CHRISTI SHIP CHANNEL
Port Aransas
CORPUS CHRISTI BAY
CORPUS CHRISTI
SHAMROCK ISLAND
MUSTANG ISLAND
OSO BAY
ENCINAL PENNINSULA
Fish Pass
Intracoastal Waterway
Corpus Christi Pass
Newport Pass
LAGUNA MADRE
LEGEND
Open beach
Gulf and shelf
Dune and barrier flat
Spoil bank
Jetty and bulkhead
Oyster Reef
Thalassia (Grass flat)
Spartina (Salt water marsh)
Juncus (Fresh water marsh)
Mudflat
Sandflat
Bluegreen algal flat
Hypersaline
Rivermouth
Bay planktonic
Undefined
Channel
Metropolitan Development
Shoreline
SCALE IN MILES
1
0
1
2
3
NSF-RANN, Bay and Estuary Management Program
Biological Uses Task Force
May 31, 1973