TEXAS AND THE GULF OF MEXICO

A general guide to marine science

in the Texas Gulf Coast region

Second Edition

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FOREWORD

Although many sources of information are currently available to marine science writers, editors, and others who work with ocean-related materials, the time spent in locating specific facts and figures about the oceans is a real obstacle to the person who continually battles a deadline.

It is our intent in compiling TEXAS AND THE GULF OF MEXICO to supply answers to some of the many questions concerning the marine resources of Texas and the coastal zone. The format has been designed to make information easy to locate within the eleven chapters of the book. A detailed table of contents precedes each section and a glossary of uncommon words and terms used in the report is provided. The first section of each chapter serves as a quick reference "fact sheet" about each topic. Following chapter sections report on each topic in greater detail.

TEXAS AND THE GULF OF MEXICO is not intended as an exhaustive encyclopedia on marine science. It is written in terms which are easily understandable by laymen and the general public. The scientific information included has been verified by outstanding scientists and engineers.

It has not been possible to include detailed elements of the marine involvement by all institutions nor has it been possible to cover all marine science in great detail. Although we have attempted to include accurate information in all instances, errors may appear. The enclosed sections of the book will be updated periodically and issued as supplements to book holders. We would appreciate comments and suggestions for improving the information contained herein.

The compilation of TEXAS AND THE GULF OF MEXICO has been partially supported by the National Sea Grant Program, National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

John C. Calhoun, Jr.
Director
Center for Marine Resources
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ACKNOWLEDGMENTS

The major effort involved in this second edition of TEXAS AND THE GULF OF MEXICO has been directed toward updating and improving the accuracy of the material presented previously. The general format of the first edition has been retained.

Regarding those sections which are primarily concerned with statistics, such as FISHERIES and PORTS & WATERWAYS, the reader is reminded of the usual lag time which exists in the availability of this type of information.

In the process of updating the ENGINEERING section, six new sections have been added.

We again acknowledge the valuable assistance of the following persons with the first edition: Dr. Sewell Hopkins, Department of Biology; Dr. George Huebner, Remote Sensing Center; Dr. Luis R. Capurro, Department of Oceanography; Dr. William Bryant, Department of Oceanography; Mr. John Miloy, Industrial Economics Research Division; Mr. Roger Anderson, Sea Grant Program Office; and Mr. Nirund Jivasantikarn, Biological Sciences; all from Texas A&M University, and Mr. Orman H. Farley of the National Marine Fisheries Service, Galveston, Texas.

We also greatly appreciate the help with this edition of Dr. Paul Crawford, Texas Petroleum Research Committee; Dr. Alan Lohse, Gulf Universities Research Consortium; Mr. T. K. Treadwell, Department of Oceanography; Dr. Wayne Ahr, Department of Geology; Mr. Ron Tomas, Department of Biology; Mr. John Miloy, Industrial Economics Research Division; Mr. Orman H. Farley, National Marine Fisheries Service, Galveston, Texas; Mr. Paul Versowsky, Department of Civil Engineering; who read and commented on all or parts of the manuscript.

Rosemary E. Boykin

TEXAS AND THE GULF OF MEXICO

Contents

GENERAL GEOLOGY OF THE GULF OF MEXICO

Contents

GENERAL GEOLOGY OF THE GULF OF MEXICO

A THE GULF AS A GEOLOGICAL LABORATORY

- Receives sediments from all the U.S. lying between the Rocky Mountains and Appalachian drainage divides, a total of 1,575,607 square miles. Total inflow from all surrounding lands is 261 cubic miles of water per year.

- Features the Gulf Coast *geosyncline*, the most important sedimentary basin still in the process of formation.

  Provides the only opportunity in North America for studying *stratigraphic* processes in a geosyncline.

  Extends less than 200 miles N of the present Texas shoreline with S limit believed to occur in the vicinity of the Sigsbee *Escarpment*.

  Contains a sedimentary trough filled with 50,000 feet of sediments (located off the Texas-Louisiana coasts); trough axis trends approximately E-W, paralleling the N margin of the Gulf.

  Explains to a large extent the composition of mineral deposits found onshore and offshore Texas and Gulf coast.

- Includes as many as 164 topographic features on the Continental shelf:

  Sigsbee Knolls - a series of submarine hills which rise as much as 1200 ft. above the Sigsbee *Abyssal Plain* in the central Gulf Basin.

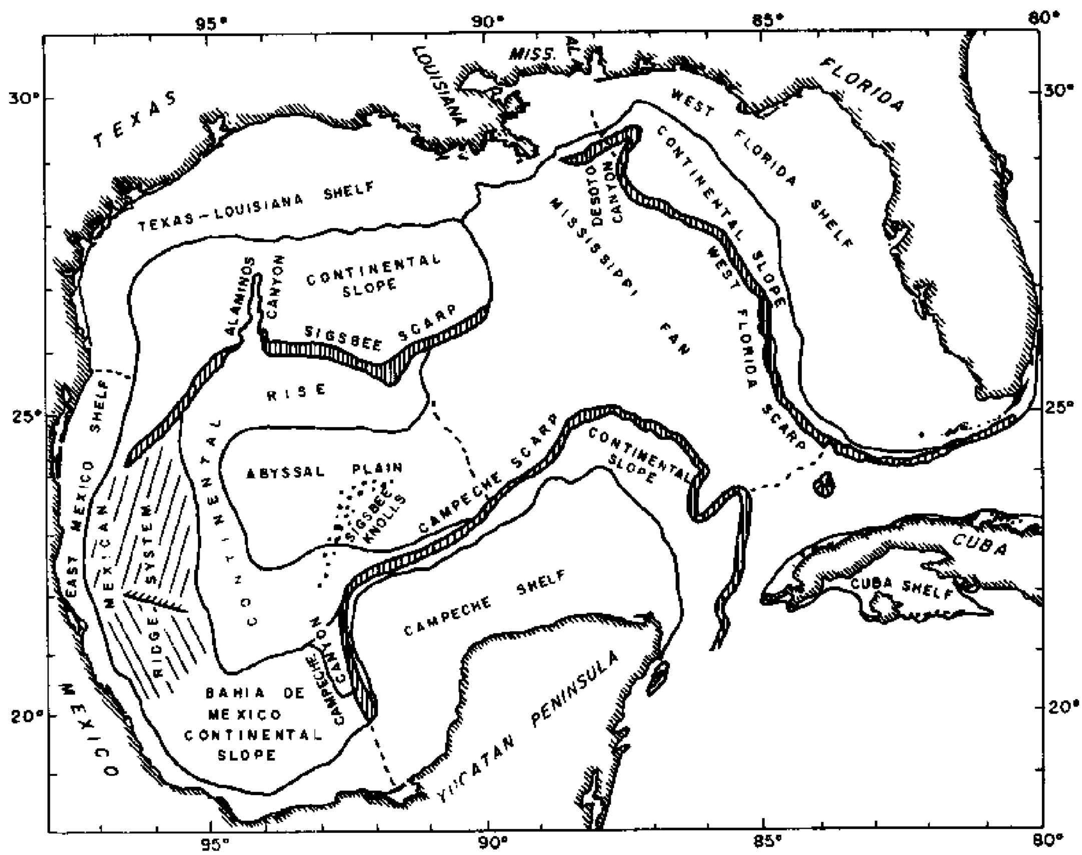
  Sigsbee Deep - deepest area in the Gulf of Mexico (12,425 feet), approximately 24°N, 92°W.

  De Soto Canyon - located off the Apalachicola R. of SW Florida; has a relief of about 600 ft., heads near the 240 Fathom (1440 ft.) contour, and terminates near the 500 Fathom (3000 ft.) contour.

  Mississippi River - brings to its mouth a daily load of sediment amounting to approximately 2 million tons.

Editor's Note: *Italicized* words are defined in the Glossary. Credit lines for figures refer to selected references.

- Depressions in N Gulf range to 2000 ft. deep and some of the hills have a relief of at least 2500 ft.
- Contains the northernmost living coral reef in North America.



Physiographic Provinces of the Gulf of Mexico
(Source: Bouma 1968)

B THE ORIGIN OF THE GULF OF MEXICO

- Time of origin has been estimated as being in the Late Paleozoic Era.

- There are two views regarding its origin:

    1. That the central portion of the Gulf was originally an extension of the coastal plain of the U.S. and that the present basin resulted from the collapse of this extension sometime during the Cenozoic Era.

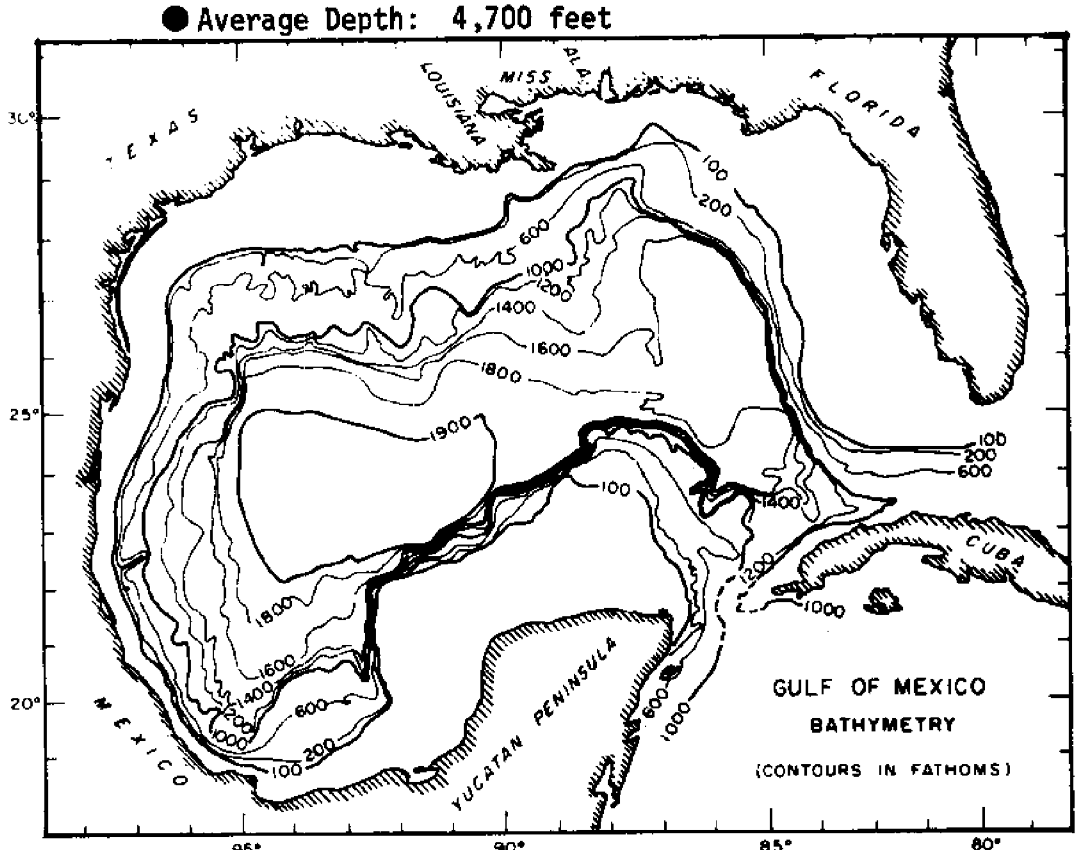
    2. That it is an ancient ocean basin.

- Recent geophysical data suggest that at least the central portion of the Gulf of Mexico is underlain by a typically oceanic crust. Some observers would take this as implying that it has always been a basin, but others regard such areas of *quasi-cratonic* nature as the sites of crustal collapse, extension and the development of new oceanic floor.

EPOCH	PERIOD	ERA
Recent Pleistocene	Quaternary	CENOZOIC 63 million years ago
Pliocene Miocene Oligocene Eocene Paleocene	Tertiary	
	Cretaceous Jurassic Triassic	MESOZOIC 230 million years ago
	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician Cambrian	PALEOZOIC 600 million years ago ?
		LATE PRECAM-BRIAN EARLY PRECAM-BRIAN

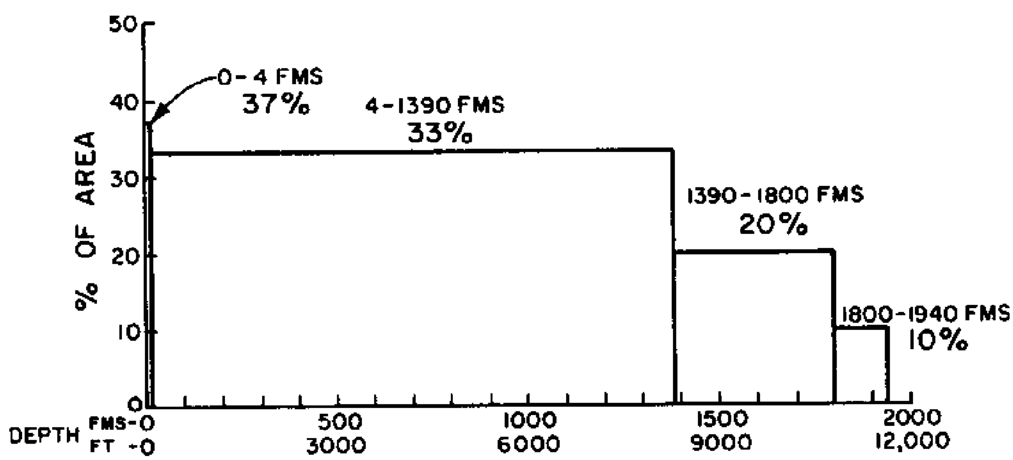
C DEPTH OF THE GULF OF MEXICO

- **Deepest Point:** Sigsbee Deep, 12,425 feet
- **Average Depth:** 4,700 feet



(Source: Harding and Nowlin 1966)

Bathymetric chart indicating ocean depth by use of lines called *isobaths* (or contour lines) which are drawn through all points in the ocean that are the same depth below sea level. For example, at the 100 fathom (600 ft.) line, all the waters beneath that contour line are 100 fathoms in depth.



Distribution of Depths in the Gulf of Mexico

(Source: Wilson 1970)

D MEASURING OCEAN DEPTHS AND SEDIMENT THICKNESSES

Basic methods for determining water depths:

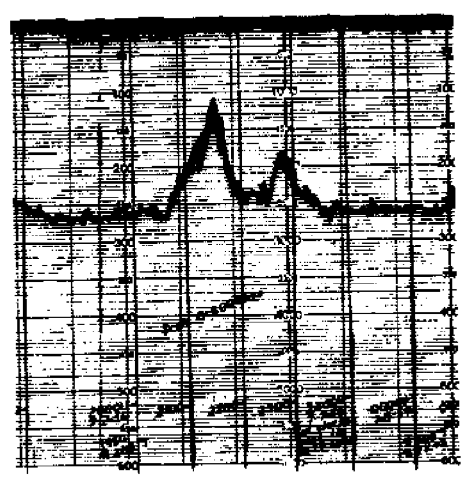
- Echo Sounding
- Seismic Profiling

Echo Sounding (sonar) along with a precision depth recorder uses a "pinger" that releases sound energy below the water surface. A small portion of this sound energy strikes the bottom, and an even smaller portion is reflected back to a hydrophone (a sensitive microphone) which converts the reflected energy into electrical impulses that are received by a ship-board depth indicator.

$$\textit{Time} \quad X \quad \textit{Speed} \quad = \quad \frac{\textit{Distance}}{2}$$

Time	Speed	Distance/2
(for pulse of sound to travel from ship to bottom and bounce back)	(of sound in water)	(from water surface to bottom)

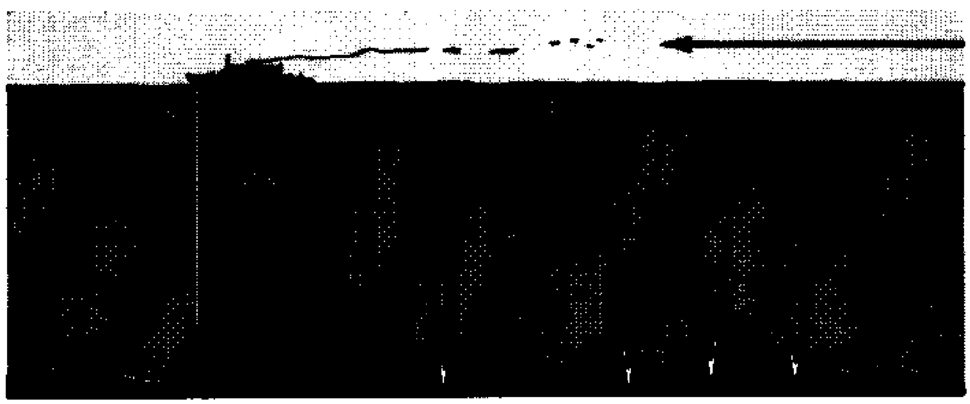
With this information the depth indicator is able to draw an accurate profile (echogram) of the land beneath the water.



(Source: U. S. Naval Oceanographic Office 1969)

Seismic Profiling to determine ocean floor composition makes use of sound waves from an underwater explosion triggered by one ship and picked up by another.

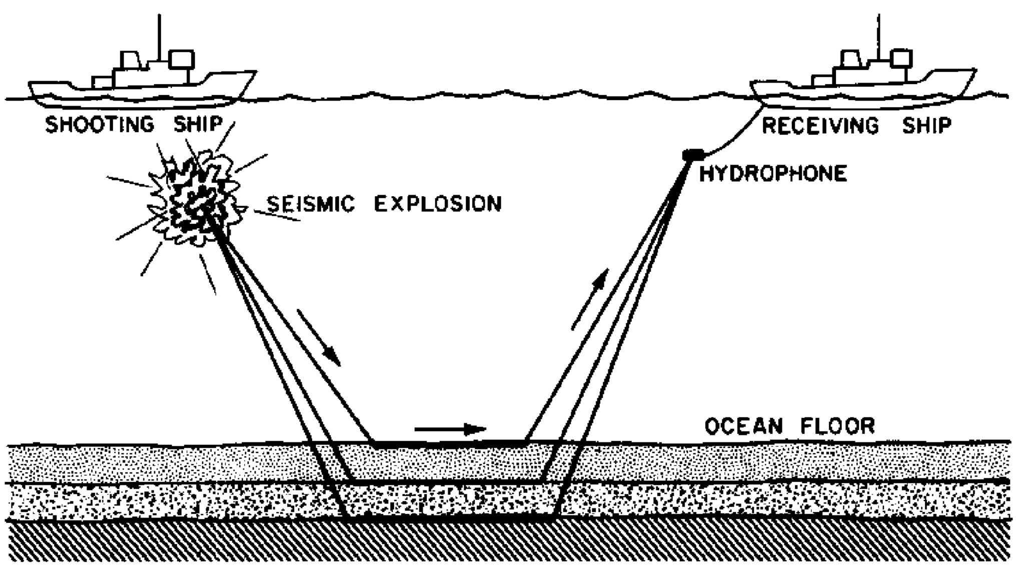
Seismic Reflection Profiling - high frequency, low penetration waves are reflected from interfaces. Both seismic explosion and the resulting shock waves may be picked up by the shooting ship. Shown below is the reflection of the shock waves off the surface. The same principle applies in detailing the subbottom features.



Seismic Reflection Profiling
(Source: U.S. Naval Oceanographic Office 1969)

Seismic Refraction Profiling - shock waves are transmitted by layers of sediments and crust. Their traveling time is recorded by a second ship some distance away.

By studying arrival times and patterns of these sound waves, geologists can determine something of the nature of the layers through which the waves have passed.



Seismic Refraction Profiling

E THE CONTINENTAL SHELF AND SLOPE

General Characteristics

Width varies from 8 to 117 miles in N Gulf, the maximum width being off W Florida.

In the NW and S Gulf, the widest portions are found off Texas and W coasts of Yucatan Peninsula.

Narrowest portion of the Gulf of Mexico shelf is off E coast of Mexico.

Steepest portion is off W Florida.

Less steep off the N shelf and is characterized by extremely *hummocky* (hilly) topography.

Also steep in extreme S portion of the Gulf and is broken between the Isthmus of Tehuantepec in the Bay of Campeche and the Yucatan Shelf by the Campeche Canyon.

Adjacent to Yucatan Shelf, slope is steep and continuous down to the abyssal plain.

Sediment Composition

Most of shelf W of Florida peninsula is hard rock, chiefly limestone, but a thin veneer of *detrital* sediment is present in local areas and fills some of the shelf depressions.

Quartz is the dominant component of the sands found on the narrow shelf off the NW coast of Florida and off Alabama.

> Quartz sands extend W to coastal Mississippi where they become mixed with silt and facies delivered by rivers that flow into Mobile Bay.

W toward the Mississippi Barrier Islands, the deltaic *mudflats* overlap the sediments of the shelf zone and sands and silts exist in places beneath and incorporated in the deltaic deposits.

Sandless terraces extend W to the central coast of Louisiana, where some sands and silts begin to appear once again on the sediment surface.

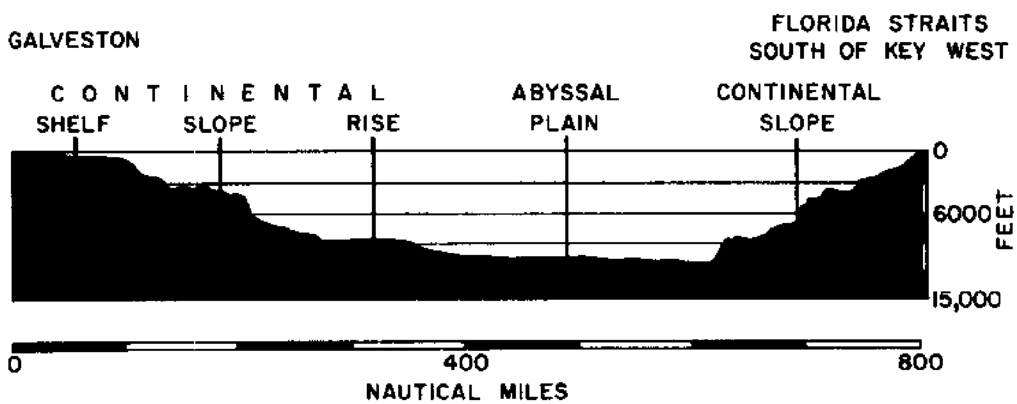
The N and NW continental shelf contains *knolls, mounds, ridges* and *domes*. Most knolls and mounds are capped by *algal reefs* which formed during a low stage of sea level during the *Pleistocene* (1 million years ago); many are caused by upward movement of salt masses.

Near Vera Cruz, coral patch reefs and mixed *carbonate-clastic* sediments constitute the sediment veneer.

The mixture of coral patch reefs and mixed sediments extends around the S margin of the Gulf to the Bay of Campeche, adjacent to the Isthmus of Tehuantepec.

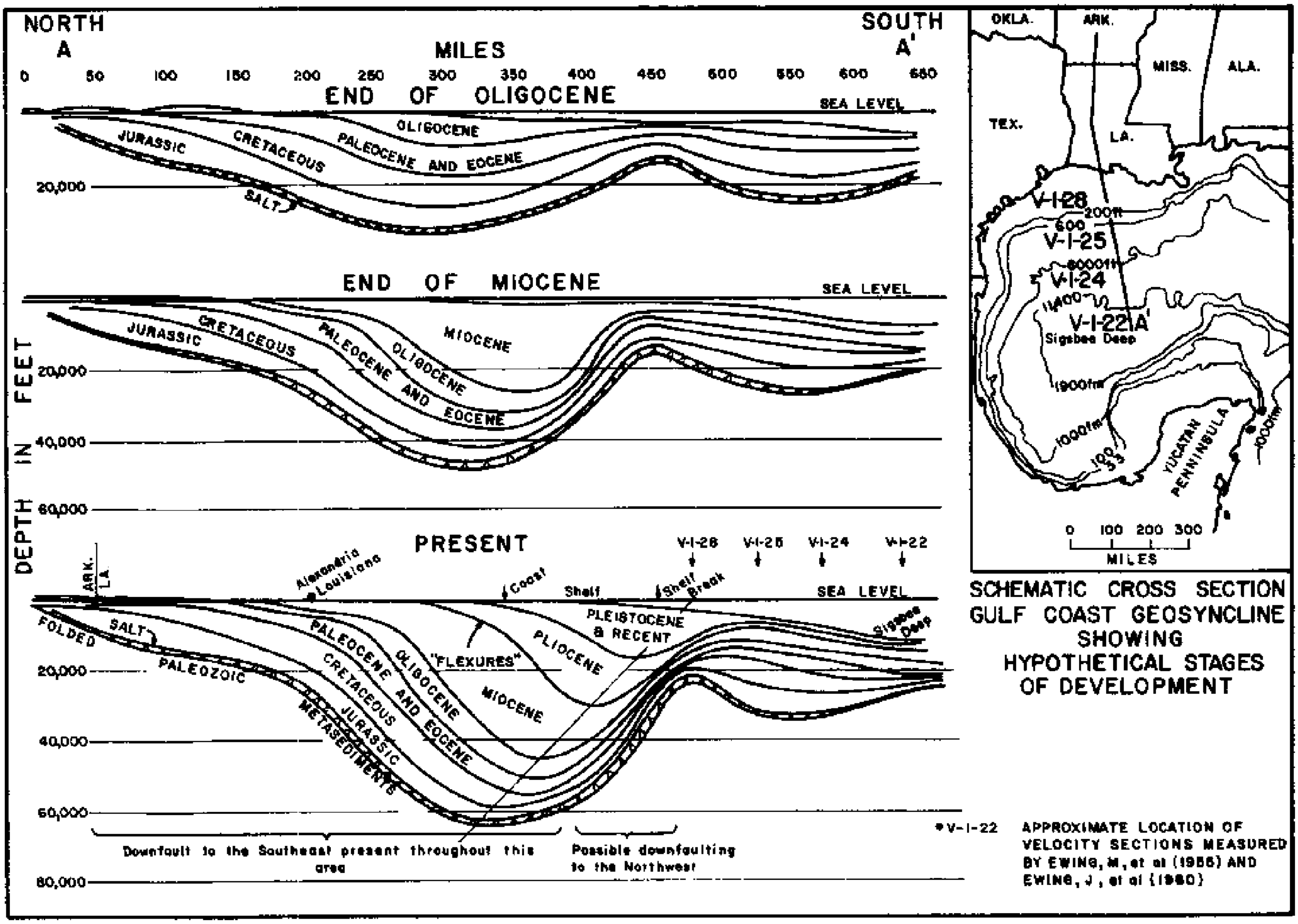
The Yucatan Platform, like the shelf off W Florida, is an extensive carbonate plateau and, like Florida, is an extension of the *Karst* surface of the mainland.

The Yucatan Shelf, broken by terraces in the form of breaks in the gentle seaward slope of the shelf, also contains an accurate line of coral reefs and non-reef-supporting mounds.



Cross Section View of Gulf of Mexico on a Line Between Galveston and the Florida Straits South of Key West

(Source: After Murray 1961)



(Source: After Hardin 1962)

These sections represent hypothetical stages in the development of the Gulf Coast geosyncline. The area of greatest subsidence moved progressively seaward as the location of the greatest thickness of sediments deposited during each unit of time moved seaward.

All ages of rocks within the Gulf Coast geosyncline contains hydrocarbons at one place or another.

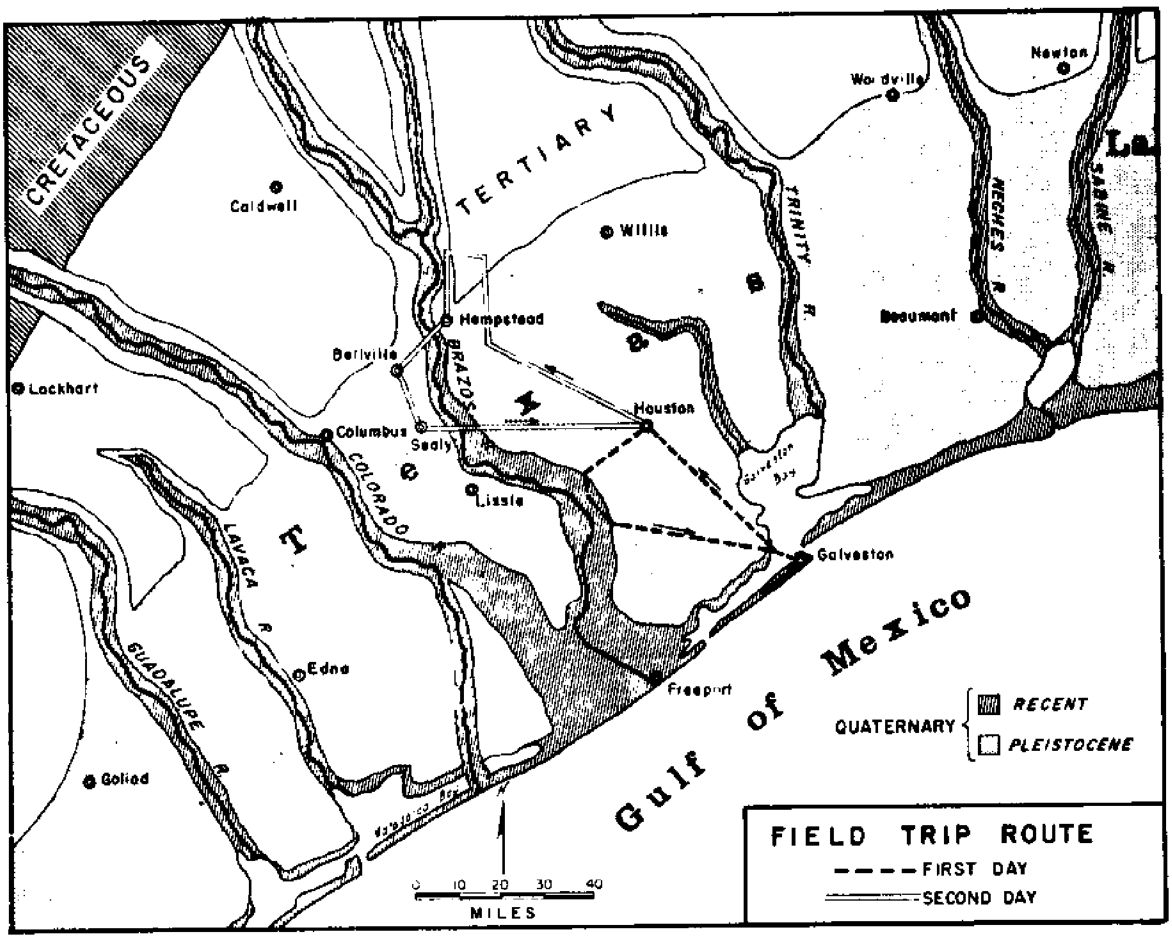
Data for the above figure were obtained both from the drilling of many thousands of oil wells and from seismic profiling.

F DEVELOPMENT OF MODERN LANDSCAPE

The present coastal landscape consists of land forms created over a million years ago when deltas built the coastal plain seaward.

During a period of lowered sea level, about a million years ago, the coastal rivers became entrenched into the coastal plain to form the present river valleys.

About ten thousand years before the present, during a stage of rising sea level, the entrenched river valleys became filled with riverborne sediments. Those valleys, not previously filled, became flooded by the rising sea level to form those existing bays whose long axes are normal to the coastline.



The Quaternary Coastal Plain of Southeast Texas

(Source: Hardin 1962)

Barrier islands, such as Galveston, were formed as recent as 4000 years ago to create a second suite of bays (lagoons) whose long axes are parallel to the coastline.

G SEA LEVEL

The oceans are generally rising along most shores of the United States.

Recent studies show that the sea has risen about one foot during the past 100 years on the Atlantic and Gulf of Mexico coasts.

Scientists differ as to whether the sea is rising or the land is subsiding, but the practical effect is the same since the water is inundating the land to a greater extent than before. Many believe it is a combination of both, caused by a number of factors, including the melting of glaciers and the removal from the ground of increasingly large supplies of water and petroleum.

Measurements of the sea level each hour around the clock are collected from 115 manned tide stations along the U. S. coasts. Forty-three of these have been operating continuously since at least 1940, and this has made it possible to establish a common series of readings for comparison over a lengthy period.

Key points along the Gulf coast where sea level has been monitored for 30 years or more are:

Site	Years monitored	Sea level change
Pensacola, Fla.	47	6.24 inches
Eugene Island, La. (near St. Charles, La.)	31	1.2 feet
Galveston, Texas	62	1.27 feet

The sea level at Eugene Island, La. (near St. Charles, La.) has shown the greatest rate of increase over the past 30 years, slightly less than one-half inch annually. Since 1940, the sea level there has risen 1.2 feet. At Galveston, Texas, where records have been kept since 1910, the water has risen 1.27 feet, but at a rate of about one-half that at Eugene Island.

The pronounced drop in sea level along the U. S. coasts has been recorded at Juneau, Alaska where the water has fallen almost 1.6 feet since 1940.

H TOPOGRAPHY AND SEDIMENTARY CHARACTERISTICS

Provinces of the Gulf

- The central basin of the Gulf is divided into three provinces:

  Sigsbee Abyssal Plain - exceptionally flat area, partially covered by sediments associated with the Mississippi Cone may be one of the flattest portions of any sea floor.

  Continental Rise - represents a build-up of sediments transported from the N toward the basin.

  Mississippi Cone - dominates the floor of the Gulf; a cone-like accumulation of sedimentary detritus, primarily from the Mississippi River discharge and transport of sediments by the River inflow.

General Characteristics of Gulf Regions

- The Northeastern Gulf

  Florida Escarpment - separates the Florida Platform from the Basin and also forms the E side of DeSoto Canyon.

  DeSoto Canyon - E edge of Canyon approximates the eastern limit of the shallow piercement salt domes.

- Bay of Campeche

  Similarities between the Bay of Campeche and the continental margin of the N Gulf coast are striking. Both are great oil producing areas with much of the production associated with the salt domes. Both areas are characterized by great thicknesses of Tertiary clastic sediments.

- Northern Gulf

  Includes the continental shelf and slope of the northern Gulf from the DeSoto Canyon to the U.S./Mexico border.

  Gulf Coast Geosyncline - major structural element within this region. Its landward limit is considered to be the outcropping Mesozoic and basal Tertiary sediments approximately 200 miles N of the present shoreline.

  Widespread Salt Domes - salt deposits comprising a dynamic structure-forming agent acting throughout the entire N Gulf region (see section on Salt Domes in the Gulf).

- <u>Mississippi Delta</u> - silt and "mud" deposits are in excess of sand on the Delta; W from the Delta is a clay-silt zone with some sand and shells; dark gray to black "mud" is present in most of the lagoons.

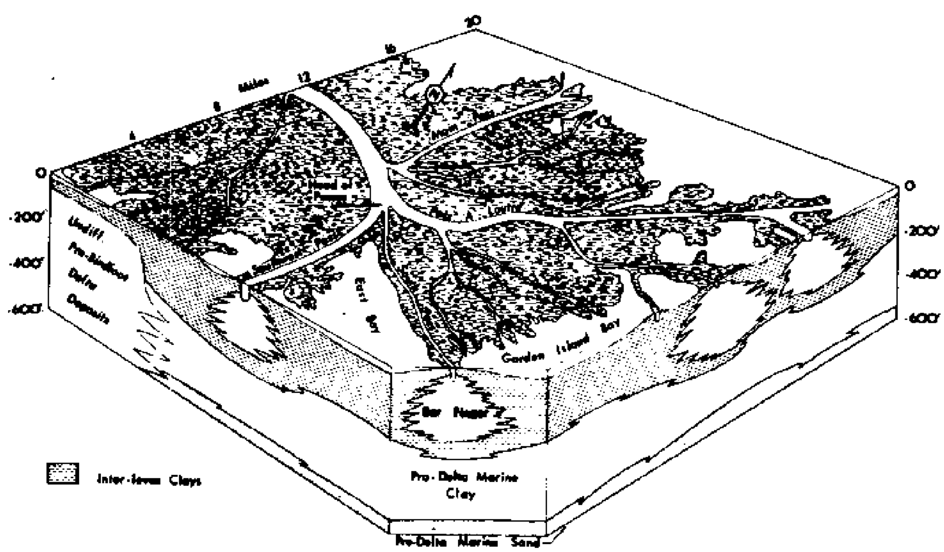
    Mississippi River brings to its mouth a daily load of sediment approximating 2 million tons.

    Upwellings of clay, locally known as mudlumps, occur uniquely near the mouths of Mississippi River passes.

    Mudlumps and mudlump islands may have mud cliffs with a relief of up to 10 feet in an area where the average relief is generally 2 feet or less.

    Cause of mudlumps: probably excessive sedimentation at the river mouth.

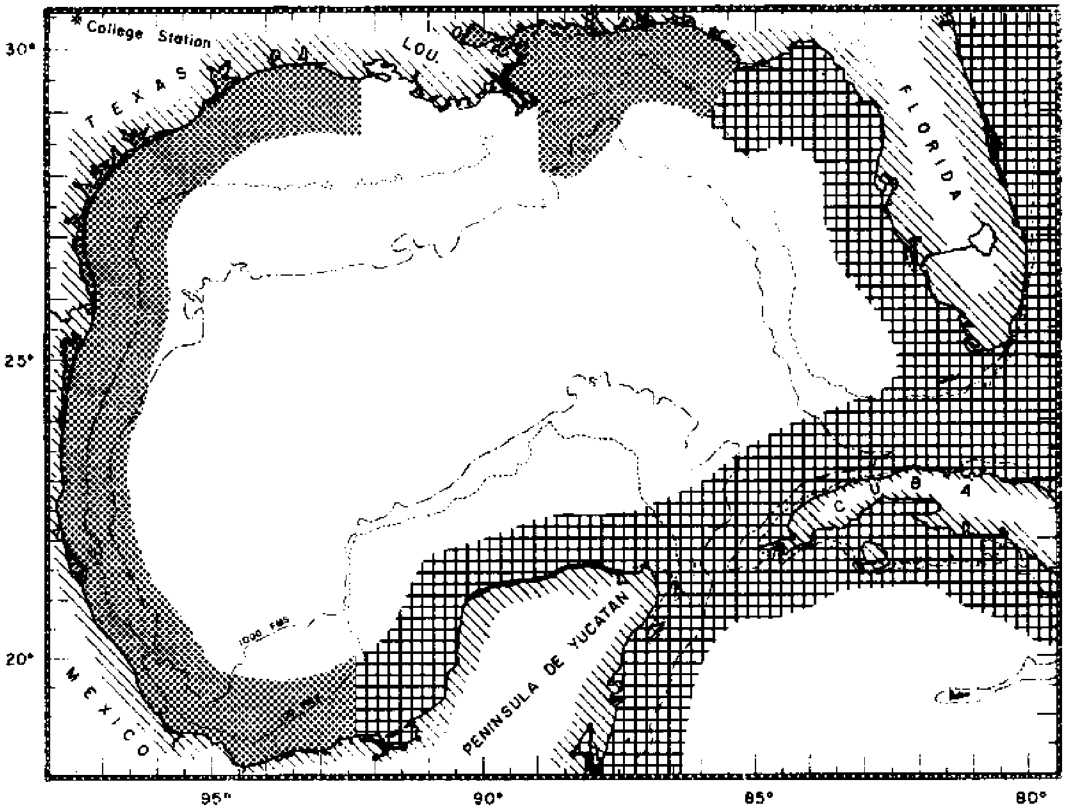
    Drainage area of the Mississippi River: 1,257,000 square statute miles.



The Birdfoot Delta of the Mississippi River

(Source: Murray 1961)

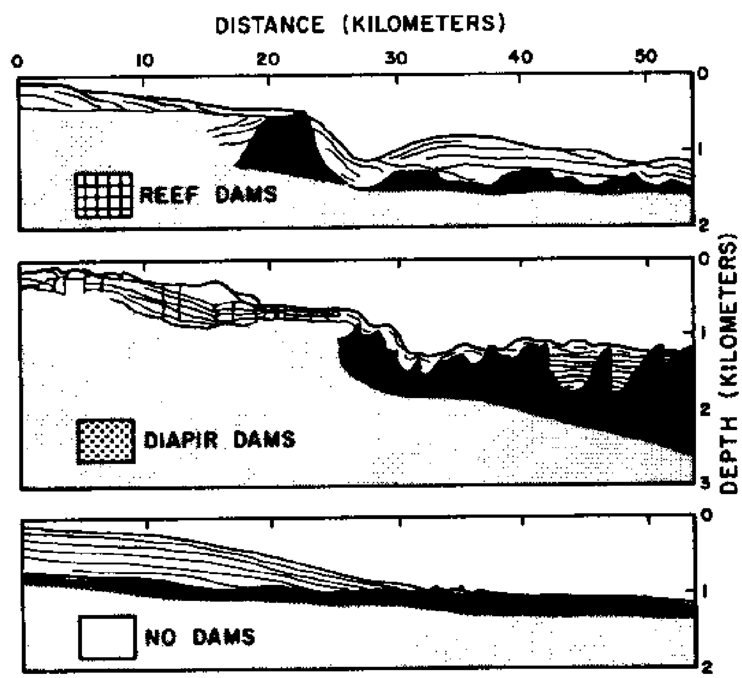
I UNDERSEA DAMS IN THE GULF



(Source: Emery 1969)

The Continental Shelf off the W part of the Gulf Coast contains a series of *diapirs*, formed by the upward movement of salt from a bed that is buried several miles deep and is about 150 million years old.

An algal reef dam is located in the Eastern Gulf. It dates from 130 million years ago and was succeeded by a coral reef off Florida at some time before 25 million years ago.

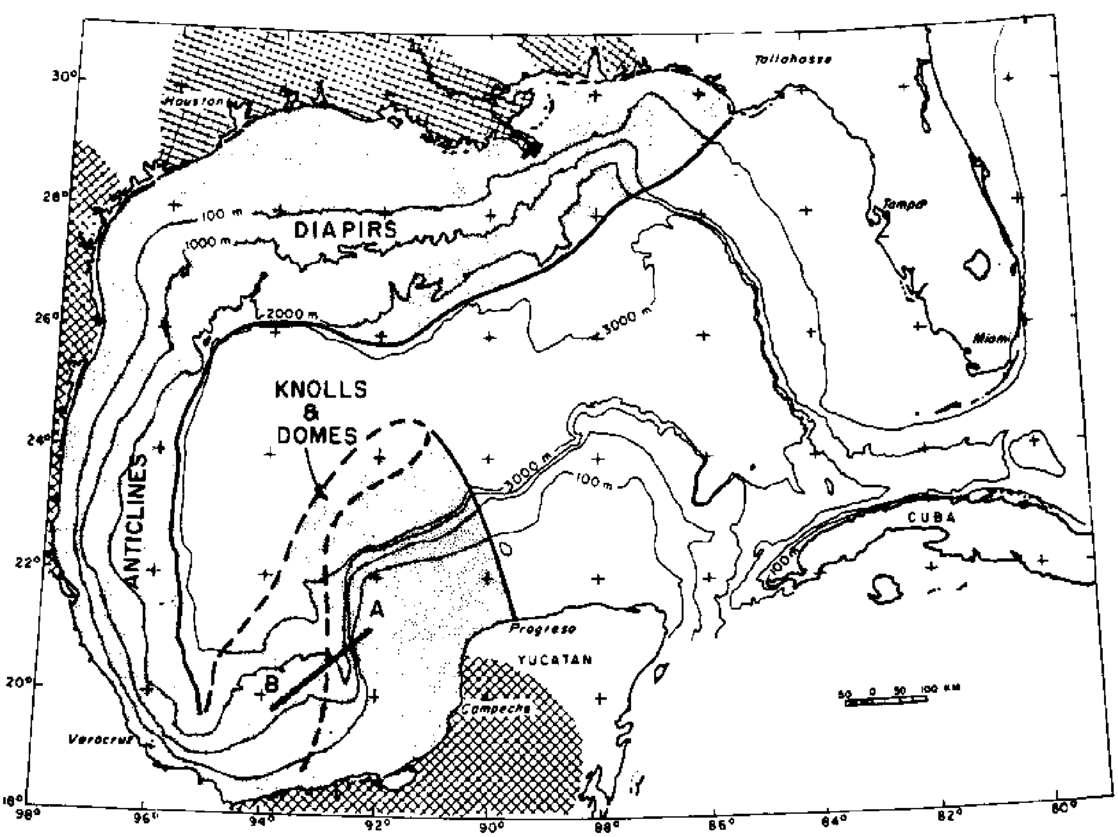


J SALT DOMES IN THE GULF OF MEXICO

- As of 1968 more than 400 salt domes are known from drilling alone, and thousands more are indicated by geophysical measurements in the Gulf of Mexico.

- On the continental shelf these salt structures are usually subsurface, but on the slope they are seen as topographic features and form a "hummocky" (haphazardly arranged mounds) zone.

- Importance of salt dome structures in the Gulf lies in the association of salt diapir formations with offshore oil production; however, "diapir" denotes piercement of overlying rock layers by salt. Not all oil is associated with piercement domes; not all domes are diapiric. Non-piercement domes are common and may be related to oil and gas.



Area of salt deposits in the Gulf of Mexico. This estimate may be conservative; some geologists think the salt may extend into Florida.

(Source: Antoine and Bryant 1969)

The results of the Deep Sea Drilling Project (DSDP) (see section on the Glomar Challenger in the Gulf, p.1-17) in the deep basin of the Gulf confirmed the hypothesis that the Sigsbee Knolls and domes are salt diapirs.

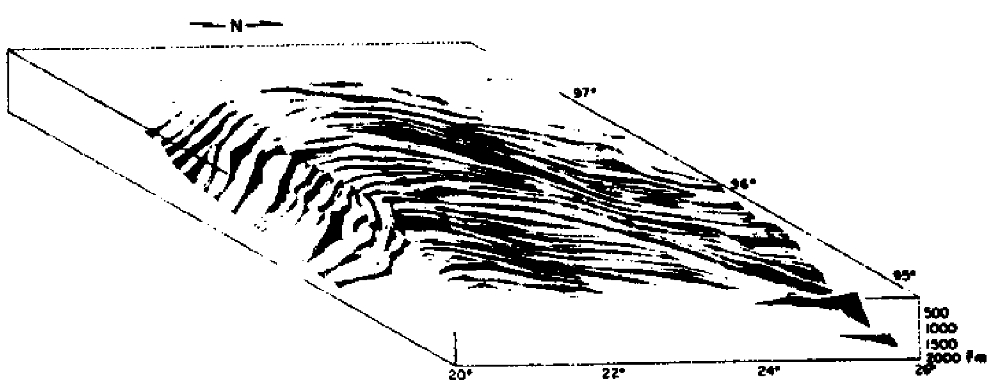
<u>Origin of the Knolls</u> may be explained in two ways:

(1) The Gulf was a shallow sea during latest Triassic and Jurrassic time (the age of the salt). Thick salt deposits accumulated across the entire sea, including the present Sigsbee Deep. Later, the central part subsided, received great amounts of sediment, and the Sigsbee Knolls and domes intruded the overlying sediment cover.

(2) The Gulf has always been a deep basin and during Triassic and Jurassic times, salt was deposited in the shallow marginal areas and in the deep central basin. The diapirs subsequently began to form.

Recent data from DSDP suggest that the Sigsbee scarp represents the southernmost extent of the salt of the N Gulf region and that the trend of the Sigsbee Knolls and domes is the N extent of the migration of salt from S Mexico.

Not only are there salt domes and knolls, but also salt ridges in the Gulf coastal plain, such as those shown below:

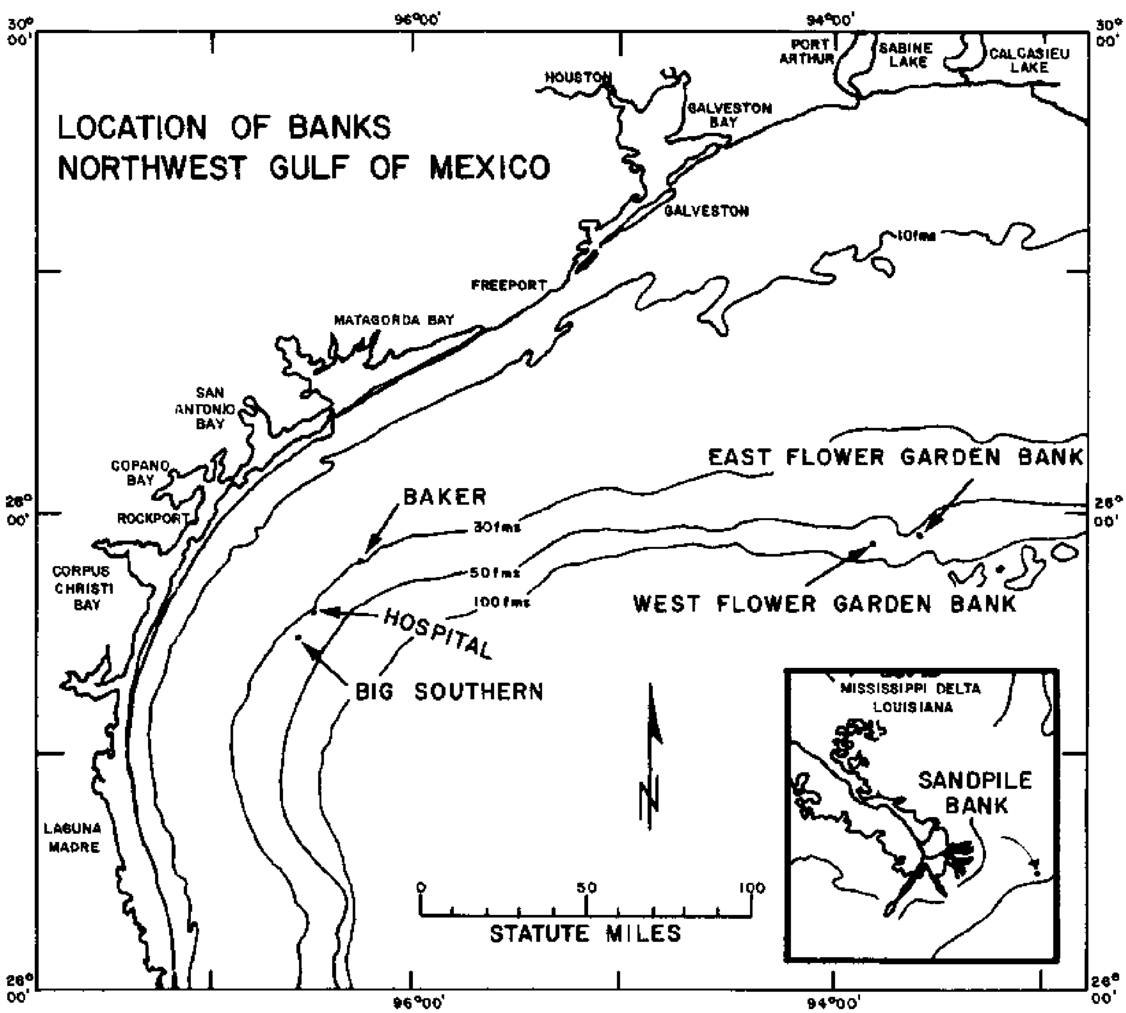


Physiographic drawing of Mexican continental shelf and slope between 20° and 26° N lat.

(Source: Antoine and Bryant 1969)

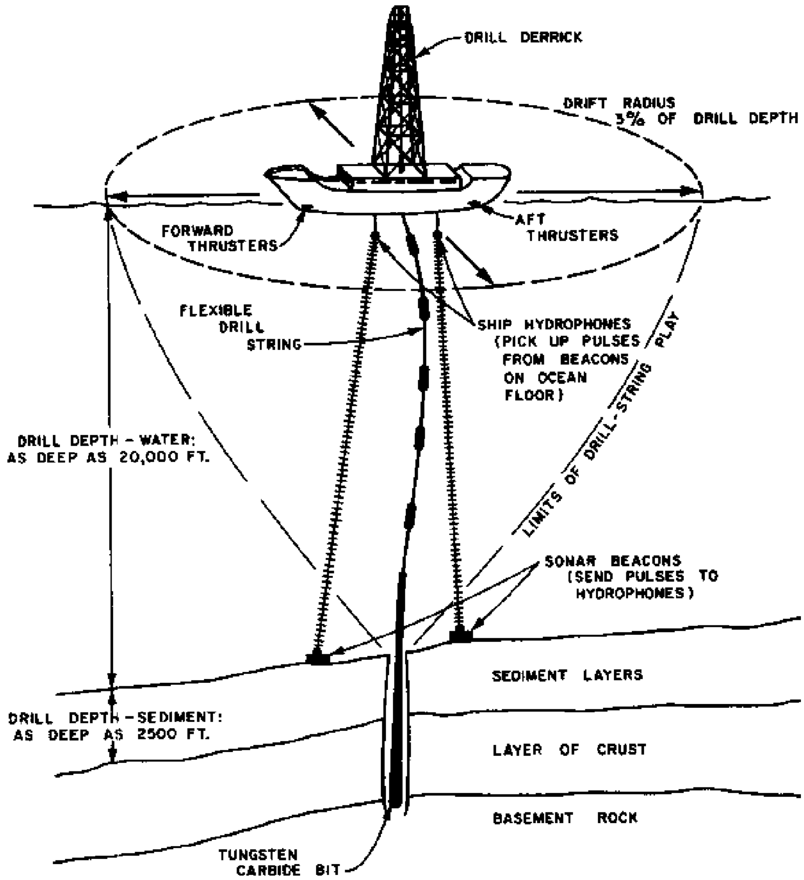
K FLOWER GARDENS REEF

- Lies approximately 110 nautical miles S-SE of Galveston; considered to be the northernmost living, shallow water coral reef in the Gulf and Atlantic Ocean.
- Crest of reef is approximately 1.5 miles long and about 3/4-mile wide. Depths on crest of reef vary from 60 to 80 feet, and on a calm day the bottom may be clearly seen from the deck of ship.
- Sub-bottom profiles show reef to be underlain by a salt dome.
- Origin of name: Fishermen bringing up fragments of coral in their nets called the area Flower Gardens.
- Other coral banks exist in Gulf but are not living.



(Source: After Murray 1961)

L THE GLOMAR CHALLENGER IN THE GULF



HOW SONAR KEEPS GLOMAR CHALLENGER
IN POSITION TO DRILL
(AFTER PHOTO BY SCRIPPS)

Looking like a lighted Christmas tree by night and a floating oil well derrick by day, the GLOMAR CHALLENGER is a unique oceanographic vessel equipped to drill through as much as 20,000 feet of moving, often rough, water and penetrate the sea floor half a mile.

Owned by Global Marine of Los Angeles, California, she has the world's record for drill penetration in the deep ocean when she drilled into the sea bed 2,528 feet through 12,327 feet of water in August 1968.

She navigates through the use of a satellite data system.

Her drilling pipe weighs over half a million pounds. The core bit is sometimes covered with diamonds, the hardest mineral we know, and sometimes covered with metal blades. This bit drills into the sea bottom to make its hole and, periodically, a coring pipe is rammed into the hole to take a sample of the sediment or whatever happens to be in the hole.

The real feat is to keep the turning drill pipe in position and almost straight, while the GLOMAR CHALLENGER manages to stay in almost exactly the same position on an always moving, sometimes rough, sea. Sonar is used to keep the ship in position on drilling sites too deep for anchoring. Through the use of beacons on the sea floor sending pulses through hydrophones to computers the forward and aft thrusters and propellers keep the ship almost exactly over the hole in the sea floor. Allowances are made for some play in the drill stem.

WORK ON THE SIGSBEE KNOLLS

The Sibsbee abyssal plain is the deepest flat portion of the Gulf of Mexico where perimeter depths range from 11,875 ft. to 11,930 ft. This area is approximately 240 nautical miles long and 180 nautical miles wide.

Its regular surface is broken only by the presence of several knolls, some rising as high as 350-400 ft. above the abyssal plain.

The first knolls were discovered by Maurice Ewing of Lamont Geological Observatory in 1954. There followed a series of discoveries of other knolls including those discovered by scientists on board the R/V ALAMINOS of Texas A&M University.

In 1968 the National Science Foundation began the sponsorship of the Deep Sea Drilling Project (DSDP) which was to take place in the Gulf, Atlantic, Mediterranean, Pacific and Indian Oceans.

The DSDP is aimed at learning more about the history and origins of the ocean basins and continents and the processes that led to their formation and modification. This is being achieved by drilling and retrieving samples of the sediments that have slowly fallen down to the deep ocean floor for millions of years. Highly sophisticated equipment aboard the GLOMAR CHALLENGER allows drill penetration in the deep ocean.

Leg I of the GLOMAR CHALLENGER's voyage was to the Sigsbee Knolls area where an indication of the presence of oil deposits associated with salt domes was found. This was the first demonstration of the formation and accumulation of hydrocarbons in deep sea conditions.

In mid-February 1970, Leg 10 of the DSDP returned to the Knolls area. Cruise co-chief scientists for this Leg were Dr. J. Lamar Worzel, associate director of Lamont-Doherty Geological

Observatory, and Dr. William R. Bryant, Texas A&M University.

Results.

From the large variety of formations encountered, the scientists concluded that the Gulf of Mexico is essentially the same now as it was 100 million years ago and that no continental drift has occurred there for 100 to 135 million years.

Thick coarse sand was found in the deep Gulf basin from about 25 million years ago (Mid-Miocene). These deposits were made by *turbidity currents* (an undersea river that may start a landslide of mud down the continental slope from the edge of a continent into the deep sea). The significance is that very coarse *turbidites* occurred at a time other than the Pleistocene ice ages (which some scientists have thought to be the only time of such occurrences) and coarse turbidities and evidence of very strong turbidity currents were found in the Gulf of Mexico for the first time.

A history of varying *chert* deposits found are of importance to geologists seeking to explain how and why cherts are formed. Until now, geologists have not encountered enough chert gradation in an area to allow full study.

The expedition also encountered natural gas, predominantly methane, in all holes drilled in the deep basin.

The hypothesis that the Sigsbee Knolls and domes are salt diapirs was confirmed.

As a result of cable troubles, the geological group was forced to restrict the coring operations to water depths of less than 10,500 ft. (1,750 fathoms). As core samples were brought up and examined, the black particles of hydrocarbons were identified under the infrared lamps. Later core samples revealed a very high percentage of asphaltic material soluble in benzene. Examinations of the calcareous mannofossils pointed to the Eocene and Pliocene geological eras. Sediment samples indicated a range in age from Miocene through Pliocene.

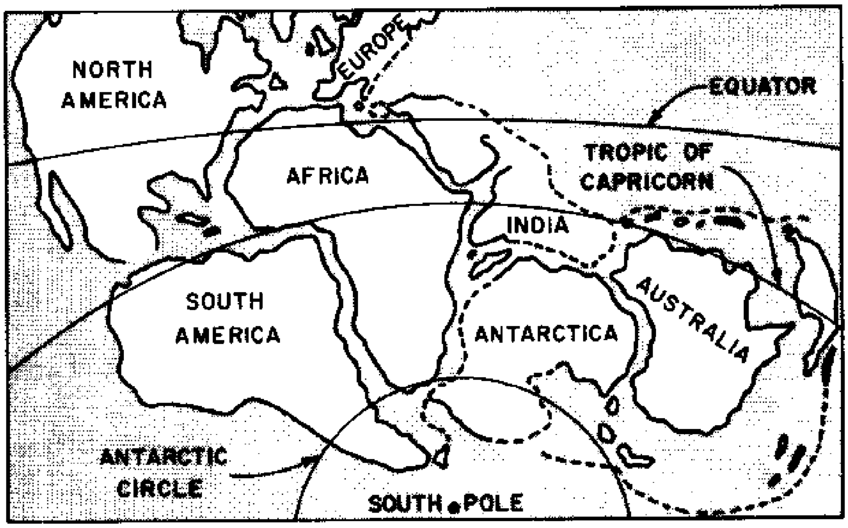
The oil potential of these knolls is being looked to with great interest and excitement since these discoveries may add another order of magnitude to the world oil reserves even though at the present time they are beyond our technical abilities for routine exploration and production.

The GLOMAR CHALLENGER is not scheduled to return to the Gulf until the summer of 1975 when Leg 44 will collect data in the Gulf and Caribbean.

M CONTINENTAL DRIFT THEORY

- Definition: *The concept that the continents can drift on the surface of the earth because of the weakness of the suboceanic crust, such as ice can drift through water.*

- The idea that at one time many of the continents were joined together as one, has been argued for more than 50 years.



(Source: After Leet and Judson 1965)

Since the mid-twentieth century, the development of geophysical techniques has brought new data into the discussion of continental drift.

The new data include studies in *paleomagnetism*, the shape of continents and ancient climatic patterns.

Some of these new data were recently acquired during the early cruises of the GLOMAR CHALLENGER in support of the theory that this "continental drift" has taken place through spreading of the sea floor outward from thermally active ridges found on the sea floor (the rate at which this new crust beneath the ocean is spreading is estimated at 1 to 4 centimeters per year).

In addition, these data verify the ocean basins as relatively young features rather than features that have existed since the beginning of the earth.

GENERAL GEOLOGY OF THE GULF OF MEXICO

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OFFSHORE OIL AND MINERAL RESOURCES IN THE GULF OF MEXICO

Contents

OFFSHORE OIL AND MINERAL RESOURCES IN THE GULF OF MEXICO

A OFFSHORE OIL AND GAS ACTIVITY

- In 1967, some 47% of all mobile offshore rigs in the world and 57% of all fixed platform rigs were operated in the Gulf of Mexico.
- In 1969, more than 2.1 billion barrels of oil and condensate and 10 trillion cubic feet of gas had been produced in the Gulf of Mexico.
- By 1975, annual oil and condensate production from the Gulf of Mexico is expected to be in the range of 750 million barrels to 1,150 million barrels and account for approximately 20-30% of the estimated total domestic production.
- The annual Gulf of Mexico crude oil and condensate production has increased steadily from less than one percent of the national total in 1954 to more than eight percent in 1967.
- For the past five years, companies have drilled an average of 900 new wells yearly.
- Production from federal leases in the Gulf is estimated at 800,000 to 900,000 barrels/day. This is exclusive of state-owned leases.
- A recent count showed that 2,408 platforms are located in state and federal waters of the Gulf of Mexico. An additional 4,105 production platforms are in state bays and waters of Louisiana and Texas.
- Until 1970, new platforms were being added at the rate of about 400 annually.
- A 1,200-mile network of chemical pipelines, called the "spaghetti bowl", connects some 73 chemical plants, 10 refineries, seven salt domes, and five gasoline-processing plants in southeast Texas to transfer feedstocks and chemical products among the plants.

In Texas

- Texas accounts for more than 30% annually of the total domestic crude oil and condensate production.
- More than 50% of the nation's petrochemical processing capability is located on the Texas Gulf coast.
- Output for oil and gas wells in Texas is controlled by a monthly allowable established by the Railroad Commission.

Editor's Note: *Italicized* words are defined in the Glossary.
Credit lines for figures refer to selected references.

- Three major structural features in Texas have affected the oil and gas accumulation in the Coastal Plain of Texas:
    - The East Texas Embayment - located in the northeastern portion of the state.
    - The Rio Grande Embayment - located in the area of Maverick, Zavala, Dimmit and Kinney counties.
    - The coastal salt domes

Geologically, all major and giant hydrocarbon fields in the coastal province occur in association with or basinward from the Mexia-Talco fault systems or its equivalents (located near Red River, Franklin, Titus and Wood counties).

More than 90% of all major oil deposits discovered in the coastal region occur Gulfward from these systems of faulting.

Houston, in Harris County, is in the center of a region characterized structurally by a great many salt domes and other structures related to subsurface salt movement. The important oil and gas deposits associated with these features have been in *Cenozoic* rocks alternating from shale to sand.

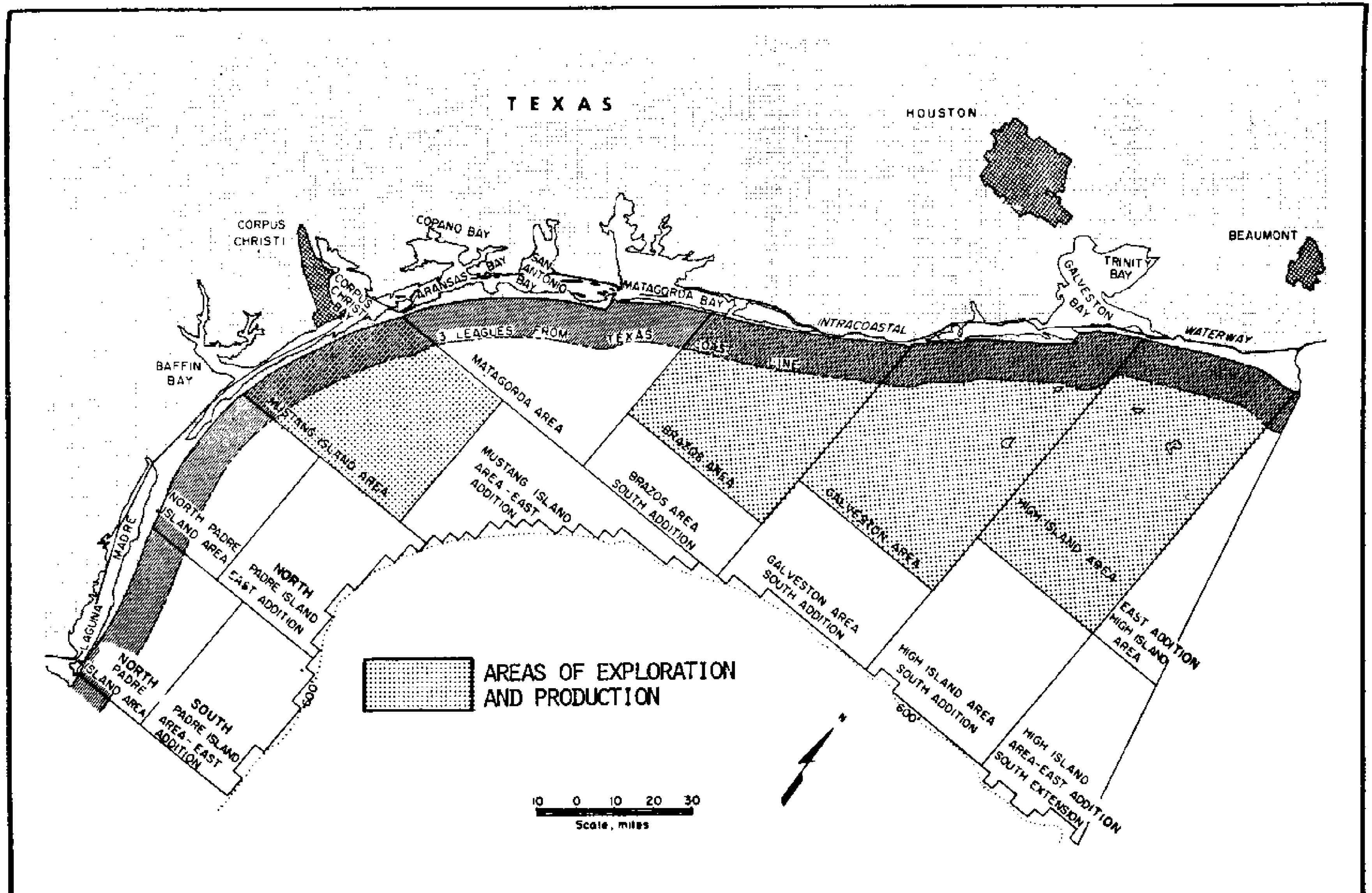
Most of the mineral production on the Texas continental shelf has been natural gas. While early production occurred in the state-owned bays, much of the current exploratory activity is on areas leased from the Federal government.

NUMBER & PRODUCTION OF TEXAS AND FEDERAL OFFSHORE GAS AND OIL WELLS

DISTRICT	NUMBER OF WELLS*		CUMULATIVE PRODUCTION (1/1/70)	
	OIL	GAS	OIL (Barrels)	GAS (MCF)**
State Offshore	21	119	3,667,831	339,024,233
Federal Offshore	38	81	5,260,164	369,453,987
TOTAL	59	200	8,927,995	708,478,220

*Includes both producing and non-producing wells

**Thousand cubic feet



Major federal and state areas of offshore oil exploration and production

(Source: Miloy and Copp 1970)

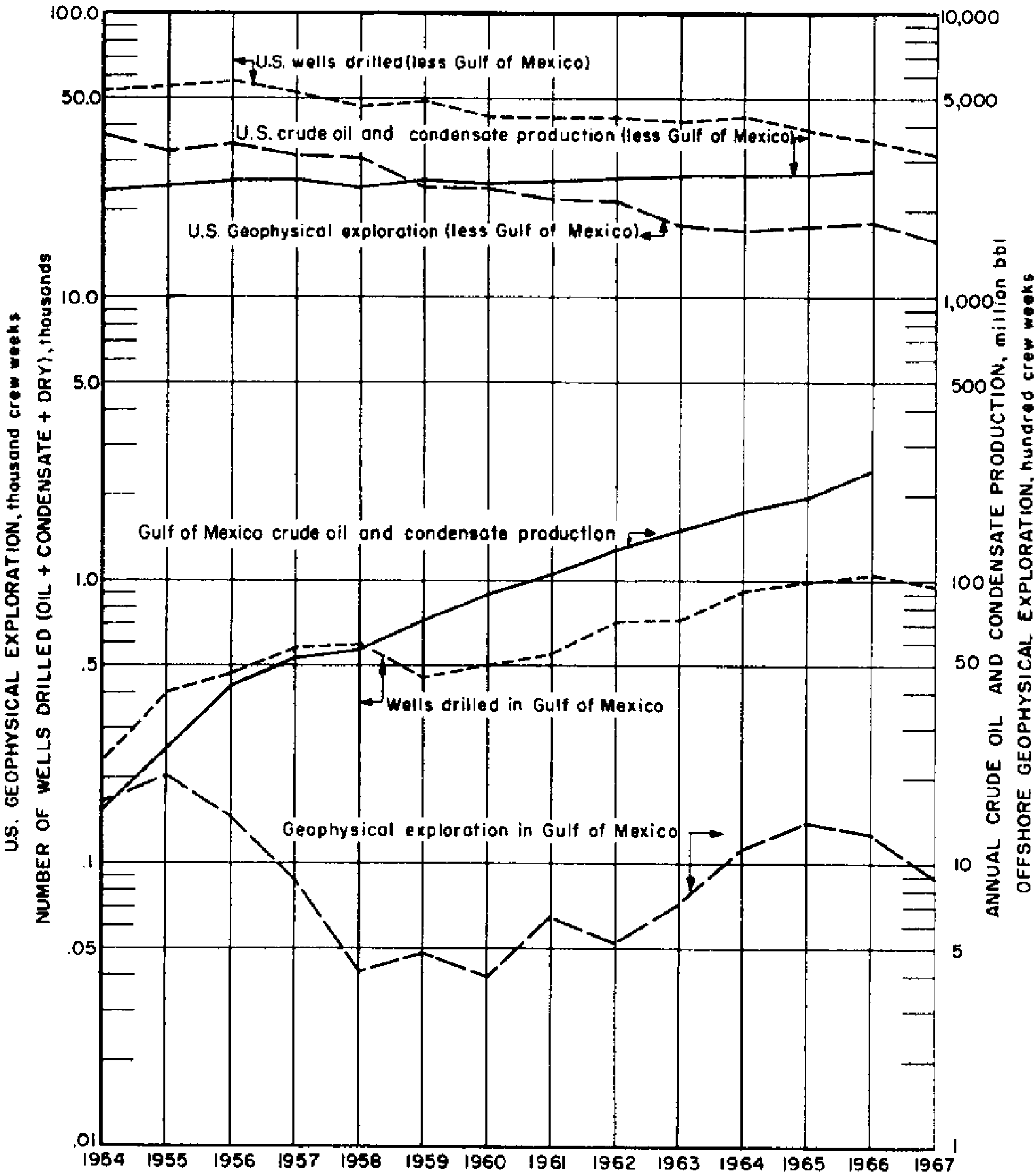
B OIL EXPLORATIONS IN THE GULF OF MEXICO

- More than 330 million submerged acres are located beneath Gulf waters less than 600 feet deep. Only 35 million acres have been explored, and only one-tenth of these are under lease.
- Capital expenditures to develop and produce a 50-million barrel model offshore field under existing conditions in the Gulf of Mexico will more than double when moving from 100 to 600 foot water.
- Exploration costs are estimated to be double that of 100-foot depths when extended out to 1,000 feet.
- The rate of offshore investment activity is expected to continue to increase at the rate of approximately 18% annually.
- The majority of the U.S. investment will be initiated by Texas-based offshore firms.
- The coastal zone area of Texas is the current location of the headquarters of 70% of all offshore-related firms in the U.S.
- More than $7.5 billion has been invested in production facilities and leases off the coast of Louisiana alone, where the oil industries' drilling costs currently exceed $2 million a day.

LOUISIANA AND TEXAS PRODUCTION ALLOWABLE RATES
1969

DEPTH INTERVAL (Feet)	BARRELS PER DAY			
	Louisiana		Texas	
	ONSHORE	OFFSHORE	ONSHORE	OFFSHORE
5,000 - 6,000	150	296	102	305
8,000 - 9,000	239	416	133-142	420
10,000 - 11,000	310	512	192-212	515
12,000 - 13,000	383	605	287-312	620

(Source: Petroleum and Sulfur on the U. S. Continental Shelf. U. S. Department of the Interior, Washington, D. C.)



Geophysical exploration, drilling, and crude oil and condensate production histories of onshore United States and Gulf of Mexico.

(Source: Miloy and Copp 1970)

- Texas' share of reserves and national output has declined over the past 20 years. From 1954 to 1968, Texas' production decreased from more than 42% to less than 35% of the U.S. total. This fact has prompted many oil geologists to observe that Texas may be over its prime as a major oil producing state.

TEXAS OFFSHORE FEDERAL LEASE HISTORY

LEASE YEAR	ACRES LEASED (THOUSANDS)	DOLLAR VALUE (MILLIONS)	NUMBER OF LEASES
1954	67.1	$ 23.4	19
1955	149.8	8.4	27
1960	240.5	35.7	48
1962	28.8	0.6	10
1968	584.6	593.9	110
TOTAL	1,070.8	$662.0	214

(Source: 1954-62 data from Petroleum Engineer, January, 1969, pp. 55 and 1968 data from Offshore, June, 1968, pp. 17)

- Recently the 60th Legislature of the State of Texas did several things to expedite marine programs in order to attack the problems of marine resources and coastal zone management. Among these was the declaration of a four-year moratorium on sales and leases of tidal lands and beaches.

C GAS EXPLORATION IN THE GULF OF MEXICO

- The major mineral produced off the coast of Texas and Louisiana has been natural gas. Less than half of all currently leased lands in the Gulf of Mexico have been explored.

- More than 99% of the Gulf of Mexico production has come from offshore Louisiana and the remainder from offshore Texas.

- The first discovery in offshore Texas was made in October 1949 on a State lease.

- Gas has continued to be the major resource produced in offshore Texas.

D SHIPPING OF OIL AND GAS

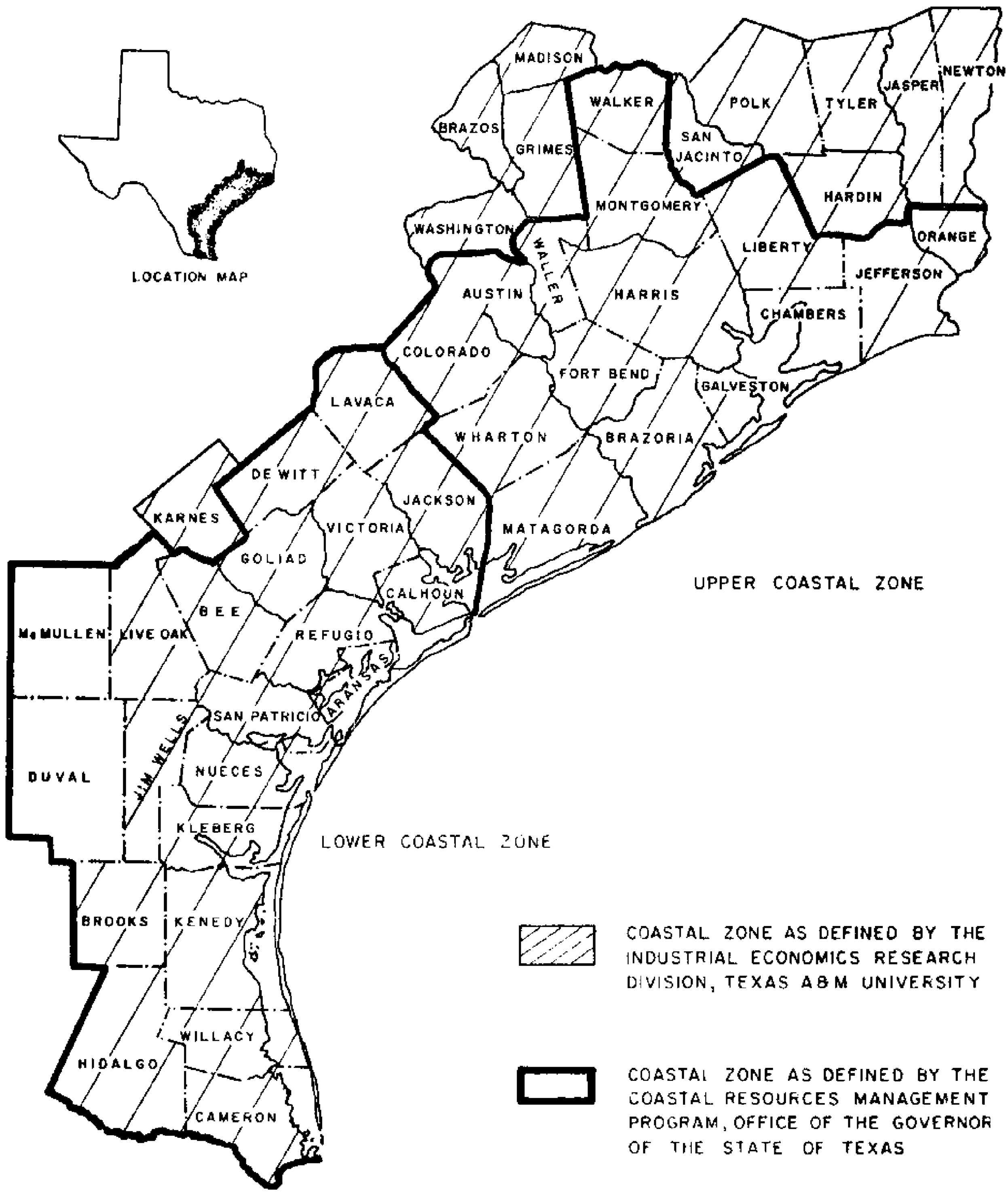
The refinery complex located in the upper coastal area of Texas is the major receiving point for offshore oil and gas from both Texas and Louisiana.

Barging is the common method for moving oil from distant deep water fields. The mobility of barges permits loading at remote wells that yield volumes of oil too small to justify construction of a pipeline.

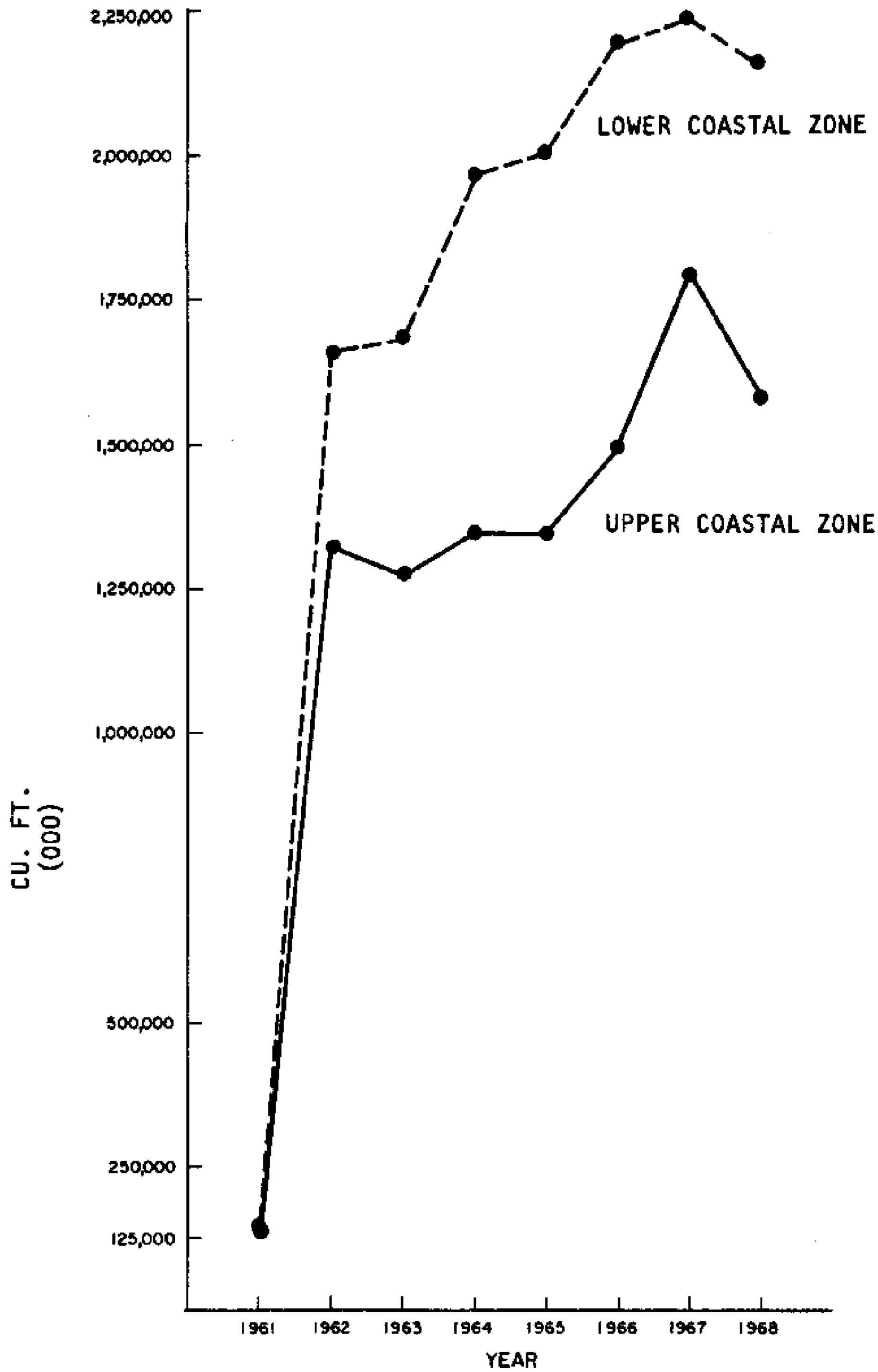
Pipeline costs to shore in the Gulf of Mexico average approximately $.10 per barrel; barging averages $.15 per barrel.

Less than 25 firms account for the majority of the Texas-based offshore geophysical industry. Total cumulative investment in boats by these firms is estimated at more than $28 million and an additional $5.9 million is expended for leasing of boats, for a total investment of $33.9 million for these activities in 1969. Annual maintenance costs for the boats are estimated at $560,000. This estimate involves 60 vessels owned and/or leased by Texas-based companies.

Investment in the marine construction industry in derrick barges, pipelaying barges, cargo and other work barges and other specialized water carriers by these offshore construction firms is estimated at $130 million. Annual maintenance costs on these vessels amount to more than $5 million.



Texas coastal zone.



Natural gas production in the Texas Coastal Zone

(Source: Miloy and Copp 1970)

E OIL AND GAS POTENTIALS IN THE GULF OF MEXICO

- The petroleum industry plans to invest more than $25 billion in offshore exploration in the next decade.

- According to one government source, the federal production could probably be increased to 1.2 or 1.5 million barrels/day, with little workover or remedial work, providing there was adequate means of transportation. Pipeline capacity is not sufficient to move this amount of crude today; barge transport loaded at the platform is probably the only method that could be used at this time to take out the additional oil.

- Very large and substantial petroleum reserves remain to be found and exploited in the Gulf. As the technology to drill commercial wells in very deep water is developed, the petroleum reserves of the continental slopes will be produced.

KNOWN RESERVES AND POTENTIAL ADDITIONS OF OIL AND GAS
IN PRODUCTIVE OFFSHORE PROVINCES AS OF JANUARY 1968

PROVINCE	OIL (Billion Bbls.)			GAS (Trillion Cu. Ft.)		
	RESERVES	PROSPECTIVE ADDITIONS*	SPECULATIVE ADDITIONS**	RESERVES	PROSPECTIVE ADDITIONS*	SPECULATIVE ADDITIONS**
Gulf of Mexico						
Texas and Louisiana	2.4	2.0	2.0 - 4.0	34.2	25.0	25.0 - 50.0
Southern California	1.4	0.5	4.0 - 10.0	N.A.	1.0	2.0 - 10.0
Cook Inlet	0.5	0.5	1.0 - 2.0	N.A.	1.0	5.0 - 10.0
TOTAL	4.3	3.0	7.0 - 16.0	34.2	27.0	32.0 - 70.0

*Estimated reserves to be found by development and extension of existing fields.

**Reserves which may be found in new fields.

N.A. - Not Available.

(Source: Petroleum and Sulfur on the U. S. Continental Shelf, U. S. Department of the Interior, Washington, D. C.)

F OTHER OFFSHORE MINERALS AND RESOURCES

- Of the 72 strategic and critical mineral commodities indispensable to our economy in time of conventional warfare, more than 40 are imported from foreign countries.

- The world's oceans are the storehouse of a wide array of mineral materials with greatly varying characteristics and occurrence, including those dissolved in the sea water, those accumulated on the ocean floor, and those locked in the rocks beneath the ocean floor.

- At the present time common salt, magnesium, bromine and fresh water are being recovered from sea water; their total annual value, world-wide, is estimated to be $385 million, of which the United States accounted for $117 million in 1966.

- If the minerals of the sea could somehow be extracted from the water and spread uniformly over a smooth sphere the size of the earth, the resulting mineral layer would be 150 feet thick.

- Marine mineral resources can be divided into six main types, based on specific environments in which they occur:

  Chemical constituents of sea water
  Submerged placer deposits and other surficial deposits (sands and gravels)
  Deposits in the substrate of shelves and slopes
  Deposits on the deep ocean floors
  Deposits in the substrate of the deep ocean basins
  Metals deposited from submarine hot waters

Chemical constituents of sea water

- The minerals presently derived from sea water - salt, magnesium, and bromine - are present in sufficient concentration in the sea as to be inexhaustible, and their production is limited only by demand and by plant capacity.

- The gross value per cubic mile of sea water of 17 common industrial elements, in most of which there is a national shortage, is slightly less than $600,000.

- The minerals of the world's oceans have been referred to as the untapped wealth in the sea, for it has been estimated that within these oceans there are some 50 quadrillion (metric) tons of minerals, including:

  2 quadrillion tons of magnesium
  100 trillion tons of bromine
  7 trillion tons of boron
  20 billion tons of uranium
  10 billion tons of gold

APPROXIMATE AMOUNTS OF MINERALS DISSOLVED IN SEAWATER

MINERAL	TONS/CU. MILE
Sodium chloride (common salt)	120,000,000
Magnesium chloride	18,000,000
Magnesium sulfate	8,000,000
Calcium sulfate	6,000,000
Potassium sulfate	4,000,000
Calcium carbonate (lime)	550,000
Magnesium bromide	350,000
Bromine	300,000
Strontium	60,000
Fluorine	21,000
Barium	6,400
Iodine	100 to 12,000
Arsenic	50 to 350
Rubidium	200
Silver	up to 45
Copper, manganese, zinc, lead	10 to 30
Gold	up 59 25
Uranium	7

(Source: F. G. Walton Smith and Henry Chapin, The Sun the Sea, and Tomorrow (New York: Charles Schribner's Sons, 1954), p. 185. and Miller B. Spangler, New Technology and Marine Resource Development (New York: Praeger Pub., 1970), p. 110)

- The major economic problem in extracting elements of low concentration from seawater is the huge tonnage of water that needs to be pumped and processed.

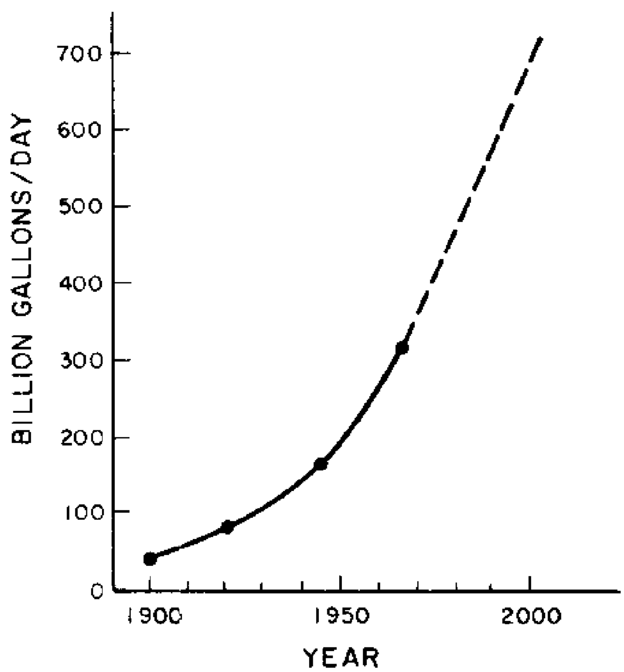
    A plant handling this much would have to process 2.1 million gallons per minute, every minute for an entire year.

- Progress has been made, however, with regard to elements of higher concentration in economically recovering a few of these.

Desalination of Seawater

- Desalting generally refers to obtaining usable water by removing salt from seawater. It also encompasses removal of such other impurities as those found in inland brackish water and pollutants from waste waters.

- Seawater can be used for human consumption if its saline content is reduced from 35,000 parts per million (ppm) to less than 1,000 ppm. The U.S. Public Health Service has established standards that good drinking water should not contain more than 500 ppm.



Water consumption in the United States.

- There are over 150 land-based desalination plants throughout the world using sea water. Actually, there are more than 600 plants, but as in the U.S., most are for powerhouse boiler water production and operate on brackish or slightly saline water.

- There are only 28 seawater feed plants located in the U.S., but almost 100 U.S.-built plants around the world. More than 50% of all seawater desalination plants throughout the world were built by the U.S.

- Four plants in the continental U.S. have capacities of at least one million gallons per day (mgd).

- Long-range estimates indicate that by the year 2000, world desalting production should be about 30 billion gallons per day, compared to about 0.10 billion gallons per day at the present time. This 30 billion gpd is about 8% of U.S. domestic consumption today.

  The desalination processes can be divided into four broad categories:

  1. distillation
  2. crystallization
  3. membranes
  4. advanced processes in initial development

  The distillation technique is being used widely even though no single technique is best for all kinds of water.

- By 1975 the cost of desalting in large size plants may decrease significantly for such water to be used for agricultural irrigation. However, these decreases hinge on technological innovation in large scale desalting developments and on the attainment of such low-cost heat sources as nuclear breeder reactors.

Magnesium Metal

- Magnesium is the third most abundant element found in seawater.

- Over 90% of magnesium metal produced in the U.S. is obtained from seawater.

- It is estimated that a cubic mile of seawater contains roughly six million tons of magnesium, which is equivalent approximately to one-sixth ounce per gallon, worth about 0.4 cents.

  The first magnesium metal from seawater was produced in 1940, extracted from the Gulf of Mexico by the Dow Chemical Company at Freeport, Texas.

- Some 65% of the world's production comes from the only two magnesium metal plants that process seawater:

  Texas Division of the Dow Chemical Company, Freeport, Texas
  Norsk Hydro-Elektrisk, Norway

  The Dow plants pump approximately 1-1/2 million gallons per minute, equivalent to almost 2 billion gallons per day. This figure includes water that is used for cooling.

  Magnesium is used extensively in airplane construction, automobile engines and for many other uses where weight is important, since magnesium is the lightest of structural metals.

Magnesia

Magnesium hydroxide is also extracted by Dow Chemical at Freeport and then sent elsewhere for conversion into magnesium oxide. Other plants along the Gulf involved in this process are located in Mississippi, Florida and Tampico, Mexico.

Bromine

Of all the minerals extracted commercially from seawater, bromine is the least concentrated, about 65 parts per million.

From 1941 to 1970 bromine was extracted from seawater by the only plant in the U.S. (Dow Chemical). This operation is no longer active so that currently the only plants are located in France, Italy (Sicily), England and Japan.

Potash

Potash is a term that means potassium oxide, but it is used widely to denote several other potassium salts as well. It is an essential ingredient of fertilizers and about 94% of the potash used in the United States is for agricultural purposes.

- Giant kelp is present in sufficient quantities to be a potential source for potash.

- Seawater contains about 380 parts per million potassium, making this element one of the more abundant constituents. Although this may be regarded as virtually limitless potential resource, the extremely large high grade land-based potash resources make it very unlikely that it will be economically feasible to recover potash from seawater for a long time.

The sedimentary rocks in the Gulf coast shelves are also a possible source of potash because of the presence of large salt deposits; however, none is known for certain.

Submerged placer deposits and other surficial deposits (sands and gravels)

Submerged placer deposits and other surficial deposits (sands and gravels) occur as patches of unconsolidated material on and immediately beneath the continental shelf (although not of placer origin, oyster shell and lime mud may be included in this group).

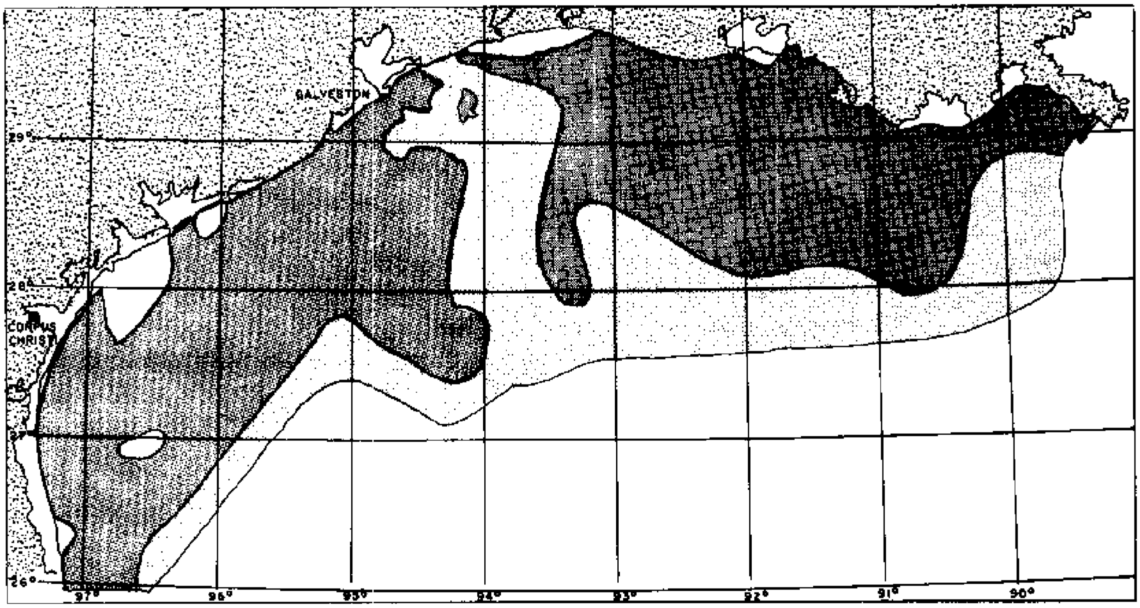
Placer deposits are formed where streams or waves and currents cause heavy minerals to be selectively deposited in isolation from relatively worthless lighter minerals that are carried away. The minerals must previously have undergone extensive weathering and erosion from their original position within igneaous metamorphic rock.

The placers in the marine environment are mainly confined to the inner edge of the continental shelves, and it is unlikely that significant placer deposits will be found on the continental slope or beyond.

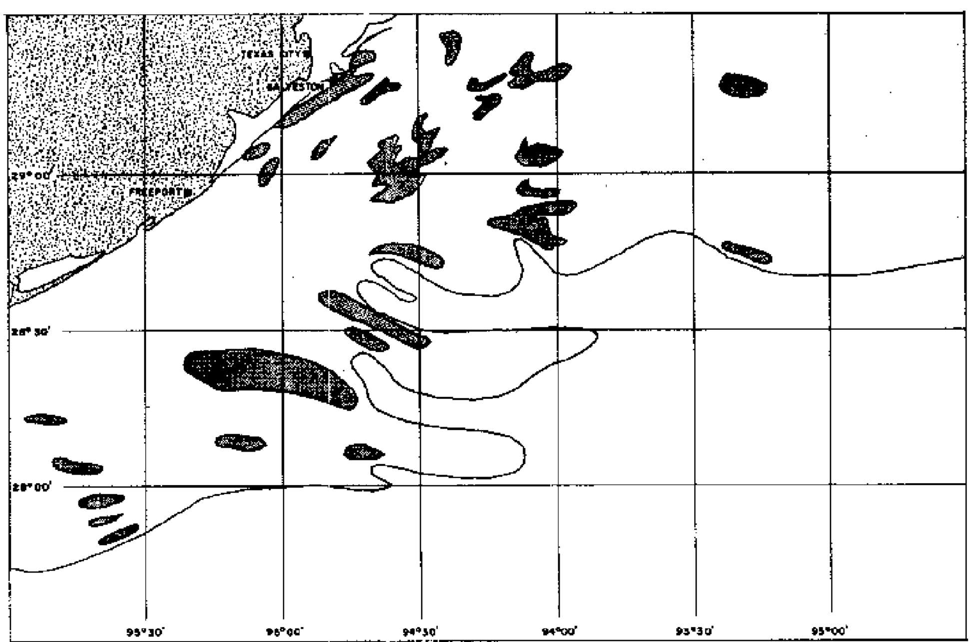
In 1968 the Geological Survey launched a geochemical survey of the Continental Shelf. Their investigations showed that high concentrations of zircon were present along with titanium and iron in the Gulf.

Zircon is used principally in refractories, or resistant types of materials, chemically resistant ware, enamels, pigments, electrical insulators and resistors, glazes, glass polish, heat transfer pebbles, porcelains and abrasives.

Zircon reserves in the U.S. are estimated to exceed 12 million tons. Almost 90% of these may be found in the beaches and sands of northern Florida, South Carolina and New Jersey.



Approximate locations of light (lighter areas) and heavy (darker areas) concentrations of free titanium in the Gulf of Mexico.
(Source: After Holmes 1969)



Approximate locations of light (lighter areas) and heavy (darker areas) concentrations of zirconium in the Gulf of Mexico.
(Source: After Holmes 1969)

Deposits in the substrate of shelves and slopes

These include oil, gas and sulphur, coal bedded salt that may contain potash-rich layers, phosphatic rock, iron ore, bauxite, beds rich in placer minerals, and possibly metallic vein deposits.

- Sulphur is being recovered from offshore salt domes in the Gulf of Mexico. Its principal use is in the production of sulphuric acid, an acid used so extensively by modern industry that it is considered an index of a nation's economic activity.

Sulphur is primarily consumed by the fertilizer industry, as well as by the chemical, paint and pigment, iron and steel, rayon and film, and petroleum industries.

Elemental sulphur obtained from sulphur-bearing salt domes by the Frasch process in the Gulf has been and will continue to be the most prolific offshore source in the United States. As yet it is not known just how many of the salt domes in the Gulf contain sulphur since the sulphur was discovered primarily during oil investigations.

Two commercial sulphur deposits have been developed offshore. Both are on the outer continental shelf off southeast Louisiana. Gulf of Mexico sulphur deposits account for about 15% of the national output.

Deposits on the deep ocean floors

The only presently known materials of potential economic importance on the deep ocean floors beyond the continental slopes are the manganese nodules and crusts.

The 1968 Geological Survey mentioned earlier also found high concentrations of manganese with correlative high concentrations of zinc, copper and lead which suggested the possibility of manganese nodules off the Florida shelf.

Deposits in the substrate of the deep ocean basins

These include chromite and nickel, neither of which has been found in the Gulf.

Metals deposited from submarine hot waters

These include copper, zinc, silver, lead, tin and gold.

Although neither copper nor tin is mined in the Gulf, both are processed there.

- The tin smelter at Texas City, Texas, has been and still is the only smelter of its kind within the United States.

Legal Aspects of Exploiting Mineral Resources

- The Outer Continental Shelf Lands Act of August 7, 1953, and the 1958 Geneva Convention on the Continental Shelf constitute the principal body of the law dealing with the exploitation of offshore mineral resources beyond the limits of jurisdiction of the individual states.

- The jurisdiction of states has been fixed (by the Submerged Lands Act of June, 1953) at three nautical miles from shore, except along Texas and the Gulf coast of Florida, where it corresponds to the three marine leagues (10.5 miles) limit that represents the historical boundaries of those states.

Oyster Shell and Calcium Carbonate Materials

Since these materials are essentially limestone, their principal uses are the same as for limestone. Most of these uses depend on the caustic properties of calcium oxide or calcium-magnesium oxide. In some cases, it serves to combine with and remove unwanted materials from a desired product as in the manufacture of steel and the refining of sugar or petroleum.

- As much as 20 million tons of oyster shell have been produced from the sea floor adjacent to the U.S. Most of this came from Texas and other Gulf coast states, but large amounts were recovered from San Franscisco Bay and lesser amounts from areas off Maryland, Virginia and Pennsylvania.

- A minimum of 100 million tons of shell may lie on the Continental Shelf off the Gulf coast.

- The production of oyster shell remains approximately constant at an estimated $30 million annually.

Uses: aggregate in concrete and road material
manufacture of cement and lime
poultry grit
fertilizer additives

G PETROCHEMICALS

- In 1967 a majority of the petrochemical industry was concentrated along the Gulf coast from Corpus Christi through Freeport to Houston, Bay City and Beaumont.

  Those petrochemicals produced are:

  aromatics
  formaldehyde
  benzene
  perchloroethylene
  trichloroethylene
  vinyl chloride monomer
  polypropylene capacity
  polyisoprene rubber
  polybutadiene
  polyisoprene
  high density polyethylene
  ethylene
  low density polyethylene
  synthetic glycerine
  ethylene oxide
  orthoxylene
  styrene monomer
  sulfurized fatty bases
  oils
  additives
  leaded compounds
  neoprene rubber
  chloroprene monomer
  isopropyl alcohol
  acetone
  metaxylene
  paraxylene
  ammonia
  propylene oxide
  ethane
  hydrogen gas
  nitrogen
  argon

- Houston produces at least 40% of every basic petrochemical produced in the United States and as much as 80% of some products such as synthetic rubber.

- Refineries and chemical plants along the Texas Gulf Coast have facilities to produce about 700 million gallons of benzene annually for conversion into chemicals. It is estimated that during 1972 the capacity will climb above 800 million gallons.

- The two largest ammonia plants in the world are at Lake Charles, Louisiana and Texas City, Texas.

- The heaviest concentration of ethylene production facilities in the U. S. and in the world is found on the Gulf Coast -- centered in the Houston area. Ethylene goes into a host of products which in turn are used in fabricated plastic items from housewares to toys, into rubber, polyester fibers and antifreeze.

H <u>METALS PRODUCED ALONG THE GULF COAST</u> (either mined or processed)

These include:

Cadmium
Copper
Iron, ore and steel
Magnesium and magnesium compounds
Magnese
Uranium
Zinc

I <u>NON-METALS PRODUCED ALONG THE GULF COAST</u>

Barite
Bromine
Cement
Clays
Gypsum
Lime
Perlite
Pumicite
Salt
Stone
Shell
Sulphur
Vermiculite

OFFSHORE OIL AND GAS ACTIVITY IN THE GULF OF MEXICO

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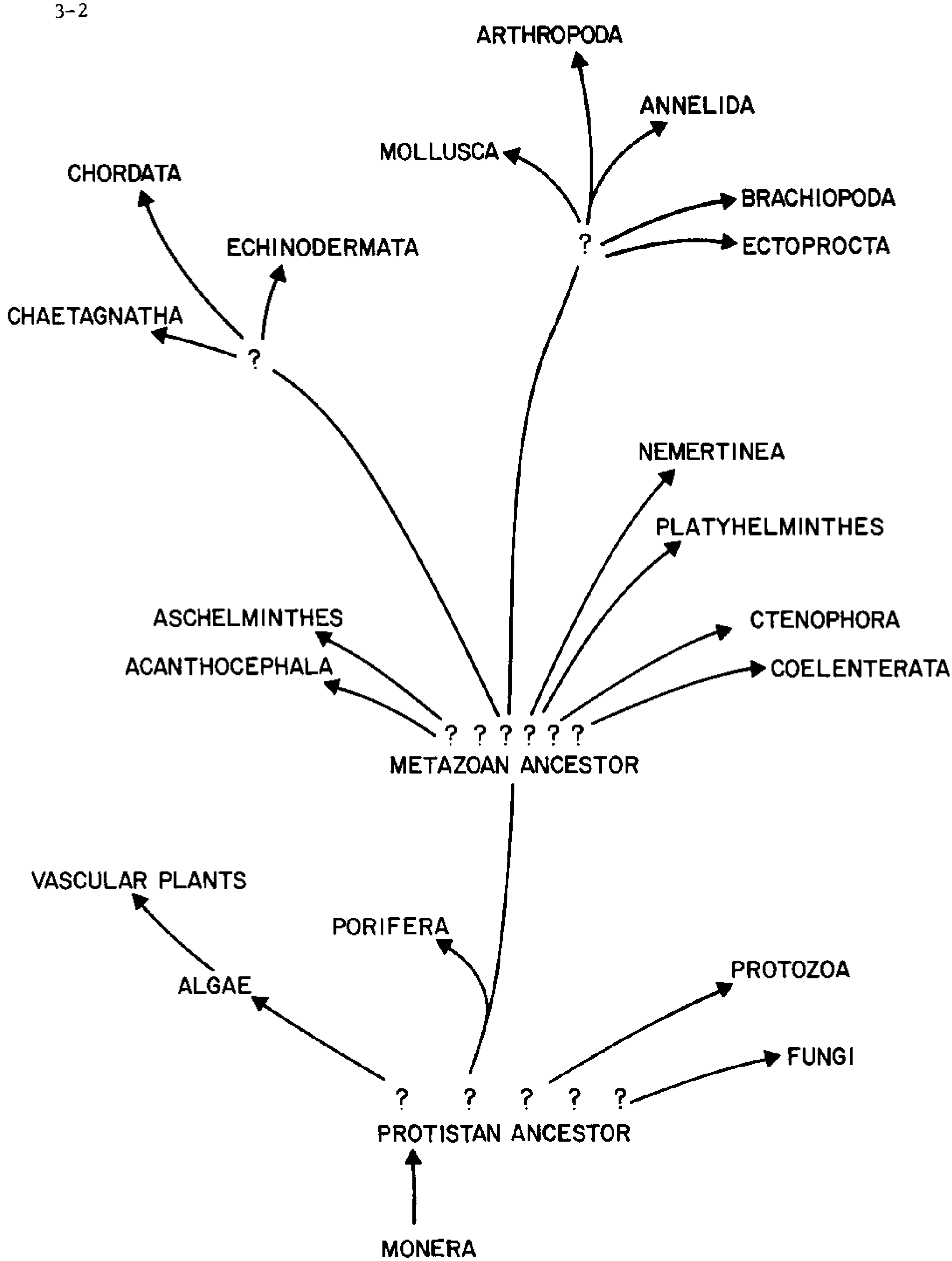
GENERAL BIOLOGY OF THE GULF OF MEXICO

Contents

GENERAL BIOLOGY OF THE GULF OF MEXICO

- Approximately 5.6 million acres of salt marshland are found here; Louisiana possesses almost one-half of the total salt marsh acreage in the United States.
- Although not found in the Gulf, the giant seaweed, kelp, is the primary source of algin used in ice cream and is a source of iodine in medical products.
- Phytoplankton are the primary food source for sea animals.
- "Red tide" (a phytoplankton bloom) is a strange phenomenon which may cause fish kills and side effects in man.
- Marine bacteria contribute to the formation of hydrocarbons and sulphur and may be useful in the removal of oil spills.
- Sponges produce 15 types of sterols (complex alcohols) and possess a chemical that inhibits virus infections and leukemia in laboratory animals.
- A sting from the "Portuguese man-of-war" may cause serious harm to man.
- The Flower Gardens are the nation's northernmost living coral reefs.
- Five major species of shrimp are caught in Gulf waters.
- Brown shrimp account for 65% of Gulf coast shrimp catch.
- Fresh water, or "river" shrimp, may reach a size of over nine inches.
- More than 1,400 square miles of Gulf are suitable for oyster production.
- Oyster reefs may extend as far as 25 miles in length.
- Seven national wildlife refuges in Texas total 129,000 acres.
- Small herds of seals visited the western Gulf as far north as Galveston as late as 1932.
- Porpoises, common in the Gulf, have a built-in sonar system which can lead them to an object as small as six inches in diameter.

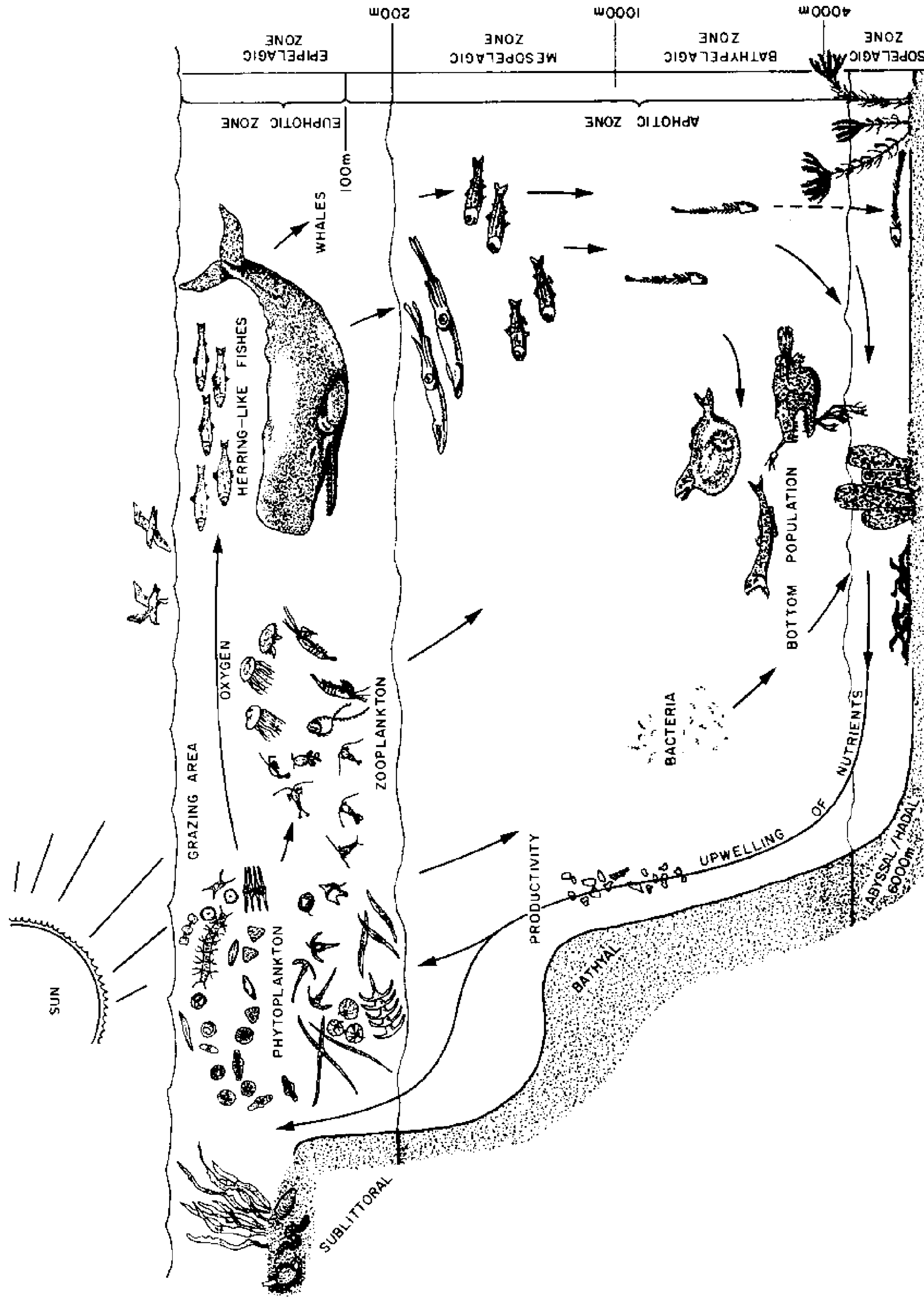
Editor's Note: *Italicized* words are defined in the Glossary.
Credit lines for figures refer to selected references.



One possible phylogenetic scheme indicating the relationships of 16 phyla which may be found in the Gulf of Mexico.

(Source: Wooley 1966)

(9/72)



SIMPLIFIED LIFE & FOOD CYCLE IN THE OCEAN

A FLOWERING PLANTS OF THE WATERS AND SHORES OF THE GULF OF MEXICO

Maritime flowering plants of the Gulf of Mexico are confined to the shores and coastal waters because:

1. They depend upon light to carry on *photosynthesis*.

2. A substrate is needed as a point of attachment for their roots or underground stems.

Considered in the natural groupings in which they usually grow, the four major plant communities are:

1. submarine meadow (so-called because they are "grazed" by larger animal life and serve the same purpose as land vegetation)

2. mangrove swamp

3. salt marsh

4. sand-strand vegetation

1. Submarine Meadow -

• More species of marine flowering plants are found in the Gulf of Mexico and Caribbean Sea than anywhere else in the Western Hemisphere.

Not only is this meadow grazed for its lush growth but for its inhabitants. Water-borne *detritus* from elsewhere, detritus derived from crops of attached plants such as the marsh-grasses and the attached diatoms and microscopic algae are essential to the existence of marine life.

Examples of grasses found in these meadows:

Turtlegrass (Thalassia)
Manatee grass (Syringodium, Diplanthera)

2. Mangrove Swamp -

• Most conspicuous of the plant communities of the Gulf coast.

• Greatest development is along SW Florida in the Ten Thousand Islands area. There one will find:

Red mangrove (Rhizophora)
Black or honey mangrove (Avicennia)
White mangrove (Laguncularia)

(9/72)

Mangrove Swamp
(Source: After Zim and Ingle, 1955)

Mangroves extend northward along the Mexican Gulf coast to southern Tamaulipas. Along the N shores of the Gulf from Cedar Keys in Florida to S Tamaulipas, typical mangrove swamp is absent, and mangrove species are represented only by the more hardy Avicennia which grows mostly as scattered shrubs, with Batis and other salt-marsh associates.

Zonation in mangrove swamps appears to be correlated with water level, degree of salinity of the water, substrate and in some areas with tidal fluctuations.

3. Salt Marsh -

- Salt marshes are best developed along the more protected temperate shores of the N Gulf of Mexico.

- Approximately 5,600,000 acres of salt marshes are located in the Southern Atlantic and Gulf States:

  Louisiana possesses almost 1/2 the total salt marsh acreage in the U.S., or approximately 2,500,000 acres.
  Texas - little more than 1,500,000 acres
  Florida - almost 700,000 acres
  Mississippi - a little over 62,800 acres
  Alabama - approximately 41,227 acres

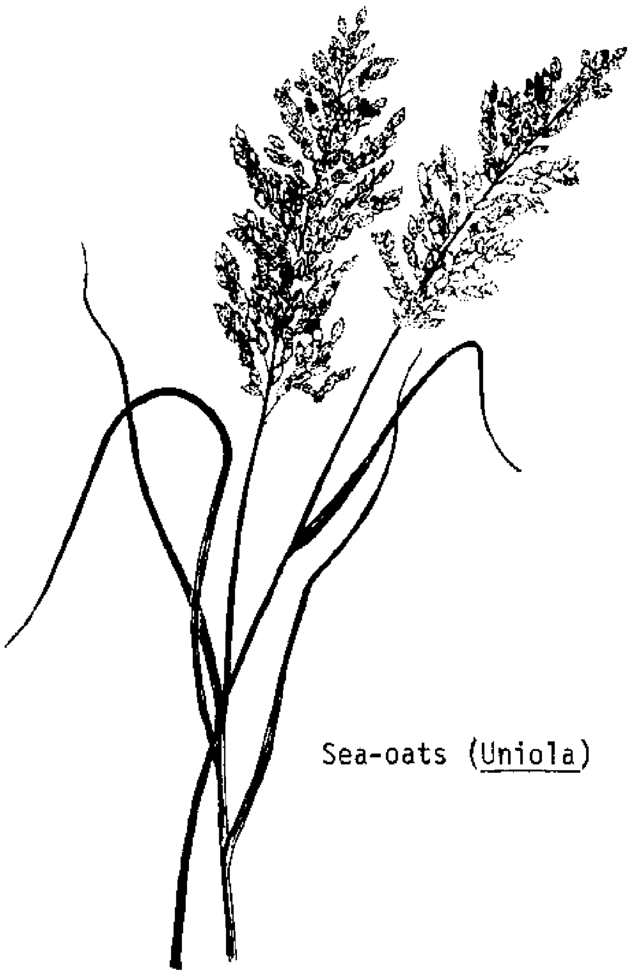
- Dominant species in Gulf salt marshes - Spartina.

4. Sand-strand Vegetation -

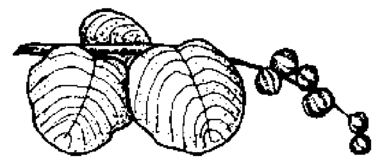
Plants tolerant to salt spray such as those commonly found along the Gulf coast barrier islands and Gulf coast beaches are referred to as sand-strand vegetation.

Preservation of sand-strand vegetation is of vital importance in the protection of the coastal areas against erosion.

Pictured below are two of the more commonly found species of sand-strand vegetation:



Sea-oats (Uniola)



Seagrape (Coccoloba)

(Source: After Miner 1950)

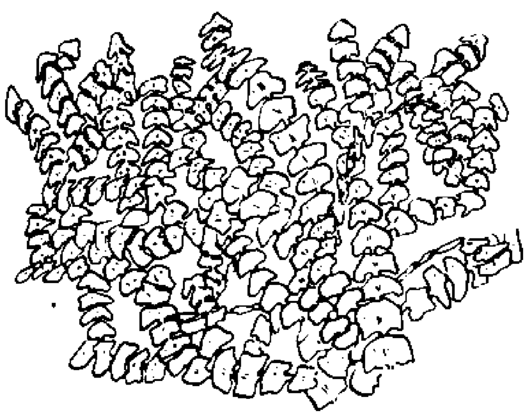
B MARINE ALGAL FLORA ALONG THE GULF COAST

Algae are the simplest of all plant forms. They have neither roots, stems nor leaves. They may range from a microscopic size to one hundred feet in length.

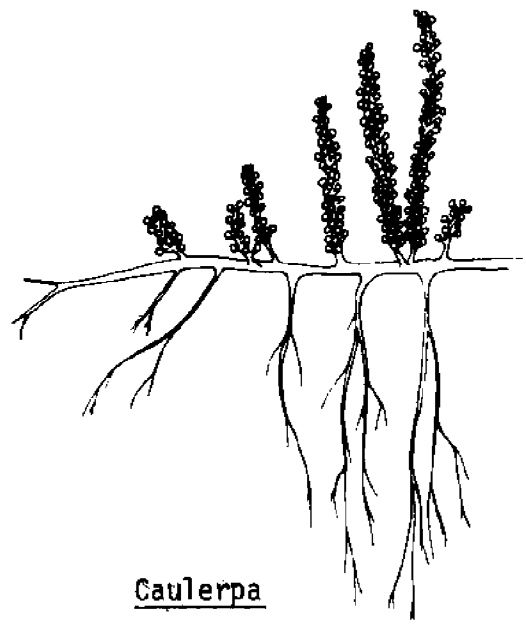
Because of the warm tropical current which sweeps through the Yucatan Straits into the Gulf of Mexico one would expect to find the marine algal flora generally tropical in character.

The most varied algal flora exists on the eastern shores, the Florida Keys and probably Cuba and Yucatan. As one progresses northward, the flora become simpler and less spectacular.

Some of the more commonly found marine algae of the Gulf coast are shown below:

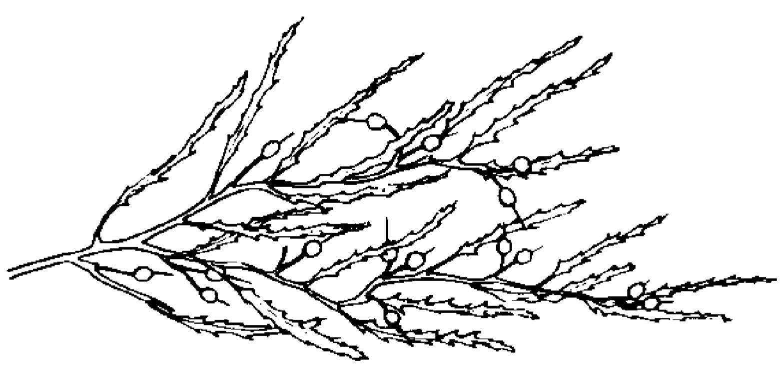


Halimeda



Caulerpa

Mermaid's Cup (Acetabularia)

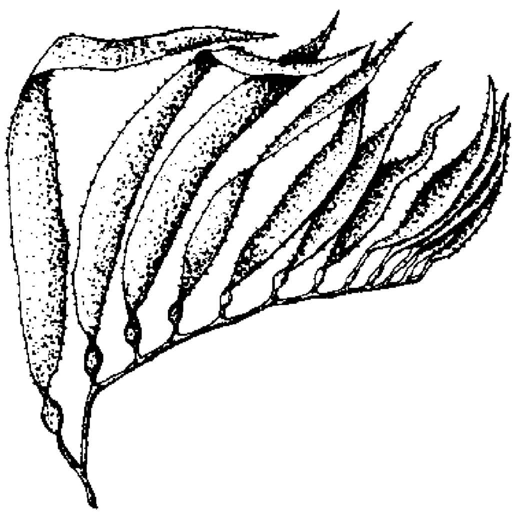


Sargassum (derived from the Portuguese word for grape , "sarga")

(Source of all drawings: Taylor, 1954)

- Seaweeds can be used as food by themselves (as vegetables), or in relishes, sauces, soups, salads and jellies as coagulates.

- Although not present in the Gulf, the giant seaweed, kelp, is the primary source of *algin* used in ice cream, frozen goods, cake mixes, and beer, or it can be sugarcoated as candy. Kelp is also used in antacid tablets and as a source of iodine in medical products.



Macrocystis

Nereocystis

(Source: After Zim and Ingle, 1955)

C PHYTOPLANKTON - Sea Fodder

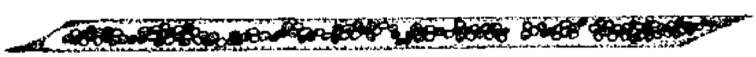
The pastures of the sea consist of numerous microscopic plants, which together almost equal the amount of all the vegetation on land and serve the same purpose: manufacturing carbohydrates out of water and carbon dioxide and, during the day, giving off oxygen for respiration of both plants and animals, as well as providing a source of food.

They consist mostly of separate single cells wandering and drifting with the ocean currents, yet all animal life depends on them for food either directly or indirectly.

Phytoplankton means "plants that wander."

Phytoplankton - primarily composed of four different types of algae: diatoms, dinoflagellates, coccolithophorids and silicoflagellates.

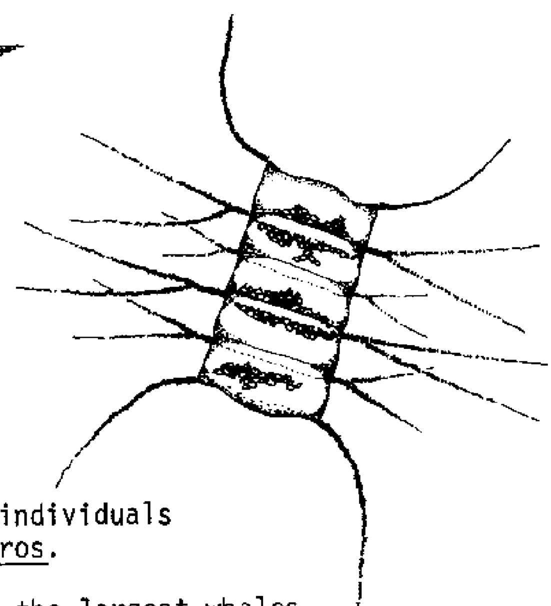
Among the most common of the microscopic plants are the diatoms, meaning "cut in two." Each cell is enclosed by a glass-like external wall, composed of two halves or two lid-like structures which form a box.



Diatoms have themselves been referred to as the "grasses of the sea." They may occur as single individuals, such as the Rhizosolenia pictured here,

OR

as a chain of linked individuals such as this Chaetoceros.



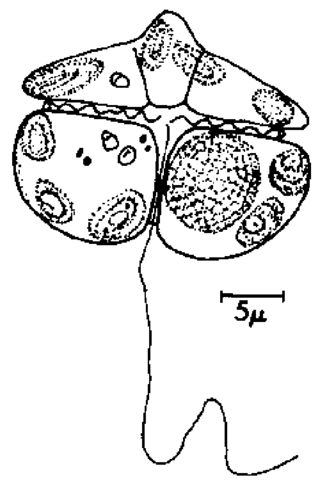
All ocean animals, from the very smallest to the largest whales, must depend directly or indirectly upon these tiny organisms for their sustenance.

Phytoplankton are a primary source of food in the estuaries, bays and lagoons for much of the sealife which has its beginning in these areas.

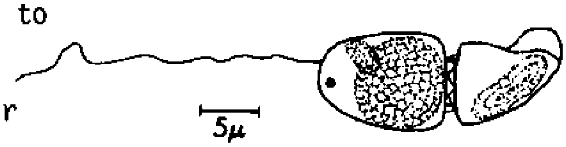
D RED TIDE

Of the many single-celled protistans found in the Gulf of Mexico, few have caused the consternation that has been provided by an *atheeate* dinoflagellate called Gymnodinium breve in producing a condition of the marine environment referred to as "red tide."

The nature of phytoplankton blooms, i.e., the extensive production of microscopic aquatic flora in localized areas, is today, as in the past, a frustrating problem facing the biologist, oceanographer, and limnologist. Many scientific reports attribute the wholesale death of fishes and other marine organisms to these phenomena. Since the affected water is discolored, resulting in a greenish, amber or occasionally red color, the popular terminology is the "red tide."



Gonyaulax monilata, another "red tide" organism, is a *theeate* dinoflagellate which has less effect on fish than G. breve. However, annelids and molluscs are more sensitive to G. monilata than G. breve. Crustaceans are resistant to both species.



Gymnodinium breve
(Source: Wilson 1967)

The color is due to refraction and/or reflection of light through the high concentration of organisms, which cause a turbid condition of the water.

Normally, there are less than 1,000 of these organisms in a quart of Gulf water. In the bloom this may reach 90 million per quart, which may turn the water syrupy.

Not only is the "red tide" a problem to the scientist, but also to the bather. Although circumstances rarely occur to present these problems, bathers near the breaking surf may inhale the fine spray containing the organism, causing a respiratory and postnasal irritation when the bloom is heavy. Occasionally, during a heavy concentration of "red tide," uptake of the organisms by oysters indirectly affects those persons eating the raw shellfish.

E MARINE BACTERIA AND FUNGI IN THE GULF OF MEXICO

Bacteria are much more abundant in shallow Gulf water than in the open ocean. This fact is attributed primarily to the higher content of growth-promoting organic matter and suspended solids in shallow waters.

From Gulf of Mexico mud, more than 20 strains of *aerobic* chitin-decomposing bacteria have been isolated.

Marine bacteria contribute to:

- *biofouling* of man-made structures, such as pilings, planks, and other wooden structures.
- destruction of unprotected steel and iron structures through oxidation of ferrous iron, production of acids, formation of hydrogen sulfides, creation of reducing conditions.
- destruction of concrete, rubber and bituminous coating materials.
- promotion of many processes involving organic compounds, and inorganic constituents.
- formation of methane and higher hydrocarbons and their modifications.
- formation of sulphur.
- removal of oil spills through use of a bacterium, Pseudomonas.

Marine fungi are primarily *saprophytic*, although numerous species are parasitic. Lulworthia is a marine, saprophytic fungus implicated in the decomposition of wood; Labyrinthomyxa is a marine, parasitic fungus which periodically kills mollusks including the commercial oyster, Crassostrea virginica.

F SPONGES

PHYLUM PORIFERA - multicellular animals of simple and loose organization, either with spicules of silica or calcium carbonate imbedded in their bodies for support or with fibrous skeletons made of the horny substance spongin, as in the common commercial sponge.

<u>Class Demospongea</u> - major sponge group in the Gulf, both as to number of genera and range of distribution.

Sheepswool sponge
<u>Hippiospongia</u>

The commercial sponges of Florida, the Bahamas, Cuba, and British Honduras are all quite similar; the sheepswool sponge, <u>Hippiospongia</u>, is the most valuable commercially. It ranks second to the highly prized Turkey cup sponge of the Mediterranean. The Army and Navy use sheepswool sponges for gun swabs. They are also in demand for cleaning automobiles. Painters like to use them because they are very soft, durable, and unusually absorbent.

Naturally, all sponges have suffered somewhat of a displacement from the market due to the synthetic sponges.

<u>Location</u>: may be found in an area extending from the *intertidal zone* down to the deepest parts of the basin, and in almost all of the firm or rocky sections of the bottom where an attachment may be provided for them.

<u>Methods of Collection</u>:

- Hooking - used in waters of less than 7 or 8 fathoms
- Diving - light-weight, full diving rigs used in depths of less than 20 fathoms
- Skin-diving - some in shallow waters
- Dredges

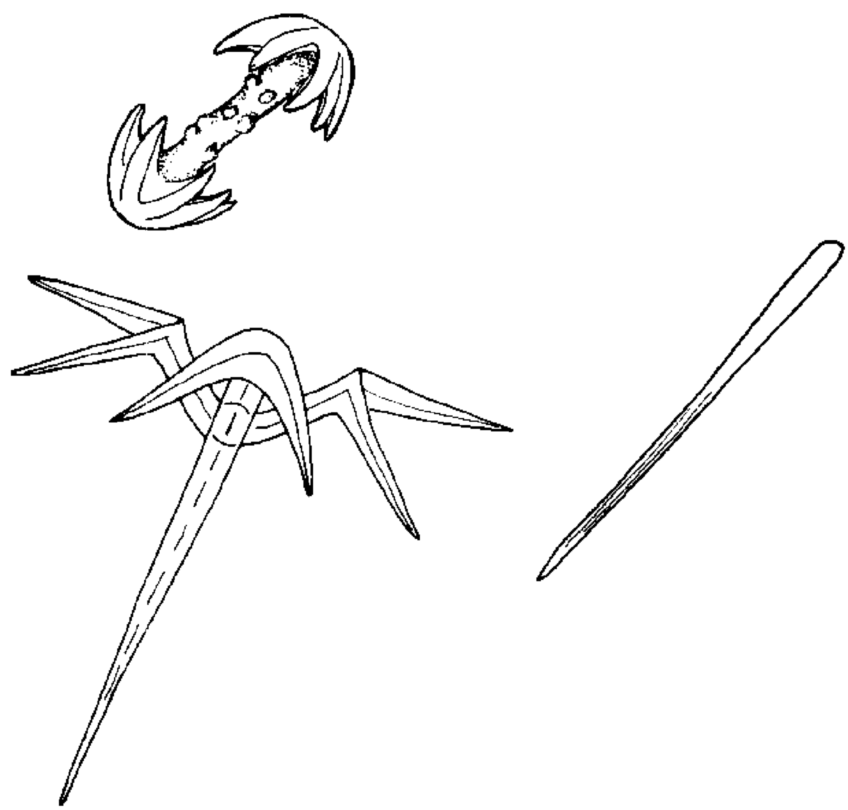
<u>Destructive Organisms</u>: An organism, tentatively identified as <u>Spongiophaga communis</u>, which is a species of fungus has caused widespread and intensive mortality among the Gulf of Mexico and Caribbean sponges.

• Shrimp fishermen are constantly plagued with the sponges catching in their nets, often resulting in damage to their hands.

• The boring sponges tear down the coral reefs and bore through mollusc shells.

• Sponges produce 15 types of *sterols* (important complex alcohols) not found in man; studying them may help scientists understand sterols which are found in man.

• Sponges also have a chemical that inhibits virus infections and leukemia in laboratory animals.



Sponge spicules
(Source: After Barnes 1968)

G JELLYFISHES AND CORALS

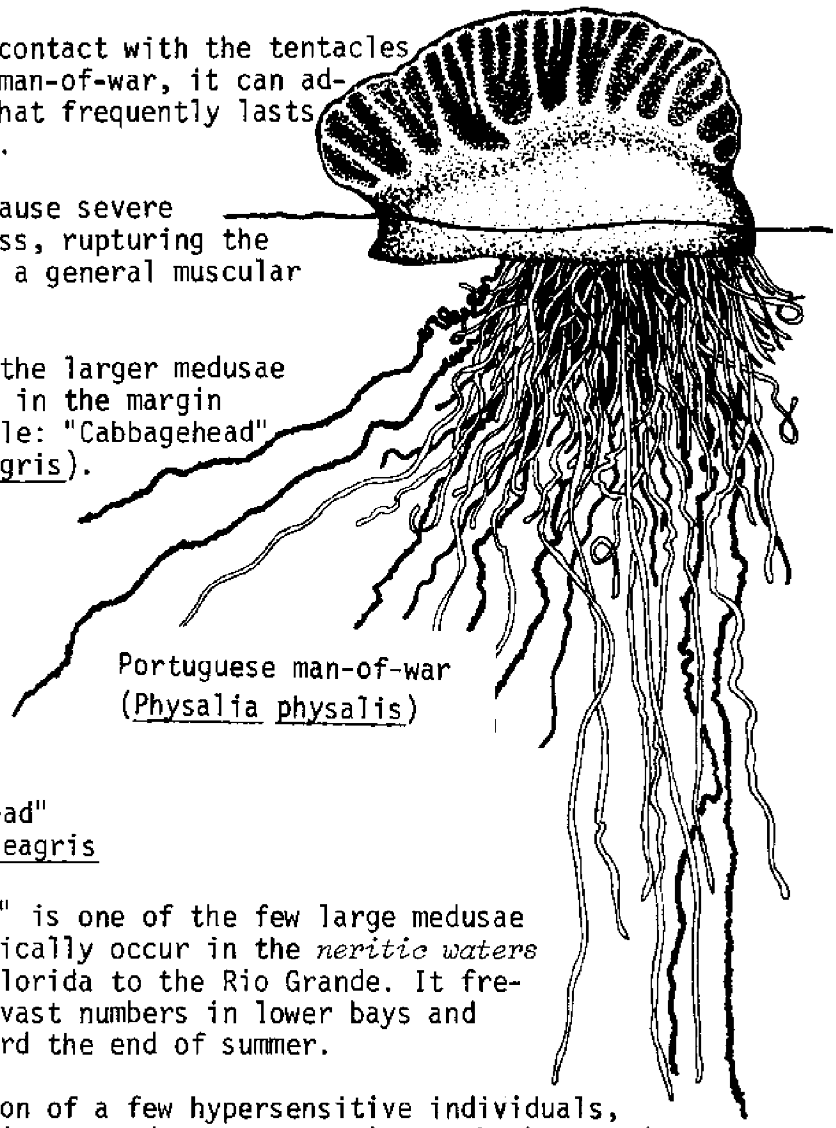
PHYLUM COELENTERATA - tube-like primitive forms with a continuous body wall surrounding a simple digestive cavity in which the opening encircled by tentacles is used in capturing food.

Class Hydrozoa - the hydroids commonly grow in little tufts on rocks and seaweeds along the coast. A typical Hydrozoan for the Gulf of Mexico is the Obelia dichotoma but the Portuguese man-of-war (Physalia physalis) is more familiar to Texas beachcombers.

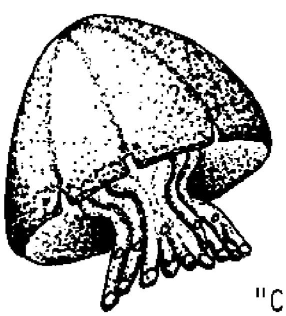
- If one comes in contact with the tentacles of the Portuguese man-of-war, it can administer a sting that frequently lasts five hours or more.

- The poison may cause severe respiratory distress, rupturing the blood vessels, and a general muscular paralysis.

Class Scyphozoa - the larger medusae with eight notches in the margin of the bell. Example: "Cabbagehead" (Stomolophus meleagris).



Portuguese man-of-war
(Physalia physalis)



"Cabbagehead"
Stomolophus meleagris

- The "Cabbagehead" is one of the few large medusae which characteristically occur in the *neritic waters* of the Gulf from Florida to the Rio Grande. It frequently occurs in vast numbers in lower bays and around passes toward the end of summer.

- With the exception of a few hypersensitive individuals, the "Cabbagehead" is not a dangerous species to bathers and may be handled with impunity.

If one were living in Thailand he would probably serve the "Cabbagehead" prepared in the following manner:

Putt Mangkrapoon

Slice into small strips jellyfish which has either been boiled or left raw.
Brown a clove of crushed or sliced garlic in a frying pan with butter or vegetable oil.
Add jellyfish strips; add salt, accent pepper and soy sauce to taste.
Stir until done and serve. The remaining sauce may be thickened with flour to make a gravy.
For a change, one may add cooking wine and a little sugar to it for another delicious dish.

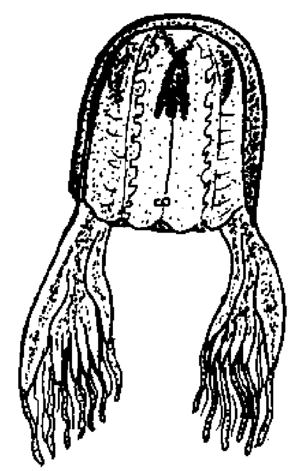
Nirund Jivasantikarn

Also included in this class is one of the most lethal venomous marine animals known to man -- the sea wasp. In 1910, A.G. Mayer had given the term "sea wasp" to the Cubomedusae, a family of jellyfish, because of the severity of the stings they inflicted on their victims. The Chironex fleckeri is the genus and species which has been found in northern Australian waters and has been held accountable for several fatalities in that area.

Fortunately, the species which does occur along the Gulf coast, Chiropsalmus quadrumanus, has not been found to be deadly but has been responsible for numerous cases of stinging on the Galveston, Texas bathing beaches.

The sea wasp uses a form of harpoon called a nematocyst to inflict its venom. These are located in the slender tentacles and may be found in other Coelenterates as well.

The nematocyst consists of a capsule-like container which is embedded in the skin; it contains the liquid venom and a hollow coiled thread tube that holds the folded spines or barbs. As these are shed by the jellyfish, new ones are later regenerated.

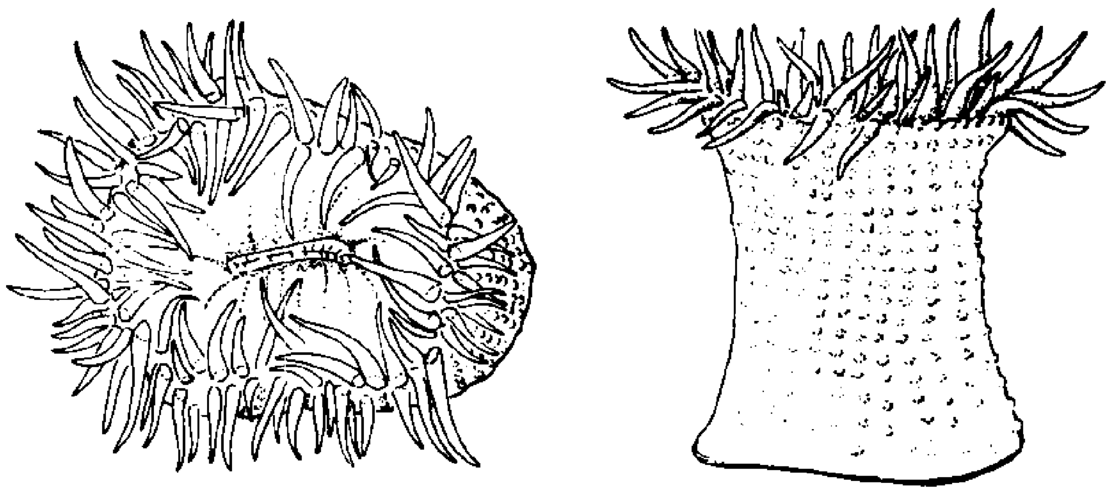


Chiropsalmus quadrumanus

(Source: After Miner 1950)

Class Anthozoa - These are soft and cup-like, with tentacles and stinging cells. Some have limy skeletons. _Bunodosoma cavernata_ (Bosc), a sea anemone which is often found on the northern coast of the Gulf of Mexico, is an example.

Bunodosoma cavernata (Bosc) is the common jetty form on the Texas coast, especially at Port Aransas and Port Isabel.



Sea anemone
Bunodosoma cavernata
(Source: Hedgpeth 1954)

Other Anthozoa include the corals and sea pens of which over 90 species have been located in the Gulf. The short-stemmed sea pansy, _Renilla mulleri_, is common in the northern Gulf.

H THE FLOWER GARDENS STORY

Diver studies coral formations in Gulf's Flower Gardens

(Source: Texas A&M University)

The Flower Gardens are unique coral reefs located 110 miles S-SE of Galveston in the Gulf of Mexico at approximately 93°50'W and 25°50'N, and covering an area of perhaps two or three football fields in size. The twin coral reef peaks, about 15 miles apart, are 500 miles farther north than any similar reefs, since the nearest living reefs are off the end of the Florida Keys and south of Tampico, Mexico.

The corals here are like the West Indian coral reefs with all the tropical characteristics and marine life which are found off the West Indies.

Local fishermen found bits of the multi-colored coral in their nets brought up from depths of 60 to 125 feet on salt domes which have pushed up from bottom depths of 300 feet or more. Because of these colors, fishermen began calling the area the Flower Gardens.

The growth rates of the corals are minimal since living coral relies on water temperature no colder than 70°F.

The Gardens have become a site for many research experiments, including a materials durability study carried on by scientists from Texas A&M University. Various items of materials such as metals, plastics and a mixture of materials are resting on a platform located in the depths of the Gardens and are periodically checked by divers for their durability of existence among the depths of the corals.

Durability tests

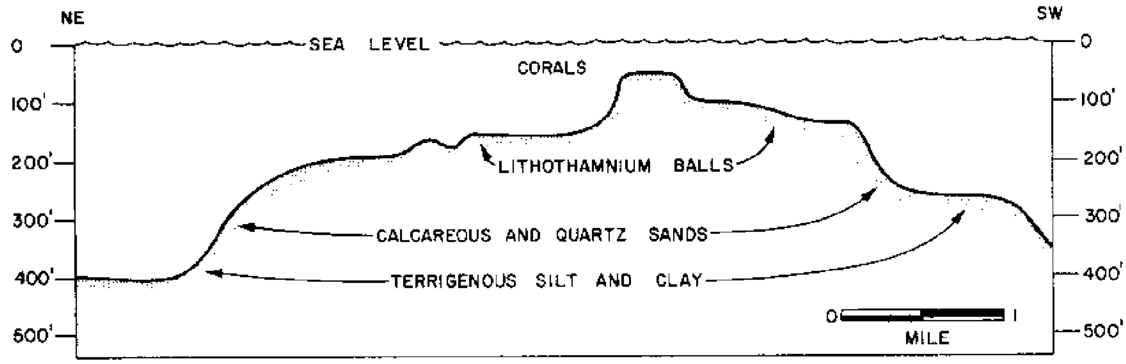
(Source: Texas A&M University)

Potential of the Flower Gardens:

- The reef is of particular interest in terms of recruitment and maintenance of fish fauna. So far, over 40 species have been identified in the area.

- It is a natural laboratory for the diving scientist who desires to study one of the immense number of problems concerning behavior and ethology of reef organisms.

- It would serve very well as a standard station for monitoring pesticides, heavy metals, and other pollutants in view of recent detection of relatively high pesticide levels in certain resident fishes.



Cross section of the East Flower Garden Bank showing the sediment zones and terraces described by Stetson.
(Source: Edwards 1971)

I MARINE WORMS IN THE GULF OF MEXICO

PHYLUM NEMATODA - Roundworms. Free-living nematodes are found in the sea, fresh water and in the soil. Parasitic nematodes of the Contracaecum species are commonly found in the Gulf area.

PHYLUM ACANTHOCEPHALA - The Acanthocephala are fairly common in fishes frequenting the shores and shallow bays throughout the Gulf where small Crustacea, which probably serve as intermediate hosts, abound.

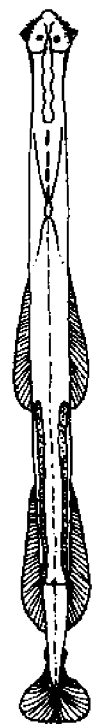
PHYLUM PLATYHELMINTHES - Flatworms, a large number of which are found in the sea either free-living or parasitic.

1. Turbellaria - Some of the largest worms within this class may grow to two inches in length; most are much smaller.

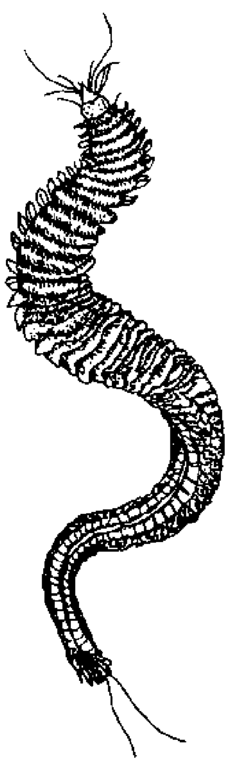
2. Trematoda - Flatworms within this class are parasitic in habit. There are approximately 200 species of *digenetic* trematodes known from fishes of the Gulf, mostly from its eastern region.

3. Cestoda - Causing considerable economic loss because of "wormy fish," this class contains the "spaghetti worms" called so because of their long, slender appearance. Commonly found in the fish called "Drum" (Pogonias cromis).

PHYLUM CHAETOGNATHA - Numerous, elongate transparent, worm-like marine animals, sometimes called "arrow worms" or "glass worms." Example: Sagitta. This genus is by far the largest both in number of individuals in the Gulf.



Sagitta
(Source: After Miner 1950)



PHYLUM ANNELIDA - True worms with elongated segmented bodies. Examples: Nereis. The Nereis is one of the largest of the marine worms, sometimes reaching eighteen inches in length. They burrow in large numbers in sandy and muddy bottoms. Belonging to this phylum is the popular fisherman's bait called "blood worms."

Nereis
(Source: After Miner 1950)

PHYLUM NEMERTINEA - Members of this class are usually found on the Gulf coast burrowing in the sand or mud in the low intertidal zone and below to areas where the depth of water is 10 meters or more.

J MOSS ANIMALS

PHYLUM ECTOPROCTA - Colonial animals, known as "sea mats" or "moss animals", form flexible tufts or thin incrustations over the surface of solid objects both in intertidal and deep waters.

Abundant in the Gulf, they encrust shells, stones, dead corals, and corallines, algae or anything else that may afford attachment.

They can cover the surfaces of the oyster shell to such an extent that the *spat* have little room in which to grow.

(Source: After Miner 1950)

K LAMP SHELLS

PHYLUM BRACHIOPODA - These animals have an upper and lower shell. The majority of species are equipped with a short stalk or peduncle by which they attach themselves to rocks or similar objects.

The brachiopods have flourished from Cambrian times to the present.

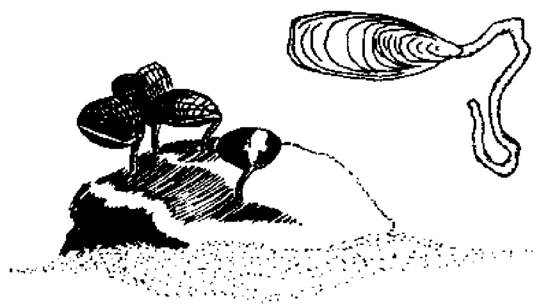
The genus Lingula is the oldest living genus of all animals.

The genus Glottidia is found along the Gulf coast.

These lamp shells often prefer deep water, but a few are found between the tides attached to rocks.

They feed on plankton, which they catch with a lophophore composed of tentacles and arms.

Their size is small - from 3/4 inch long to over 2 inches in length. The sand-dwelling forms may be a bit longer.



Lamp Shells
(Source: After Berrill 1966)

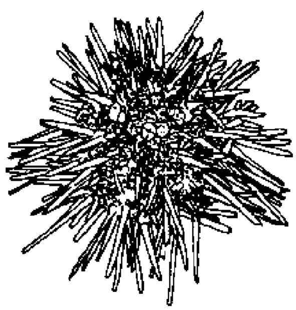
L SPINY-SKINNED ANIMALS

PHYLUM ECHINODERMATA - Animals with calcareous plates forming a more or less rigid skeleton, or with scattered plates and spicules embedded in the body wall. Many are provided with spines. All are marine, possess a water-vascular system, and all but a few sea cucumbers are *benthic.*

Sea cucumbers - Class Holothuroidea

Sea lillies - Class Crinoidea

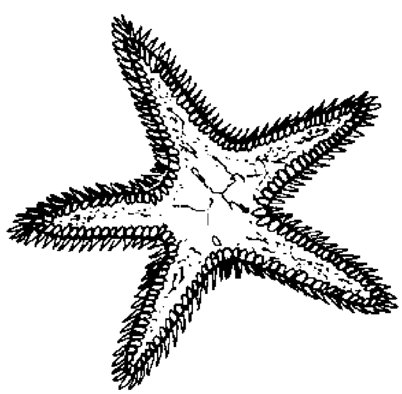
Sea urchins - Class Echinoidea



This species is found on rocky shores, jetties, sea walls, etc. thus in a few areas along the Gulf.

Purple sea-urchin
(Arbacia punctulata)
Upper Side

Starfish - Class Asteroidea



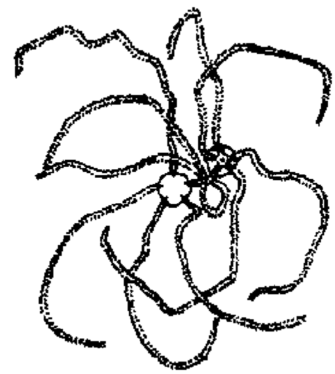
This species is widely distributed from the upper Atlantic coast to the Gulf of Mexico.

Starfish
(Astropecten articulatis)
Upper Side

(Source of all drawings: After Miner 1950)

Brittlestars - Class Ophiuroidea

These may be found in bays along the Gulf coast, but are more common offshore.



Brittlestar
(Amphioplus macilentus)

(Source: After Miner 1950)

Chemical substances produced by sea cucumbers, starfish and shellfish may one day help medical science to combat viruses, microbes, cancer and nerve disorders. An extract from the sea squirt was found to cure leukemia in mice and to destroy human cancer cells in tissue culture experiments. A biotoxin from the puffer is 200,000 times more powerful than the drug curare, used today for blocking nervous activity.

M ARTHROPODS

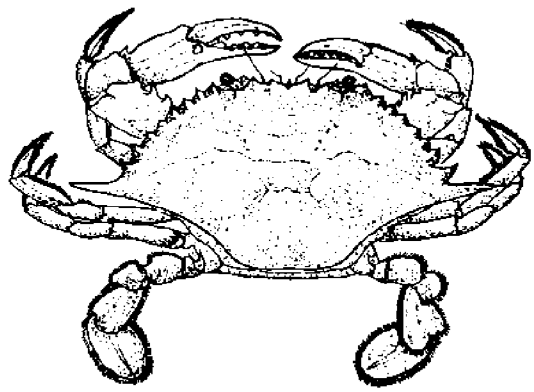
PHYLUM ARTHROPODA - Includes animals with a segmented, chitinous exoskeleton and with jointed appendages, variously modified for locomotion, feeding and other activities.

Class Crustacea - Includes the crayfish, crabs, shrimp, barnacles, water fleas and others.

- The spiny lobster or crawfish is one of the important edible crustaceans. Panulirus argus (Latreille) is the most common species. Abundant in the Florida Keys.

- Crabs - 92 species reported in Texas so far.

- Blue crab (Callinectes sapidus Rathbun) - most important crab on the Texas coast, supporting a large commercial fishery each year. (See FISHERIES section)

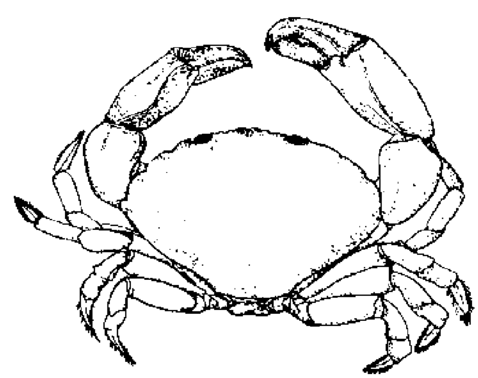


Callinectes sapidus Rathbun
Blue Crab
(Source: Leary 1967)

Life history of the Blue Crab -

- Life span of two or three years.
- In Texas, the usual spawning season occurs from December of one year to October of the next.
- A period of about 15 days is required for the eggs to develop.
- Immediately after leaving the egg, the young crab larva is called a "Zoea." Molting may occur as many as 7 times during this stage.
- The second stage, "megalops," molts once.
- During their second summer, at the age of twelve to fourteen months, the crabs mature and mate.
- "Soft-shell" crabs are taken after the last molt of the female or the next to the last molt of the male, just before sexual maturity.
- Prominent in bays and around the mouths of rivers, and prospers in the Gulf as well as in brackish flats and areas of almost fresh water.
- Favors mud bottoms.
- Diet consists of: certain types of vegetation and small fish.

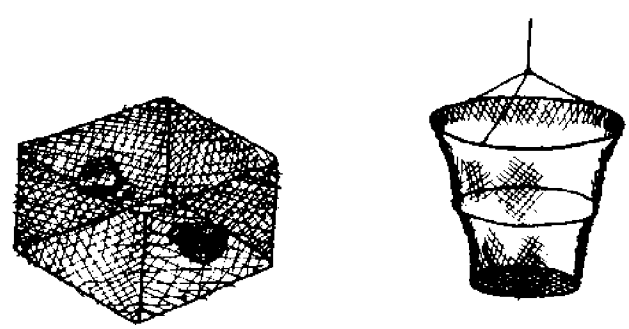
- Stone Crab (Menippe mercenaria Say)
  - May be found burrowing under rocks and in crevices around jetties and oyster reefs.
  - In some areas supports a sizeable fishery, although not in Texas due to its limited availability.
  - Its body is too small for economic purposes, but its huge claws contain large portions of sweet, rich meat.
  - Found all along the South Atlantic and Gulf coasts, and is used extensively for food in areas where it is found in sufficient numbers.
  - Regeneration of lost claws is its greatest asset.



Menippe mercenaria Say
Stone Crab

(Source: Leary 1967)

Commercial methods for crab fishery - Traps or pots are used almost exclusively.



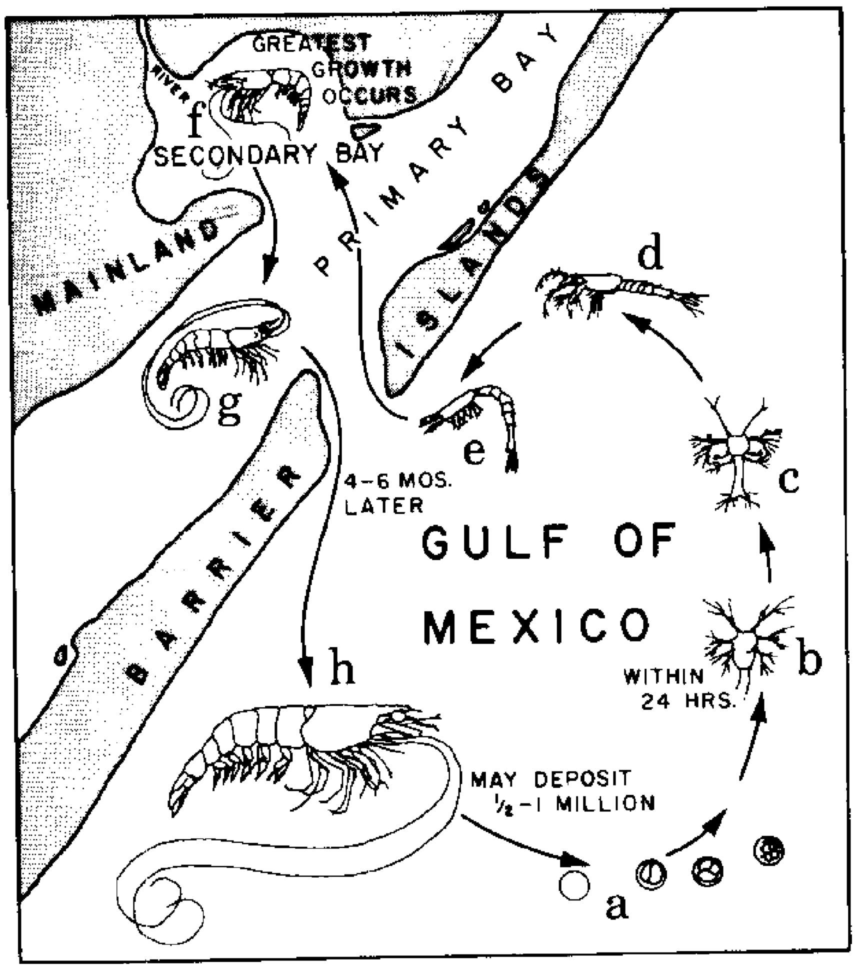
- Shrimp - There are five major species of shrimp caught in Gulf waters: white, brown, pink, Royal Red, and seabob shrimp.

- Life histories of these Texas shrimp are similar:

  a. young hatched in the Gulf of Mexico

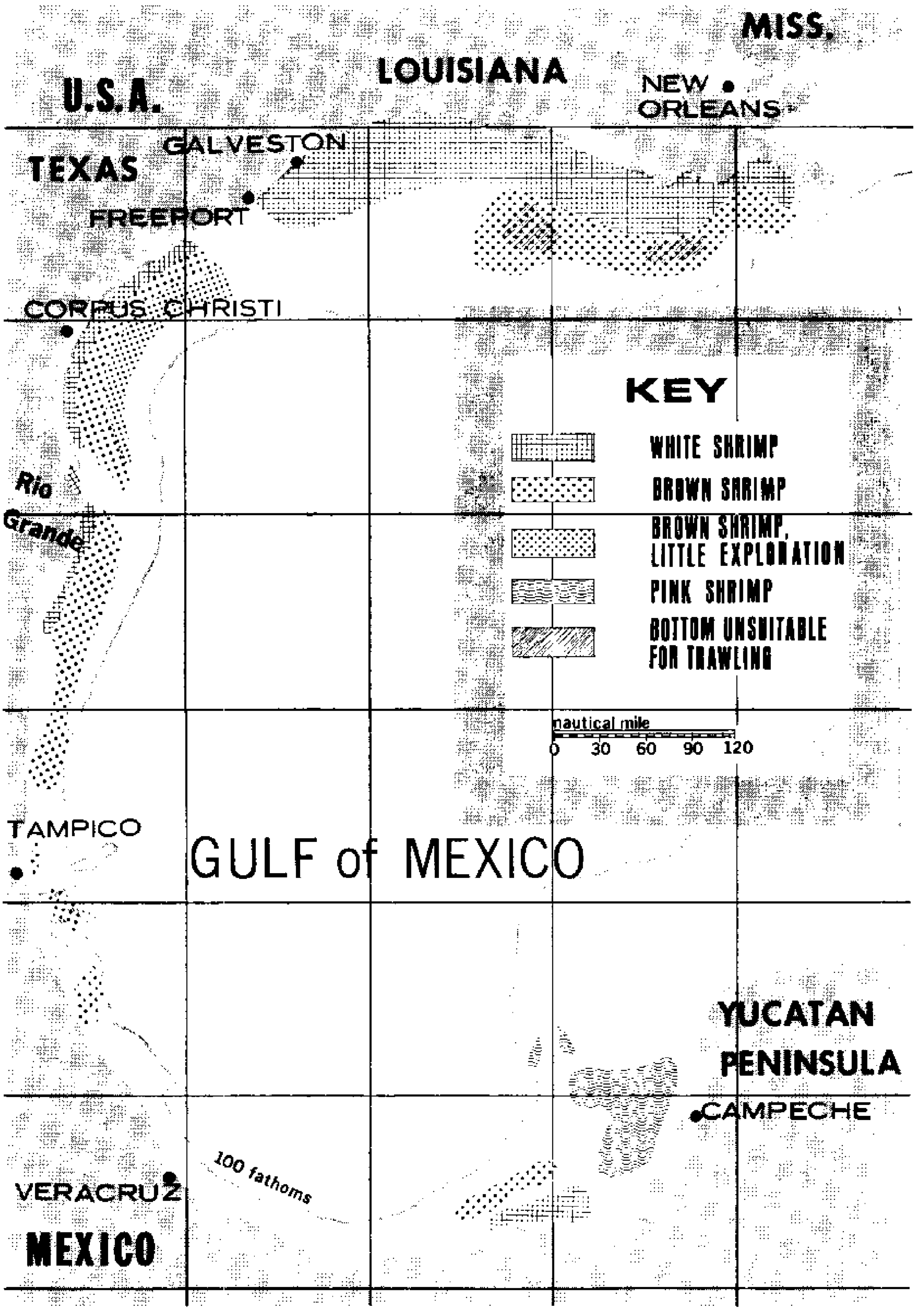
  b. carried by on-shore water movements to shallow estuaries and coastal lagoons, where they feed, grow rapidly, and then

  c. start long trip back to the Gulf spawning grounds.



Life history of white shrimp: (a) shrimp eggs, (b) nauplius larva, (c) protozoea, (d) mysis, (e) postmysis, (f) juvenile shrimp, (g) adolescent shrimp, (h) mature adult shrimp, (a, b, c, d, and e after Heegaard). Life histories of other shrimp are similar.

(Source: After Moffett 1967)



Shrimping areas of the Western Gulf of Mexico

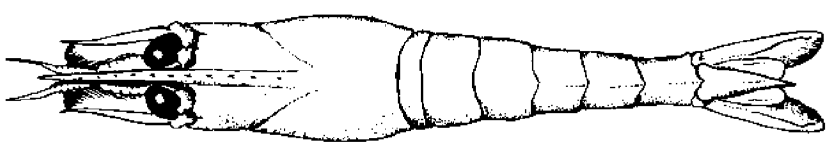
(Source: Moffett 1967)

Pink shrimp (Penaeus duorarum)

(Source: Moffett 1967)

Pink Shrimp

- Increase in commercial value since the Mexican government has recently limited U.S. fishermen to an area no less than 12 miles off the Mexican coast.
- Although they are usually found in waters between 36-108 feet in depth, pink shrimp abound in the Campeche area which extends as far as 150 feet deep off the coast of Mexico.
- Most productive areas: Gulf coast, Campeche, Dry Tortugas and Sanibel Island.
- They may vary from 5-8 inches in length.



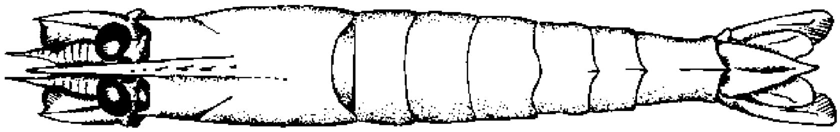
Royal Red shrimp (Hymenopenaeus robustus)

(Source: Moffett 1967)

Royal Red Shrimp

- Never found in Gulf estuaries. Occur in water 900-2250 feet in depth, often 50 miles or more away from shore so that fishing for them presents special problems.
- Very few commercial vessels are currently involved in Royal Red production.
- The best domestic areas for Royal Red fishing have been found to be in a 180-square mile area between St. Augustine and Ft. Pierce off the east coast of Florida, a 77-square mile area south to southwest of the Dry Tortugas, and a large 740-square mile area from Mobile, Alabama, west to the Mississippi Delta.
- They may vary from 5-9 inches in length.

(9/72)

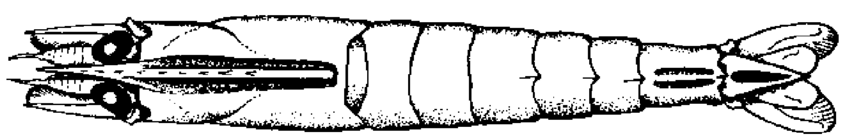


White shrimp (Penaeus setiferus)

(Source: Moffett 1967)

White Shrimp

- Until 1948 white shrimp accounted for almost 90% of the total catch of shrimp in the Gulf of Mexico. Now white shrimp account for only about one-sixth of the Gulf coast production, due to the availability of brown and pink shrimp.
- Caught primarily during daylight hours, in water usually no deeper than 90 feet, and rarely deeper than 210-240 feet.
- Most abundant in areas that are characterized by having an inland, brackish marsh connected by passes with an adjacent shallow offshore area of relatively high salinity and mud or clay bottom.
- The female, somewhat larger than the male, may reach a length of 10 inches and weigh up to three ounces.

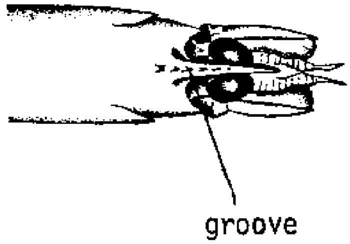


Brown shrimp (Penaeus aztecus)

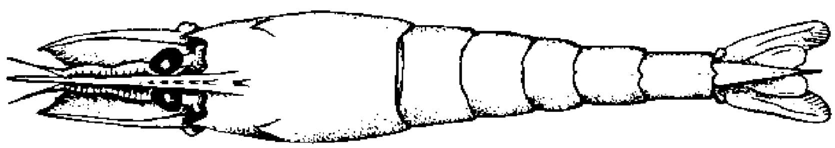
(Source: Moffett 1967)

Brown Shrimp

- Brown shrimp now account for 81% of the Gulf coast production.
- Principal species found along the continental shelf from Alabama to the Rio Grande River, with particularly heavy concentrations off the Texas coast.
- May be found in water between 66-120 feet deep, and as deep as 300 feet.
- May reveal a length of from 5-8 inches.



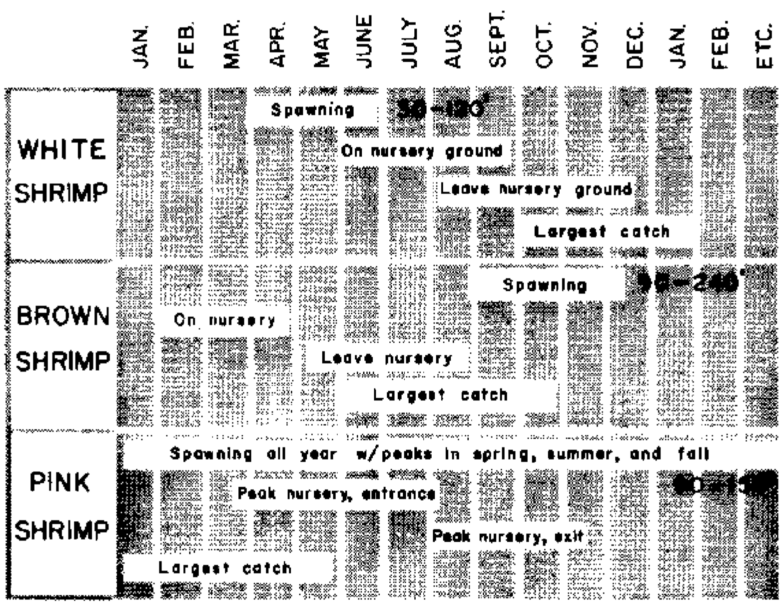
Gulf coast fishermen actually use a thumbnail measurement of the depth of this groove to differentiate among the species rather than color.



Seabob shrimp (<u>Xiphopeneus</u> <u>krøyeri</u>)
(Source: Moffett 1967)

<u>Seabob Shrimp</u>

- Less than four inches long.
- Are of limited commercial value, but are occasionally sold as bait.
- Are fished to some extent in the Sabine Pass area.



Species variations on the biological life cycle.
(Source: After Knopf 1970)

- Temperature variations influence the growth rate of shrimp. Growth is rapid during the warmer months but slows down or even stops in the nursery grounds and the offshore waters during the winter months. With the return of warmer weather, growth resumes. Seasonal migrations of shrimp are also affected by temperature and salinity changes.

- Not only do the shrimp serve as delicacies for human consumption, they are also a food source in the growth cycle of the larger marine animals.

- The tiny brackish water shrimp, Palaemonetes, often referred to as "grass shrimp" are prevalent in the bays and estuaries and small rivers.

Grass shrimp

(Source: After Miner 1950)

River Shrimp

Since before the sixteenth century, the giant freshwater shrimp, Macrobrachium, has been a favorite food among the natives of the tropical Americas. Ideal for aquaculture development, these shrimp were raised for many years by certain tribes of South American Indians who collected the young, placed them in pools, and fed them until they grew to an edible size.

Such freshwater shrimp farming is now taking place in certain areas in Florida and along the Mississippi River.

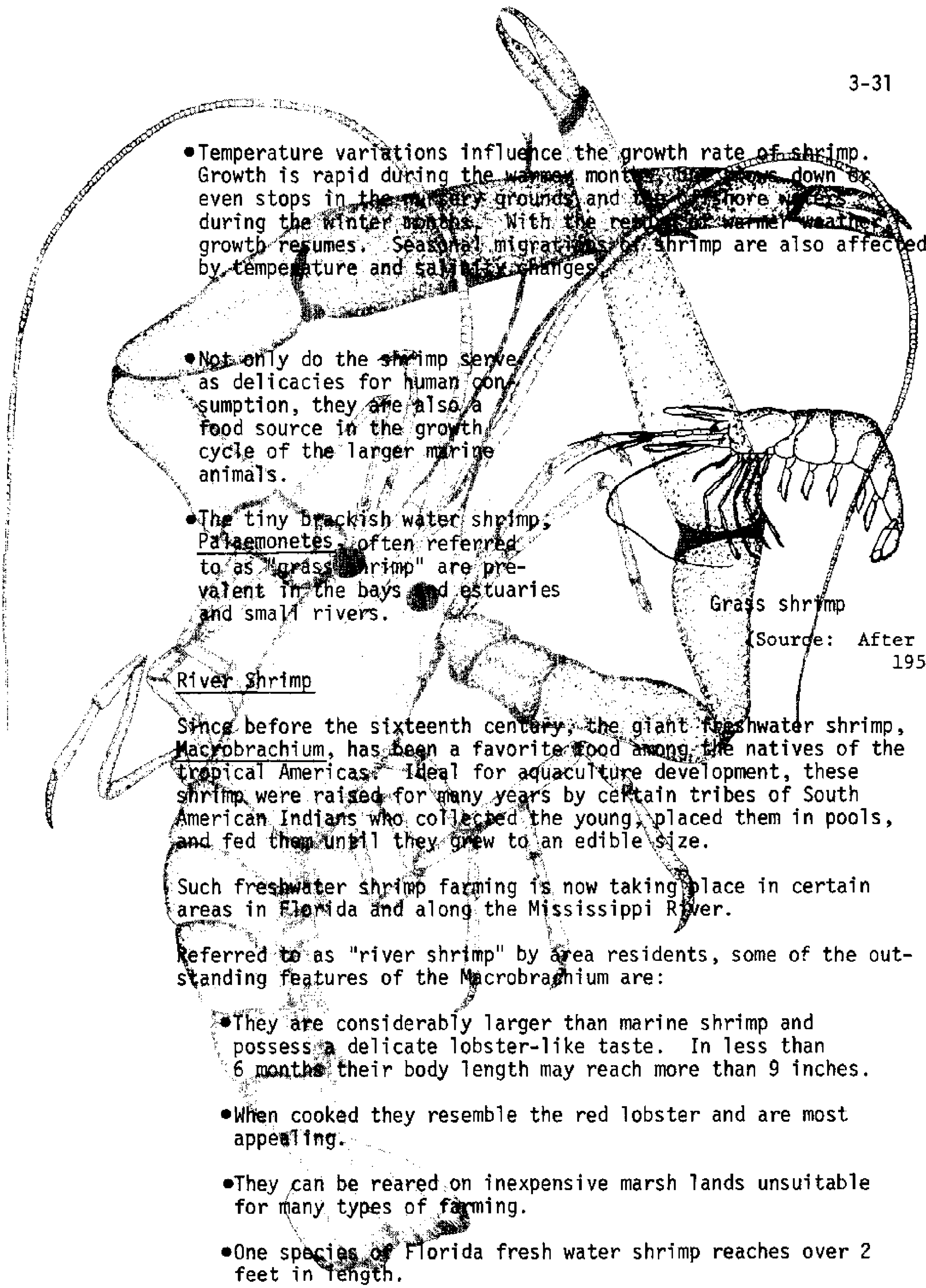
Referred to as "river shrimp" by area residents, some of the outstanding features of the Macrobrachium are:

- They are considerably larger than marine shrimp and possess a delicate lobster-like taste. In less than 6 months their body length may reach more than 9 inches.

- When cooked they resemble the red lobster and are most appealing.

- They can be reared on inexpensive marsh lands unsuitable for many types of farming.

- One species of Florida fresh water shrimp reaches over 2 feet in length.



River shrimp (Macrobrachium)
(actual size)

N OYSTERS

PHYLUM MOLLUSCA - Noted particularly for their construction of an infinite variety of calcareous shells encasing the body and for structural modifications that have taken place in the soft parts known as the foot and mantle, which are associated with the method of locomotion and capture of food.

Class Pelecypoda - Consists of clams, oysters and mussels which possess two lateral shells with a dorsal hinge, and many of which have hatchet-shaped foot which may be used for digging.

Crassostrea virginica (Gmelin) - the commercial oyster in Texas.
Ostrea equestris Say - the small Gulf oyster.

Life histories of Texas oysters are similar:

a. Oyster larvae found in plankton in the period from April through October.

b. During November to March when water temperatures range from 10°-20°C., the major increase in growth takes place.

c. Approximately 1/3 of the oysters setting in the early part of the summer become sexually mature by the time they are a month old and still less than an inch in diameter, thus it is a normal event for 2 generations of oysters to be produced in the Gulf each summer.

d. The oyster is extremely versatile in adapting itself to changes in temperature and is commonly found where the annual range is from -2° to +30°C.

e. They feed on microscopic plants in water to some extent.

Shell of oyster showing Gulf oysters attached.

Oyster Communities -

- Primarily found in estuaries and bays. Only a small percentage of the total oyster population is found in the Gulf.
- Probably more than 1,400 square miles of water bottoms along the Gulf coast are suitable for and are more or less populated with oysters.
- Small isolated patches of oysters may be found-on elevated islands in seas of soft mud.
- When the bottom is relatively firm, oyster communities may be up to 25 miles in length.
- Colonies may flourish in depths of from one foot above mean low water to a depth of 30-40 feet.
- Some colonies have been found as far as 5 miles out.
- Persist in isolated marsh ponds where waters connect with the open sea only for short intervals in time of flood or storm.
- Require a mixture of salt water from the Gulf or oceans with the fresh water from land drainage (*brackish waters*).
- Oyster communities are located in four distinct areas:

  1. head of a typical estuary - average salinity of 10°/₀₀ or below.
  2. reefs - yearly average salinity of 15°/₀₀.
  3. nearer mouth of typical estuary at and above low tide level - yearly average of 25°/₀₀ salinity.
  4. junction of typical estuary with waters of Gulf consistently high salinity level, above low tide level.

The many rivers draining into the Gulf annually deposit an enormous load of silt which produces multiple effects in the estuary. The silt-laden water decreases the penetration of sunlight into the water, thus limiting the production of phytoplankton, the oyster's food supply to some extent.

This fine silt coats the old shells on the bottom, making them no longer available as *cultch* for the young oysters.

Rechanneling of bays by man has caused salinity changes in some areas resulting in the development of new oyster populations, but the increased salt content also encourages the survival of the "conch", Thais, which has decimated or entirely destroyed many large oyster reefs. A secondary result from this channeling has been an increase in erosion along the shore.

Overharvesting without replacement of shell cultch inevitably causes the deterioration of a reef.

Hurricanes have done their share in destroying the reefs through excessive wave action which carries mud over the reefs and destroys them.

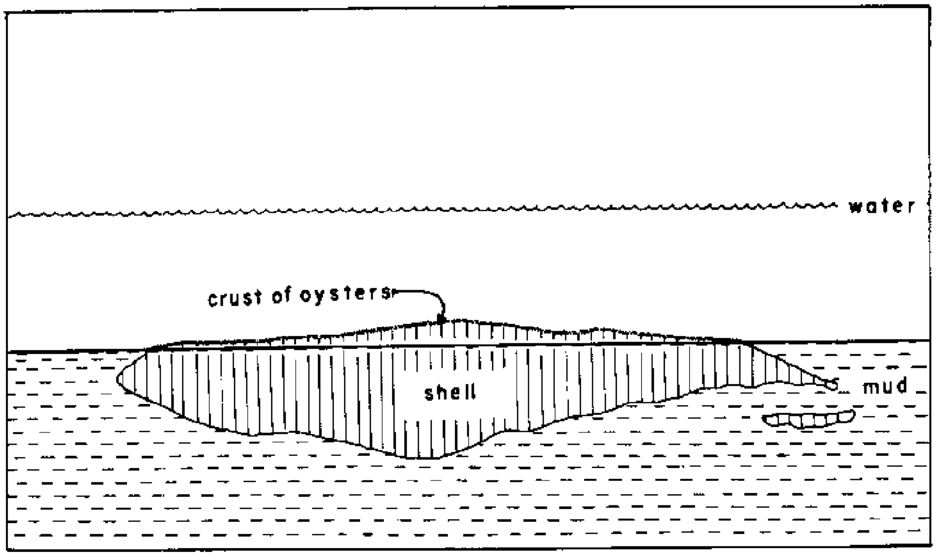
Industrial pollution has affected the oysters in that it sometimes makes them unpalatable.

Pests, Predators and Parasites

- The most serious natural predator of oyster populations in the Gulf area is the conch or oyster drill, Thais.

Thais

Three *commensal* animals occur in numbers sufficient to affect the biology of the oyster seriously. However, their injurious effects are of greater importance to the oyster industry than to the continuity of the species: the boring sponge, Cliona; the boring clam, Martesia; and the mud worm, Polydora bore into the oyster shell, existing ar various population densities depending upon the environment.



Generalized cross-section of an oyster reef.
(Source: Hofstetter 1967)

- Drum, sheepshead and skates or rays may produce major damage, esp. to young oysters on newly planted beds.

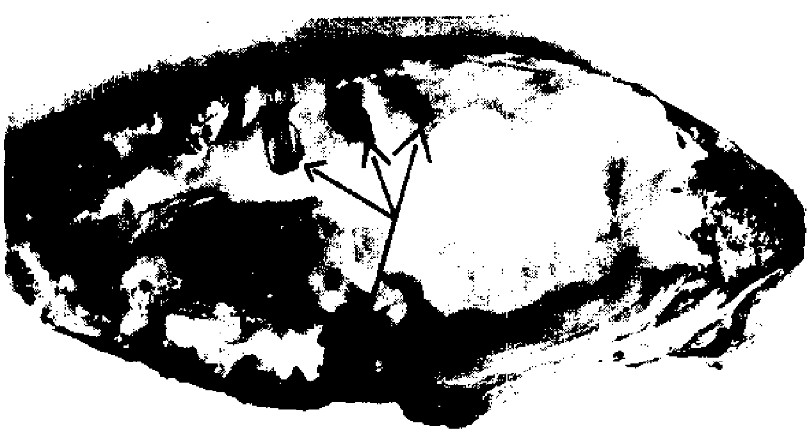
- Any of the larger crabs may destroy oysters, depending on the size of the oysters, size of the crabs, environment, etc. On the Gulf coast the most active is *Menippe mercenaria*, a crab with very heavy and strong claws, which can crack large, heavy-shelled oysters and also *Callinectes sapidus*.

- Extensive mortalities have been attributed to the predaceous flatworms in some Florida locations. Some eat spat (oysters 2 inches in size).

- Mollusk mortalities have also been attributed to *Labyrinthomyxa marina* (*Dermocystidium marinum*), a parasitic fungus. This fungus is particularly destructive to the commercial oyster, *Crassostrea virginica*.

- The effects of pollution damage are greatest at the source of the toxin and the effects on oysters diminish with distance from the source.
- Pollution effects may not involve a toxin, but instead may modify the habitat in some indirect manner so as to cause mortalities.
- Bryozoans (moss animals) - see section on PHYLUM ECTOPROCTA.

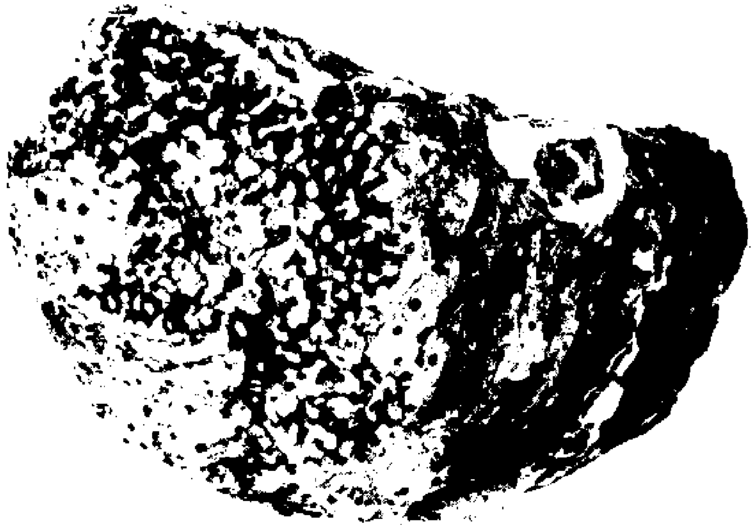
At times clusters of mussels will completely cover large oysters, making it impossible for the oysters to secure food. As a result, such oysters are usually poor in quality.

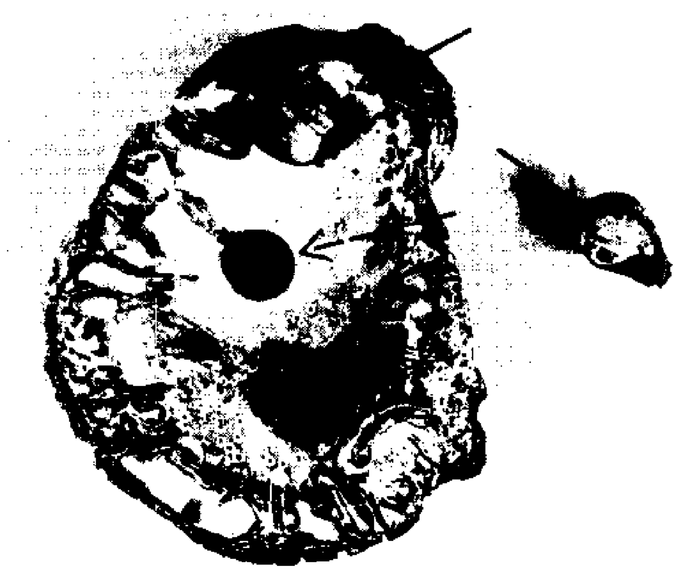


The mudworm (Polydora) enters the oyster while the valves are open. It collects a pile of silt between the mantle and inner shell surface to make a burrow which irritates the oyster. The oyster covers worms and silt with a layer of shell, forming a "mud blister." Shell damage repairs by the oyster keep its resistance to disease low, causing it to be of poor quality.

(Source of all photographs: Hofstetter 1967)

The boring sponges (Cliona) penetrate the shell, forming extensive networks of channels through the shell with many openings to the outside. This causes a weak shell which crumbles under the slightest pressure.





The boring clam (Diplothyra) is a small, thin-shelled mollusc which bores into the very young oyster shell, thus hindering the growth of the oyster and often riddling the shell so that it can be easily broken.

Barnacles do not present as much of a problem as the mussels and bryozoans but do take up space on the oyster shell which could be used by the young oyster, *spat*.

(Source of all photographs: Hofstetter 1967)

O OTHER MOLLUSCA

Class Gastropoda - Conchs, Nudibranchs and Snails

A study of the Campeche Bank area in 1961 and 1962 by Winnie H. Rice and Louis S. Kornicker included a collection of 90 species of gastropods.

Class Cephalopoda - Squids and Octopods

May be found in the Florida current and lower Florida Keys. Texas bays have an abundance of "short squid," *Lolliguncula brevis* which are used for bait.

P FISHES IN THE GULF OF MEXICO

PHYLUM CHORDATA (Subphylum Vertebrata) - The chordata are animals which, during some stage of their life, have gill slits and a skeletal axis known as a *notochord*. This subphylum includes animals with vertebrae. Some are cold-blooded and some are warm-blooded.

Class Osteichthyes (Bony Fishes)

The fish in the Gulf of Mexico may be divided into three categories:

1. Shorefish - those which occur along the perimeter of the Gulf.

   For example:

   Sheepshead - *Archosargus probatocepahlus*
   Channel bass - *Sciaenops ocellatus*
   Speckled trout - *Cynoscion nebulosus*

2. *Pelagic* fish - these are found to be the same as those of the Caribbean and adjacent parts of the Atlantic Ocean.

   For example:

   Blue marlin - *Makaria ampla*
   Black drum - *Pogonias cromis*
   Little tuna - *Euthynnus alletteratus*

3. Deep-Sea fishes - Examples of which are:

   Anglerfish - _Melanocetus murrayi_
   Hatchetfish - _Argyropelecus sp._

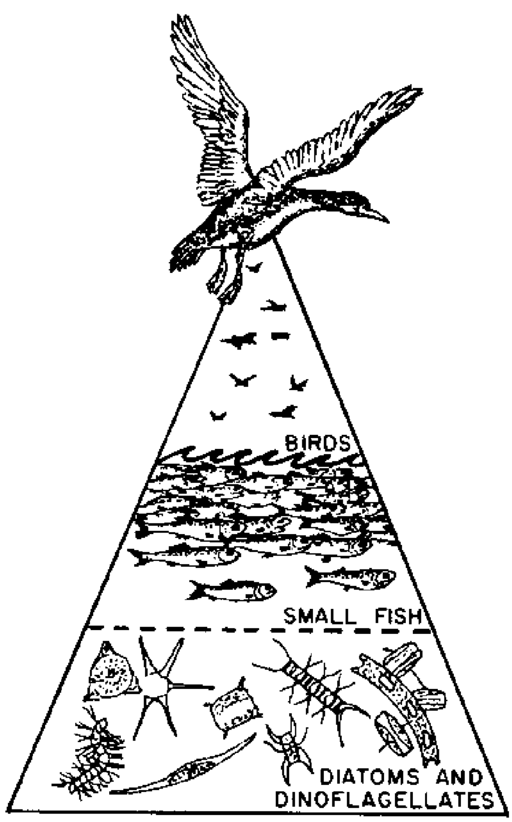
More information regarding the fishes in the Gulf of Mexico may be found in the section on FISHERIES IN THE GULF OF MEXICO.

Q THE BIRDS OF THE GULF OF MEXICO

PHYLUM CHORDATA - Animals which in some stage of their lives have gill slits and a skeletal axis known as a notochord.

Birds - Class Aves.

Once again the food chain makes its appearance. In this case, the birds are dominant.



(Source: After Berrill 1966)

The birds of the Gulf of Mexico may be classified into three groups:

1. Offshore birds - although all birds must come to shore to nest those listed below are among those which are rarely seen by an observer on the mainland.

   Sooty Shearwater
   Audubon Shearwater
   Greater Shearwater
   Leach Petrel
   Blue-faced Booby
   White-winged Scoter
   Red Phalarope
   Pomarine Jaeger
   Kittiwake
   Sooty Tern
   Dovekie

2. Coastal birds - those species that occur more frequently on the shore of the mainland than on the open sea. These may be subdivided into three groups:

   a. Coastal breeding birds such as:

      Brown Pelican
      Little Blue Herons
      Certain Egrets, Bitterns, Rails and many others

   b. Regular visitants to the coast such as:

      Pectoral Sandpipers
      Dowitchers
      Sanderlings

   c. Visitants to coast not of regular annual occurrence such as:

      Great black-backed Gulls
      Eskimo Curlews
      Trumpeter Swans

3. Land Birds over the open Gulf - the land birds and the inland water birds that from time to time and in varying numbers have been observed over the open Gulf during the seasons of migrations. Some of those birds most frequently seen are:

   Barn Swallows
   Purple Martins
   Black and White Warblers
   Common Yellow-throat
   American Redstart
   Scarlet Tanagers
   Painted Buntings

- There are seven national wildlife refuges in Texas totaling 129,000 acres. They are:

  Hagerman National Wildlife Refuge
  Anahuac National Wildlife Refuge
  Buffalo Lake National Wildlife Refuge
  Laguna Atascosa National Wildlife Refuge
  Muleshoe National Wildlife Refuge
  Santa Ana National Wildlife Refuge
  Aransas National Wildlife Refuge
  San Bernard National Wildlife Refuge
  Brazoria National Wildlife Refuge

- Only 50 of America's magnificent whooping cranes exist after near extinction in the 1940's.

  Aransas National Wildlife Refuge was established in 1937. Later (1939-40) a count of 22 adult cranes and 6 young wintered there. A recent count has shown 44 adults and 6 young.

R REPTILES IN THE GULF OF MEXICO

PHYLUM CHORDATA

Class Reptilia - Turtles, Lizards, Snakes, Crocodiles, and others.

- Of the nine species of living sea turtles found throughout the world, five occur in the Gulf areas. Only three of these are found in sufficient quantity to be of any commercial value:

  Green turtle - *Chelonia mydas* (Linne)
  Loggerhead turtle - *Caretta caretta* (Linne)
  Hawksbill - *Eretmochelys imbricata* (Linne)

Green turtle - carapace length of about 36 inches, weight of 200 lbs. Valued principally for use as food. More frequently found in the Florida Keys.

Loggerhead turtle - carapace length of 3 1/2 feet, weight rarely exceeds 350 lbs. More frequently found in the Florida Keys.

Hawksbill turtle - carapace length of approximately 4 feet. Its tortoise-shell plates overlap one another like the slats on the roof of a house, and its head resembles that of a hawk. Has been found on all the coasts of the U.S.

S MAMMALS OF THE GULF OF MEXICO

PHYLUM CHORDATA

Class Mammalia - Manatees, Seals, Whales, Porpoises, and Dolphins

West Indian Manatee (*Trichecus manatus* Linnaeus) - The present and recent past distribution of *T. manatus* is from south central and southern Florida, through the West Indies and Antilles to Mexico, and southward throughout Middle America to British Guiana.

It is most improbable that they live year-round on the northern Gulf coast; they are continuous residents in the U.S. only in Florida.

Heavy bone structure, paddle-like forelimbs and no hind limbs. Pure vegetarians. Upper lip is more or less cleft and the two halves can be manipulated independently.

West Indian Seal (*Monachus tropicalis* (Gray)) - Small herds occasionally visited the western Gulf as far north as Galveston, Texas, as late as 1932.

Large adults measure up to 7.5 feet in length. The color is brown, tinged with gray, caused by the hairs being light at the extreme tip. The color becomes lighter on the sides, and gradually passes into pale yellow or yellowish-white on the ventral side of the body.

Sperm Whale (Physeter catadon Linnaeus) - Largest known males attain a length of 65 feet. Females are only about half this size or less.

No dorsal fin, head is huge and rectangular, but the jaw is long and narrow. Teeth are present only in the lower jaw.

Color is almost black above, shading to lighter below.

At one time frequented the E and NE Gulf.

Pygmy Sperm Whales (Kogia breviceps (Blainville)) - Maximum length around 13 feet. Black in color and has a dorsal fin.

Only one known catch on record: on beach of Pinellas County, Florida, 1949.

Other whales include the Goose-beaked Whale (Ziphius cavirostris Cuvier), the Atlantic Killer Whale (Grampus orca Linnaeus), Short-finned Blackfish or Pilot Whale (Globicephala macrorhyncha (Gray)), and the Baleen Whales.

Dolphins known to have appeared in the Gulf are: the Long-snouted dolphin (Stenella plagiodon (Cope)), Rough-toothed dolphin (Steno bredanensis (Lesson),1817). Bottle-nosed dolphin (Tursiops truncatus), commonly known as the porpoise, is also numerous in the Gulf.

- Dolphins are the most accomplished of all swimming animals, excelling in marine acrobatics, long-distance travel and navigation. Of high intelligence, they communicate among themselves and are quite playful with bathers, gently nudging them with their bodies.
- They have a built-in sonar and can detect objects at a distance by giving off a sound and receiving the echo. In fact, a blindfolded porpoise in an aquarium pool can locate an object as small as six inches in diameter by echo alone.

GENERAL BIOLOGY OF THE GULF OF MEXICO

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FISHERIES AND FISHING INDUSTRY OF THE GULF OF MEXICO

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FISHERIES AND FISHING INDUSTRY OF THE GULF OF MEXICO

A SHELLFISH AND FINFISH STATISTICS

- The Food and Agriculture Organization of the United Nations recently reported that the total world's catch of fish was 69.3 million metric tons, an increase of more than 10% over 1970, establishing a new record.

- Commercial landings in the United States amounted to 5 billion pounds of fish, shellfish, and other aquatic animals and plants in 1971. The total catch was valued at $643 million at dock-side--the highest dollar value in history.

- Fish landings in the U.S. for human food were 2.4 billion pounds in 1971, a decline of 4% from a year ago. Landings of fish used for industrial purposes, such as fishmeal and oil, increased by 7% and reached 2.6 billion pounds.

- Shrimp was the most valuable fishery in the U.S. in 1971. United States fishermen landed a little over 234 million pounds (heads-off) compared with 224.5 million pounds in 1970. This catch was worth $166.2 million to the fishermen.

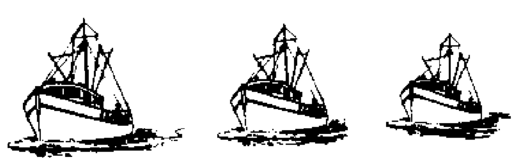
- There are more than a million pounds of shrimp consumed every day in the United States.

- The value of fishery products processed in the United States in 1971 from both domestic and imported raw materials was a record $1.85 billion--7% above 1970.

- Menhaden production in the Gulf of Mexico broke all records in 1971 with more than 1.6 billion pounds landed in Mississippi, Louisiana and Texas, the largest single catch in U.S. history.

- Shrimp landings from three states--Alaska, Louisiana and Texas--accounted for 70% of the entire U.S. shrimp catch in 1971.

- During the period of from October 1970 through October 1971 there were 145 foreign fishing vessels operating off the U.S. in the Gulf of Mexico. Their catch amounted to 8.7 million pounds worth $3.2 million.



Editor's Note: *Italicized* words are defined in the Glossary.
Credit lines for figures refer to selected references.

(9/72)

B COMMERCIAL FISHERY

The largest fish populations are found in the *littoral* zones, which are located from the high tide levels down to a depth of about 600 feet. Here the nutrients necessary for their growth may be found.

Offshore Bank Fishery:

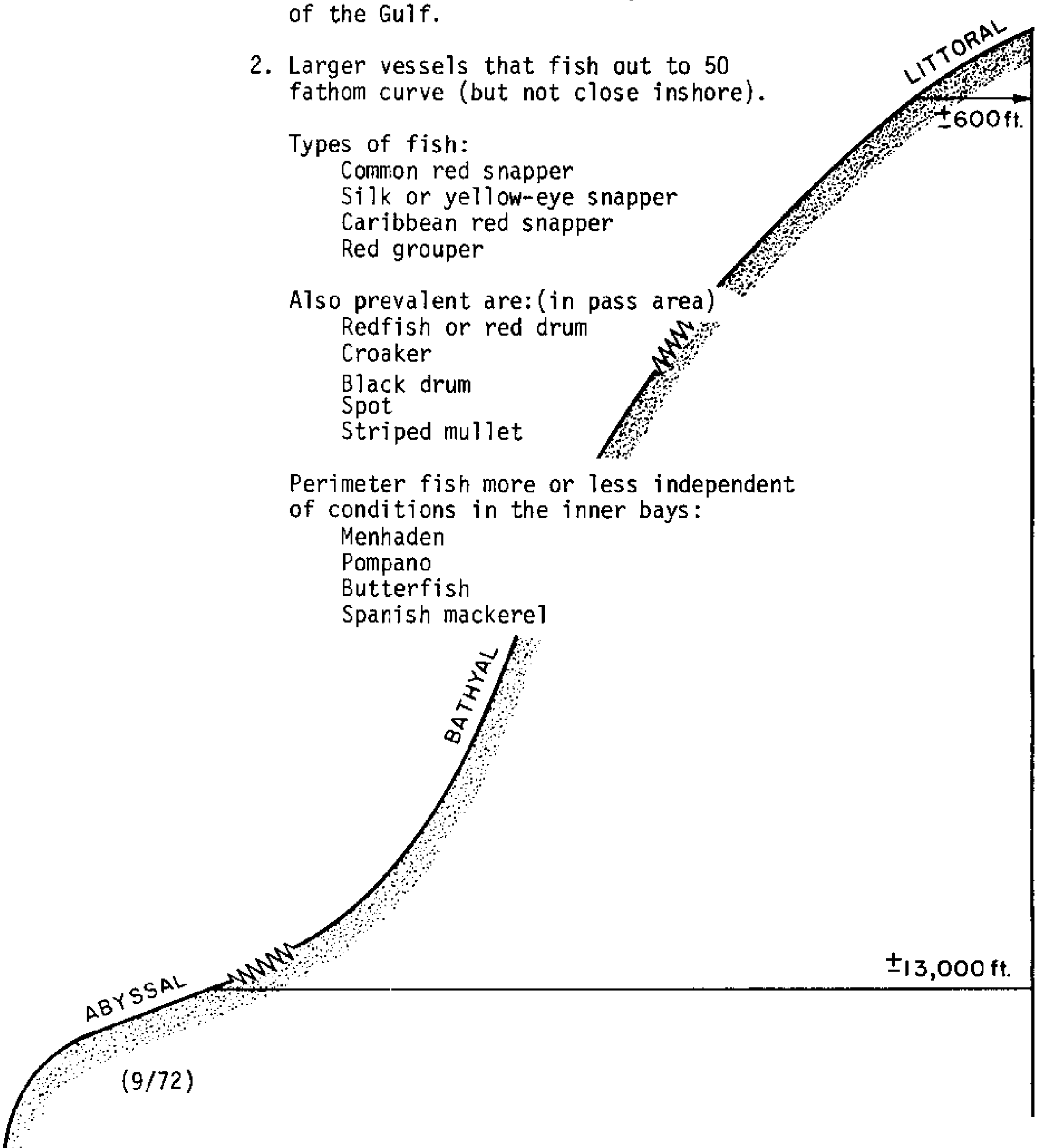
1. Small boats that fish along the shores of the Gulf.

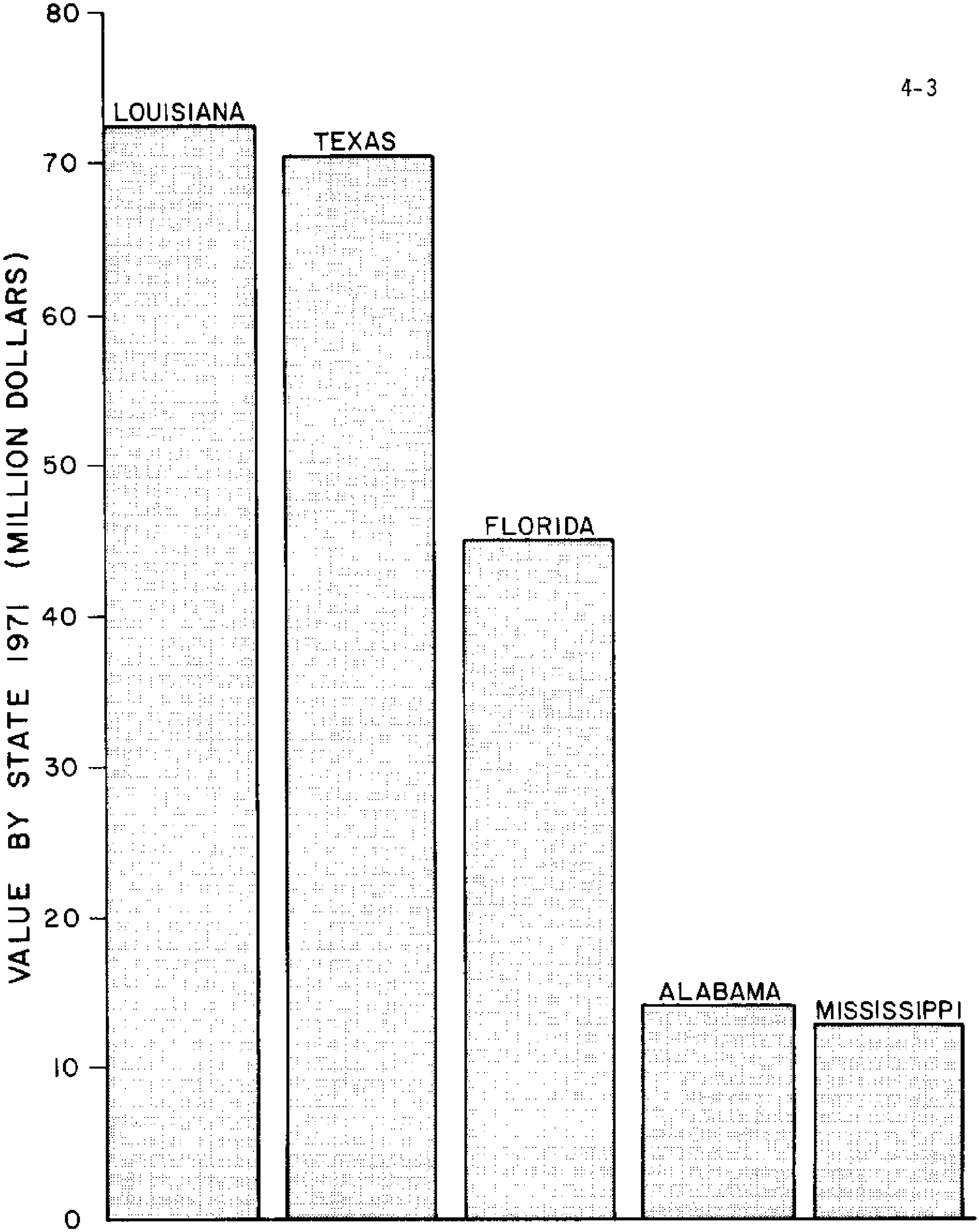
2. Larger vessels that fish out to 50 fathom curve (but not close inshore).

   Types of fish:
   - Common red snapper
   - Silk or yellow-eye snapper
   - Caribbean red snapper
   - Red grouper

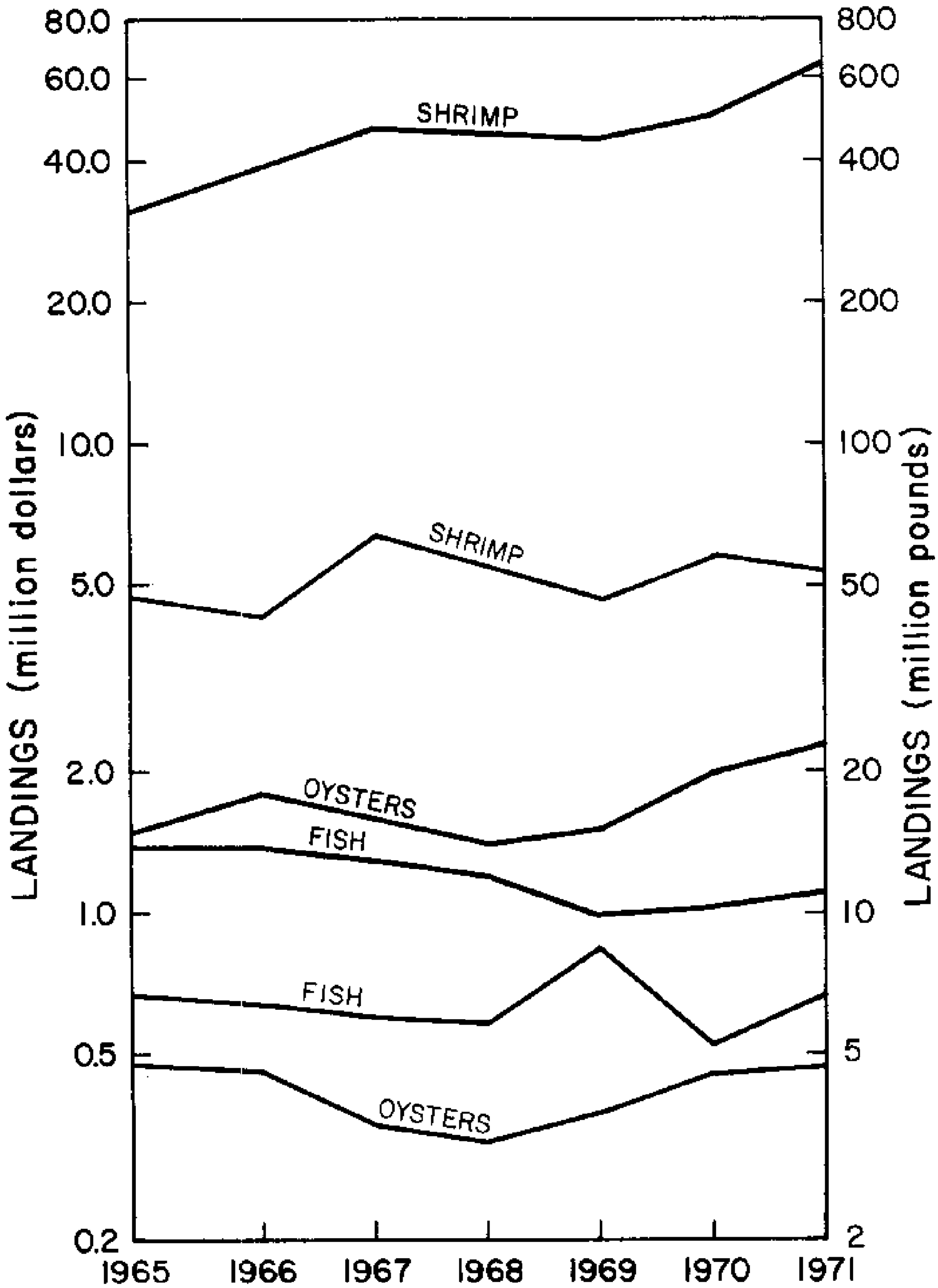
   Also prevalent are:(in pass area)
   - Redfish or red drum
   - Croaker
   - Black drum
   - Spot
   - Striped mullet

   Perimeter fish more or less independent of conditions in the inner bays:
   - Menhaden
   - Pompano
   - Butterfish
   - Spanish mackerel





Value of Catch by Gulf States in 1971
(Source: Wheeland 1972)



Dollar value and pounds of oysters, shrimp (heads-off) and edible finfish* landings in Texas, 1965-71.

(Source: Farley 1965-71)

*Edible finfish do not include those used for bait reduction, mullet and menhaden.

(9/72)

POUNDS AND VALUE OF TEXAS CATCH OF FINFISH AND SHELLFISH

1970 and 1971

SPECIES	1970		1971	
Finfish	POUNDS	VALUE	POUNDS	VALUE
Cabio (Ling)	18,500	$ 2,014	14,700	$ 1,580
Croaker	107,200	6,113	54,600	2,942
Drum				
Black	782,700	83,854	1,138,400	116,800
Red (Redfish)	1,586,200	349,903	1,990,700	484,326
Flounders				
Unclassified	297,200	64,844	319,100	75,603
Groupers	59,300	5,617	137,600	13,459
King Whiting (Kingfish)	62,600	3,832	80,200	5,859
Menhaden	43,059,600	902,722	(Included in Unclassified)	
Mullet	11,100	579	97,600	3,836
Pompano	1,700	763	3,400	1,606
Sea Catfish				
(Gafftopsail)	32,900	1,847	44,600	2,882
Sea Trout				
Spotted	1,156,800	256,533	1,487,400	357,363
White	1,000	104	1,900	207
Sheepshead (salt water)	175,500	14,647	133,700	9,722
Snapper, Red	916,400	379,923	1,082,400	495,127
Warsaw	-	-		
Unclassified:				
For Food	105,300	5,455	107,600	5,815
For Bait Reduction				
and Animal Food	26,800	927	62,981,200	1,051,919
TOTAL FINFISH	48,400,800	$2,079,677	69,675,100	$2,629,046

(CONTINUED ON NEXT PAGE)

POUNDS AND VALUE OF TEXAS CATCH OF FINFISH AND SHELLFISH, continued

SPECIES	1970		1971	
Shellfish	POUNDS	VALUE	POUNDS	VALUE
Crabs, Blue	5,525,400	$ 508,770	5,809,600	$ 567,172
Oysters, Meats	4,674,700	2,040,749	4,744,300	2,377,914
Shrimp (Heads-On)				
Brown and Pink	69,252,000	38,406,687	72,759,925	53,129,189
White	19,071,100	10,206,532	14,091,924	11,056,448
Other	2,600	291	64,260	5,561
Squid	9,700	909	9,500	1,508
TOTAL SHELLFISH	98,535,500	$51,163,938	97,479,509	$67,137,792
GRAND TOTAL (Finfish and Shellfish)	146,936,300	$53,243,615	167,154,609	$69,766,838

(Source: Texas Landings, Respective Years, "Fisheries of Texas," Respective Years, Orman H. Farley, National Marine Fisheries Service, U.S. Dept. of Commerce, Galveston, Texas and Texas Parks and Wildlife Service, Austin, Texas.)

REGION AND VALUE OF TEXAS CATCH OF FINFISH AND SHELLFISH

1970 and 1971

REGION	FINFISH 1970	FINFISH 1971	SHELLFISH 1970	SHELLFISH 1971
Gulf of Mexico	$1,428,133	$1,734,846	$44,924,316	$60,544,035
Sabine Lake	100	-	73,016	214,817
Galveston and Trinity Bays	44,019	33,778	3,919,976	4,407,289
Matagorda, East Matagorda and Lavaca Bays	79,664	59,334	994,811	978,486
San Antonio, Mesquite, Espiritu Santo Bays and Green Lake	41,485	53,576	554,875	600,933
Aransas and Copano Bays	78,144	119,856	602,815	318,320
Corpus Christi and Nueces Bays	23,043	36,658	91,872	71,647
Baffin Bay and Upper Laguna Madre	188,675	297,036	425	24
Central and Lower Laguna Madre	196,414	293,962	1,832	2,241
TOTAL	$2,079,677	$2,629,046	$51,163,938	$67,137,792

(Source: Texas Landings, Respective years, "Fisheries of Texas," Respective years, Orman H. Farley, National Marine Fisheries Service, U.S. Dept. of Commerce, Galveston, Texas, and Texas Parks & Wildlife Services, Austin, Texas.)

REGION AND VALUE OF TEXAS CATCH
OF SHRIMP - 1971

REGION	1971 POUNDS	1971 VALUE
Gulf of Mexico	78,908,800	$60,538,458
Sabine Lake	42,500	26,809
Galveston and Trinity Bays	5,403,300	2,139,038
Matagorda, East Matagorda, Lavaca Bays	1,286,800	820,912
San Antonio, Mesquite Espiritu Santo Bays, and Green Lake	748,600	375,104
Aransas and Copano Bays	422,700	247,279
Corpus Christi & Nueces Bays	103,400	61,598
TOTAL	86,916,100	64,191,198

(Source: Texas Landings, Respective years, "Fisheries of Texas," Respective years, Orman H. Farley, National Marine Fisheries Service, U.S. Dept. of Commerce, Galveston, Texas, and Texas Parks & Wildlife Service, Austin, Texas.)

C THE SHRIMP FISHERY IN THE GULF OF MEXICO

- Even though the United States produces more shrimp than any other country in the world, since 1961 this country has imported much more shrimp than it produces to keep up with the rising demand.
- Imports of shrimp decreased from 219 million pounds (product weight) during 1970 to 191 million pounds in 1971, coming from more than 25 countries and accounting for almost 19% of the value of all edible seafood imports.
- Most of these imports are received from Mexico, but imports from Asian countries (particularly India) are growing.
- Shrimp landings in the Gulf states in 1971 amounted to 227.1 million pounds out of the total 387.9 million. Louisiana remained the leading producer in the Gulf with landings of 92.4 million pounds, heads-on.
- There are five major species of shrimp caught in the Gulf of Mexico:

Brown shrimp (*Penaeus aztecus*)

(Source : Moffett 1967)

In 1971 brown shrimp accounted for approximately 81% of the Gulf coast shrimp catch.

Landings of brown shrimp are gradually becoming more spread out over a greater part of the year rather than being concentrated in the peak months of June, July and August.

Pink shrimp (*Penaeus duorarum*)

(Source: Moffett 1967)

In 1971 pink shrimp accounted for approximately 2% of the Gulf coast shrimp catch.

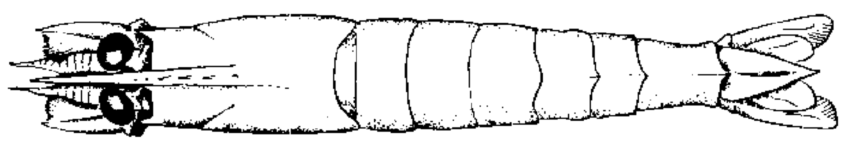
Pink shrimp landings have fluctuated somewhat, but have tended to decrease since 1964.

They may become increasingly important since the Mexican government has recently limited U.S. fishermen to an area no less than 12 miles off the Mexican coast.

Most productive areas for pink shrimp include: Gulf coast, Campeche, Dry Tortugas and Sanibel Island.

The Tortugas area alone yields an average of 20,000,000 pounds per year worth $6 million to fishermen.

White shrimp (*Penaeus setiferus*)

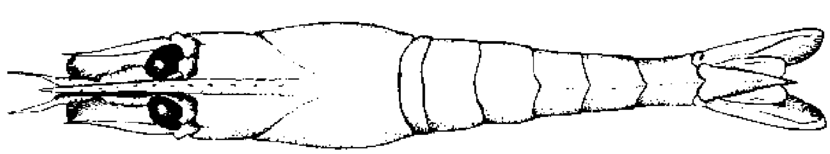


(Source: Moffett 1967)

The white shrimp accounted for about 16% of the Gulf coast production in 1971.

The discovery of extensive resources of brown and pink shrimp has lowered the popularity of the white shrimp.

Royal Red shrimp (*Hymenopenaeus robustus*)



(Source: Moffett 1967)

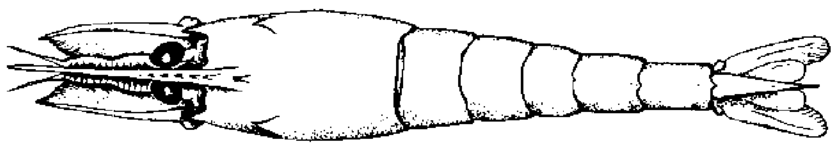
Given the name "Royal Red" because of their brilliant color.

Occur in water between 900-2250 feet in depth, often 50 miles or more away from shore so that fishing for them presents special problems.

Since heavier and more expensive gear is required, this resource remains largely untouched.

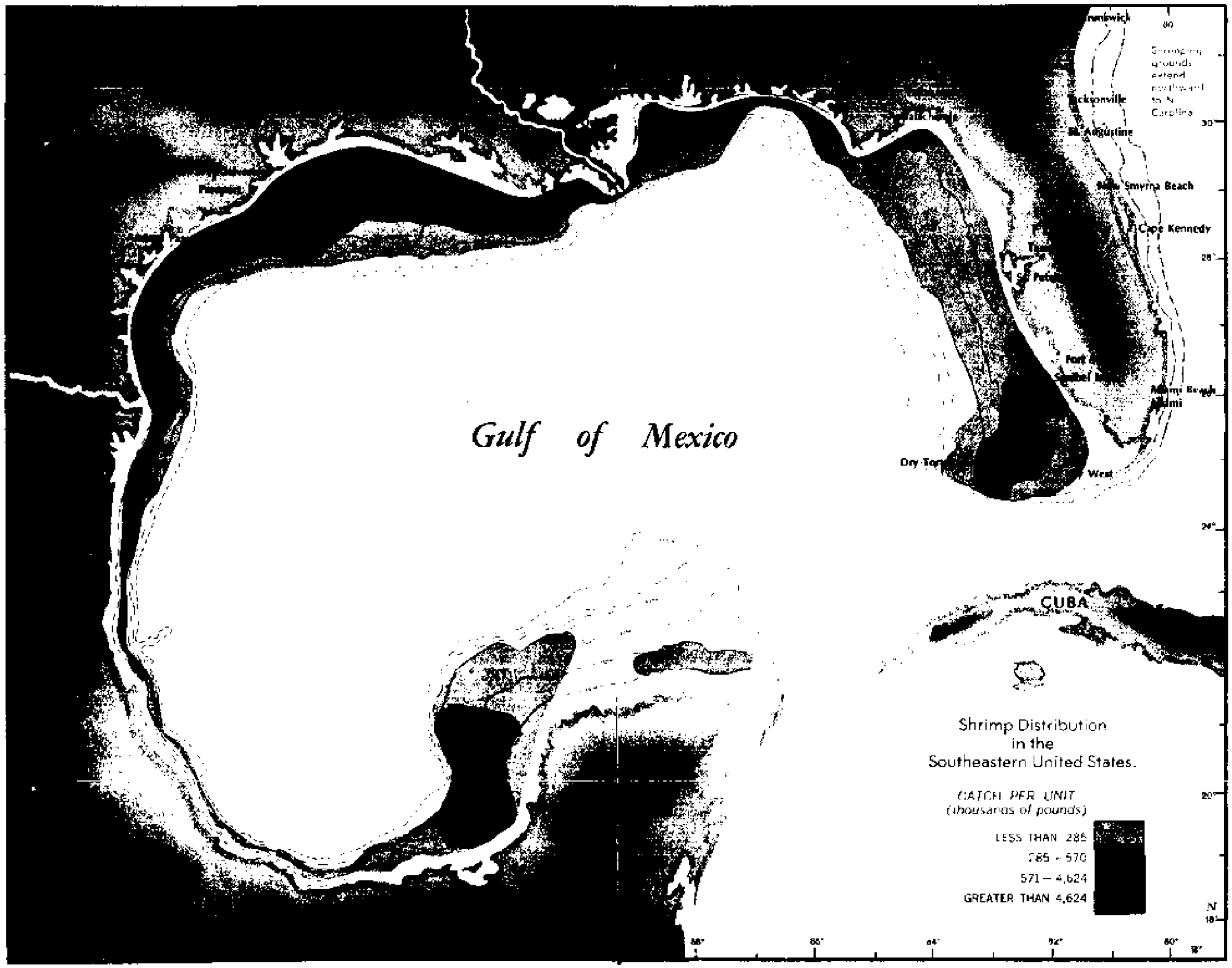
Accounted for less than 1% of the Gulf coast production in 1970.

<u>Seabob</u> (<u>Xiphopeneus</u> <u>krøyeri</u>)



(Source: Moffett 1967)

Accounted for less than 1% of the Gulf coast production in 1970.



(Source: National Marine Fisheries Service,
U.S. Department of Commerce)

Note: Greatest concentration of brown shrimp occur off the central and lower coast of Texas. White shrimp occur in greatest quantities in an area extending from Freeport northward along the coast to New Orleans. Pink shrimp concentrations are located off the central and lower coast of Texas, Florida's Dry Tortugas and Mexico's Campeche Banks.

GULF SHRIMP LANDINGS BY STATE

1966-1971

HEADS-OFF WEIGHT (Million Pounds)						
STATE	1966	1967	1968	1969	1970	1971*
Florida	21.3	17.8	20.2	17.7	19.4	15.7
Alabama	6.6	9.0	9.6	9.4	9.5	10.5
Mississippi	4.7	6.0	6.3	5.6	6.0	6.0
Louisiana	39.6	47.5	42.8	52.7	57.6	58.6
Texas	43.8	64.2	52.3	44.4	55.6	54.4
TOTAL	116.0	144.5	111.2	129.8	148.1	145.2

*Preliminary

(SOURCE: Shellfish Situation and Outlook, 1971 Annual Review, National Marine Fisheries Service, U.S. Department of Commerce, Washington, D. C.)

Note:
1) Texas landings comprise approximately 37% of total landings in the Gulf states.

2) Diminishing catches of brown shrimp in 1968 and 1969 were the main factor for reduced shrimp landings in these years in Texas.

PROJECTIONS OF FRESH AND FROZEN PROCESSED SHRIMP PRODUCTION
BY PRODUCT TYPE AND BY AREA
1970 to 1985

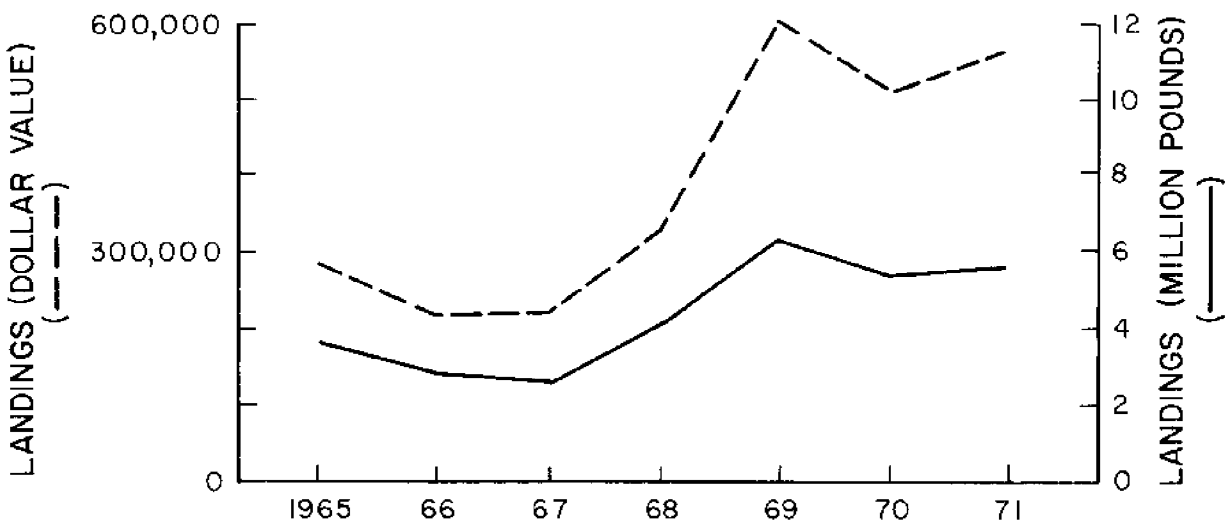
AREA	RAW	PEELED	BREADED	TOTAL	WEIGHTED AVERAGE PRICE (PER POUND)
	(Thousand Pounds)				
Southern Texas:					
1970	12,264	11,086	37,395	60,745	$1.028
1975	13,493	16,036	49,430	78,959	1.035
1980	14,447	21,805	61,178	97,430	1.043
1985	15,599	27,261	73,892	116,752	1.047
Central and Northern Texas:					
1970	15,131	1,534	4,539	21,204	0.915
1975	16,647	2,219	6,000	24,866	0.916
1980	17,825	3,018	7,426	28,269	0.918
1985	19,246	3,773	8,969	31,988	0.919

(Source: Demand and Price Structure for Shrimp, 1969, Donald P. Cleary. Division of Economic Research, Nat. Mar. Fish. Services (formerly Bureau of Commercial Fisheries), U.S. Department of Commerce, Washington, D.C.)

D CRABBING IN THE GULF OF MEXICO

Blue Crab

- Of the 92 species of crabs reported off the Texas Gulf coast, the blue crab (*Callinectes sapidus* Rathbun) is the most important.

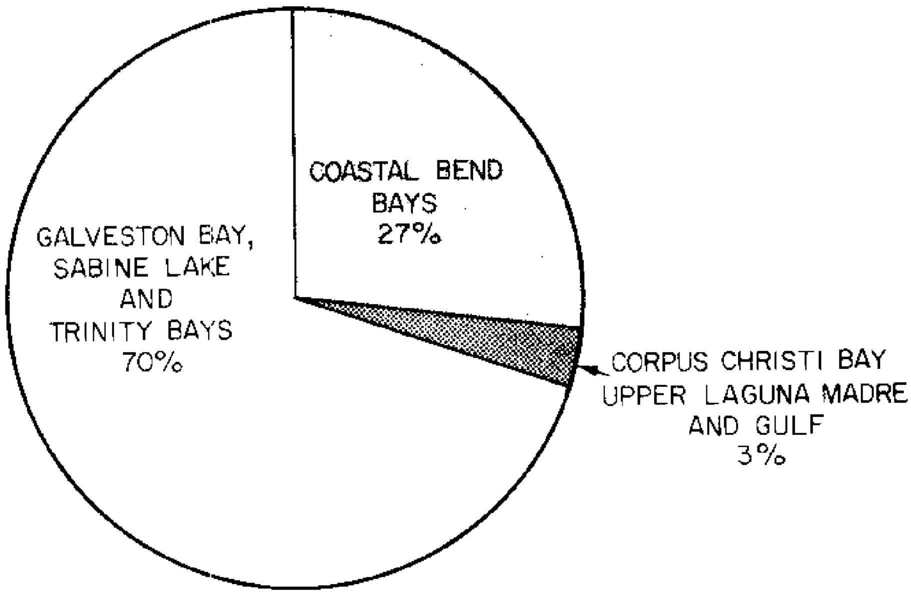


Blue crab landings and values in Texas.

(Source: Farley 1965-1971)

While the crab industry is steadily growing, it is not a stable fishery due to a number of factors which create high and low peaks in production:

weather conditions
food availability
fluctuations in abundance of predators and enemies
fishing intensity



Distribution of total crab catch in Texas, 1971
(Source: Farley 1971)

Over 30% of the total Texas landings in 1969 were sold through seafood markets as whole crabs.

Stone Crab

The stone crab is next in importance.

In some Gulf areas a sizeable fishery, although not in Texas due to its limited availability.

Its body is too small for economic purposes, but its huge over-sized claws contain large portions of sweet, rich meat.

Because it can regenerate missing claws, it is even more valuable since fishermen can haul them in, remove their claws and throw them back into the water.

Found all along the South Atlantic and Gulf coasts and is used extensively for food in areas where it is found in sufficient numbers.

Traps or pots are used almost exclusively for crab fishery.

Nine Texas crab processing plants in 1971 picked over 680,000 pounds of crab meat valued at $1,100,000.

The plants are located in Galveston, Aransas Pass, Matagorda, Port Bolivar, Sabine Pass and Port Lavaca, Texas.

Pond Culture

Although not much has been done to date toward raising crabs in ponds or artificial impoundments, it is believed that they would do well in such places if certain basic conditions were met. Since the crab has a high degree of tolerance for changing water conditions, tedious requirements would not be necessary.

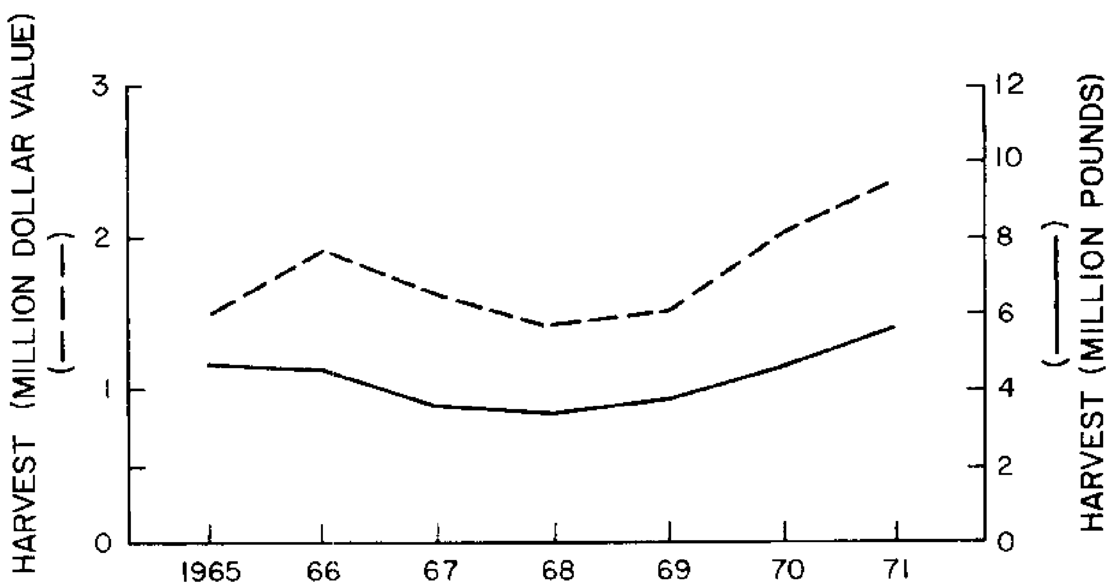
Processing of Crabs

"Bob" method: crabs are boiled, cleaned and picked by hand.

E THE OYSTER FISHERY IN THE GULF OF MEXICO

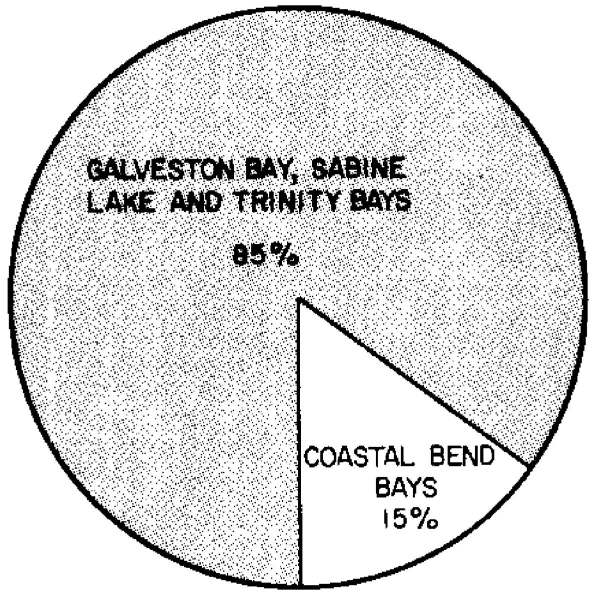
- The commercial oyster in Texas bearing the scientific name *Crassostrea virginica* (Gmelin) is distributed along the Atlantic and Gulf coasts from Canada to Mexico.

- Second in importance is the small Gulf oyster, *Ostrea equestris* Say, which can be found in the saltier Texas bays as well as in the Gulf.



Oyster Harvests and Values in Texas

(Source: Farley 1965-1971)



Distribution of total oyster harvest in Texas in 1971
(Source: Farley 1971)

Harvesting

- The original method of obtaining oysters was by wading along the shallow reefs and picking them up by hand. Oysters in the deeper waters were gathered by diving. Even today these methods are still employed to some extent.
- Oyster tongs are also used, but not in water over six feet deep. Just as they imply, they consist of two long, wooden handles joined together near one end like a pair of scissors. Each handle has a metal rake at the end with a small basket to hold the oysters.
- The oyster dredge offers a more efficient means of obtaining oysters in quantity. Mechanical harvesters are also used.
- The yield of oyster meats for 1971 averaged 2.22 gallons per Texas barrel (316 pounds of live oysters).
- The harvest from private reefs amounted to 280,100 pounds of oyster meats valued at $145,110. This represents approximately 6% of the State's total production (4,744,300 pounds).
- The yield from public reefs amounted to 4,464,200 pounds of oyster meats valued at $2,232,804.

Processing

- Oysters are sold either in the shell or shucked.
- Most oysters are sold shucked.
- No canneries operate on the Texas coast but a few dealers in this location package frozen oysters.
- The usual method for opening an oyster is with a special knife, cutting the muscle close to the shell. After shucking, the oysters are washed to remove particles of shell and mud. They are then packed in glass or metal containers and kept in cold storage until sold.
- Oysters in their shells are sold in sacks.
- In either case, the containers or sacks are tagged by the State Health Department.

Oyster Farming

It has been known for some time that oysters can be transplanted from one area to another.

The method of transplanting "seed" oysters to more suitable beds gives them a chance to grow to market size. This method of transplanting seed stock to growing areas is in common practice along the Gulf coast.

Some oystermen specialize in the raising of seed oysters for sale to other growers.

Lease laws for bay and estuarine oyster beds are administered by the Texas Parks and Wildlife Department.

F JUBILEE

- At infrequent intervals in Mobile Bay, crabs, shrimp and several species of fish crowd to the shallow water where they may easily be taken by anyone on the beach at the time. This phenomenon has been locally termed "jubilee".
- "Jubilee" occurs during the summer months chiefly along the northeast shore, occurring most frequently during the dark hours on a rising tide following a day of east wind. Changes in tide, wind or other meteorological conditions result in water aeration and terminate the "jubilee".

G STATISTICS ON FISHERMEN AND VESSELS

Labor Supply for Fishing and Offshore Industry

- Training schools have been established to provide classroom, workshop and on-the-job training of crewmen, mates and captains for offshore support companies, underwater welders and marine science and engineering technicians.

- A Sea Grant supported program of technician training is located at Brazosport College, Lake Jackson, Texas. There technicians may prepare themselves for such U.S. Coast Guard recognized positions as:

  Master to 1000 tons
  Engineer to 10,000 Horsepower
  Tankerman (All Grades)
  Able Seaman

- Other program activities at Brazosport College include navigation, ship operation, ship maintenance, SCUBA diving and marine electronics.

- In Waco, Texas, a program is underway at Texas State Technical Institute to train underwater welders. Students develop plumbing, welding and other maintenance skills in the classroom, then move through the same activities in various underwater situations. Graduation exercises are then held upon completion of dives in the Gulf of Mexico at 150 - 200 feet.

- Del Mar College at Corpus Christi offers training in marine engineering and technology. Students receive both classroom and practical training in marine science on research vessels operating in the Gulf of Mexico.

- Future activities may be concerned with shipbuilding, sport fishing, mariculture and support of new offshore structures.

H SHRIMP TRAWLER CONSTRUCTION AND OPERATION

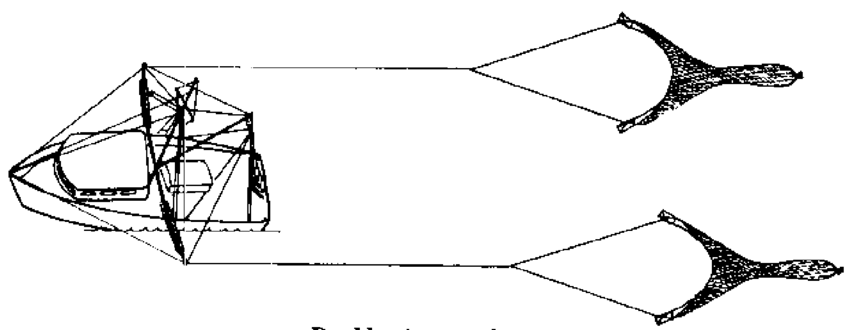
- Early shrimpers were about 25 feet in length, had a shallow draft, an engine in the stern and a fish-hold forward. Fishermen fished off the side with a cast net or a haul seine, which was replaced in the early years of this century by an otter trawl towed with rope lines.

- The use of the diesel engine in the 1940's led the way to larger boats and new innovations in gear. This resulted in the Florida-type trawler now widely used all over the world.

- Florida-type trawler:

  powered by diesel engine
  50-65 ft. wooden boat with a steel cable and drum hoist winch
  operating off the main engine
  drags trawl 75-120 ft. wide

- Since the 1950's more and more boats have converted to a "double-rig" trawling arrangement in which two smaller trawls are towed from outriggers, with a small trynet between.



Double-rig trawling

(Source: Moffett 1967)

- The trend is toward larger boats; 75-80 feet long with engines of 300 horsepower are becoming more common.

- At least 50% of the shrimpers in use today are made of steel.

- Steel trawlers cost on the average of 25% more than wooden ones but their operating life expectancy is double that of wooden vessels.

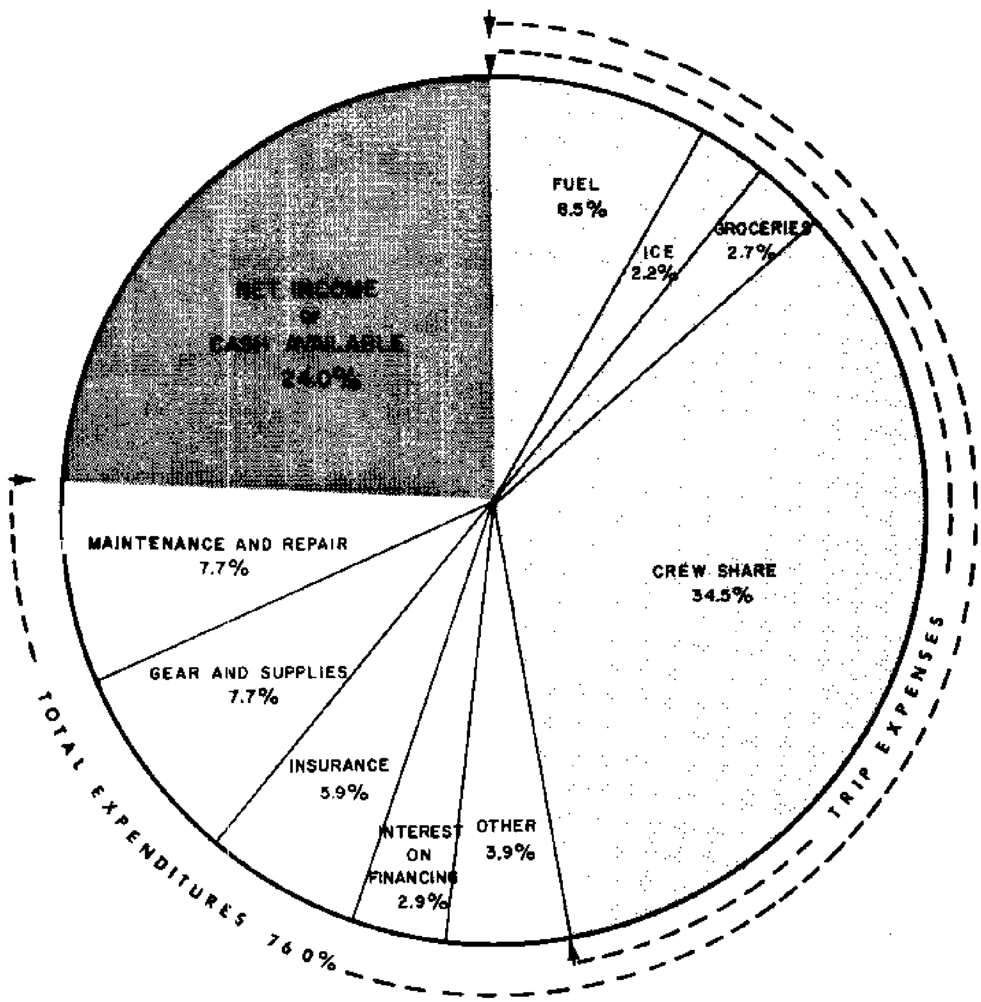
- Until recently fiberglass was a rival of the steel construction, but recent figures show that construction trends are leaning more and more back toward the wooden vessels because of construction costs.

- Electrified trawls to increase shrimp catches are undergoing experimentation and testing. An electric shock forces the shrimp from burrows upward into the nets. Much testing remains before the technique can be considered successful.
- In 1971 approximately 4,000 shrimp vessels were operating in the Gulf of Mexico and employed crews totalling a little over 10,500. Of this number over 50% landed at Texas ports.
- An average shrimp vessel is operated by three men: the captain, the rigger and the header. Thus, a conservative estimate can be made that employment on shrimp vessels which landed at Texas ports employed almost 6000.

I FINANCING SHRIMP FISHING

1. Banks are the major source of capital for new boat construction.
2. Commercial credit companies
3. Government programs:

   Fisheries Loan Fund of the Federal Government
   Federal Fishing Vessel Mortgage and Loan Insurance Program
   Fishing Vessel Construction Differential Subsidy Program
   Capital Construction Fund



Percentage breakdown of cost and return of newly constructed vessels of all kinds which are fully capable of operating anywhere in the Gulf of Mexico.

(Source: Knopf 1970)

J PROCESSING

NUMBER AND LOCATION OF FIRMS
PROCESSING FISHERY PRODUCTS IN TEXAS
1971

COUNTY	LOCATION	NUMBER OF FIRMS 1971
Brazoria	Freeport	12
Chambers	Anahuac	3
	Smith Point	2
Galveston	Crystal Beach	1
	Galveston	11
	Gilchrist	1
	Kemah	1
	Port Bolivar	6
	San Leon	2
Harris	Baytown	1
	Houston	9
	Seabrook	6
Jefferson	Beaumont	1
	Port Arthur	4
	Sabine Pass	5
Matagorda	Matagorda	4
	Palacios	4
Aransas	Aransas Pass	1
	Conn Brown Harbor	7
	Austwell	2
	Fulton	2
	Rockport	2
Calhoun	Port Lavaca	7
	Port O'Connor	1
	Seadrift	3

(CONTINUED ON NEXT PAGE)

NUMBER AND LOCATION OF FIRMS PROCESSING FISHERY PRODUCTS IN TEXAS, 1971, continued

COUNTY	LOCATION	NUMBER OF FIRMS 1971
Cameron	Brownsville	22
	Harlingen	4
	Port Isabel	12
Hidalgo	McAllen	1
	San Carlos	1
Nueces	Corpus Christi	2
	Flour Bluff	1
	Port Aransas	1
San Patricio	Ingleside	1
Willacy	Port Mansfield	1
TOTAL		144

(Source: National Marine Fisheries Service, U.S. Department of Commerce, Galveston, Texas)

K COSTS AND ECONOMIES OF THE FISHING INDUSTRY

- Preliminary figures show that the per capita consumption of commercially-caught fish and shellfish in 1971 in the U.S. amounted to 11.2 pounds. This included 6.5 pounds of fresh and frozen items, 4.3 pounds of canned items and 0.4 pounds of cured items.

EXVESSEL PRICES FOR BROWN, WHITE AND PINK SHRIMP FOR SELECTED PORTS ALONG THE GULF COAST, 1970

SIZE	Port Isabel, Texas (Brown shrimp)	Morgan City, La. (White shrimp)	Tampa, Florida (Pink shrimp)
Large (15-20 lbs.)	\$1.28 - \$2.14	\$1.30 - \$2.11	\$1.20 - \$1.88
Medium (31-35 lbs.)	.89 - 1.24	.82 - 1.28	.90 - 1.24
Small (51-65 lbs.)	.66 - .91	.56 - .84	.62 - .89

(Source: Shellfish Sitatuion and Outlook, 1971 Annual Review. Current Economic Analysis S-24, National Marine Fisheries Service, U.S. Dept. of Commerce, Washington, D.C. April 1972.)

DIRECT EMPLOYMENT AND SALES IMPACT
OF THE FISHERIES INDUSTRIES IN TEXAS

1969

FISHERIES INDUSTRY	DIRECT EMPLOYMENT	DIRECT SALES
Fisheries Catch Operations*	5,233	$ 50,009,000
Processing Firms	5,064	66,200,000
Distribution: Wholesale and Retail	1,271	62,436,600
Distribution: Wholesale and Retail	162	7,590,253
Processing Firms	400	15,000,000
Distribution: Wholesale and Retail	397	17,745,100
FISHERIES TOTAL	12,527	$218,980,953

* Includes finfish, shellfish, shell dredging and live bait shrimp sales.

(SOURCE: National Marine Fisheries Service, U. S. Department of Commerce, Galveston, Texas and Industrial Economics Research Division, Texas A&M University, College Station, Texas.)

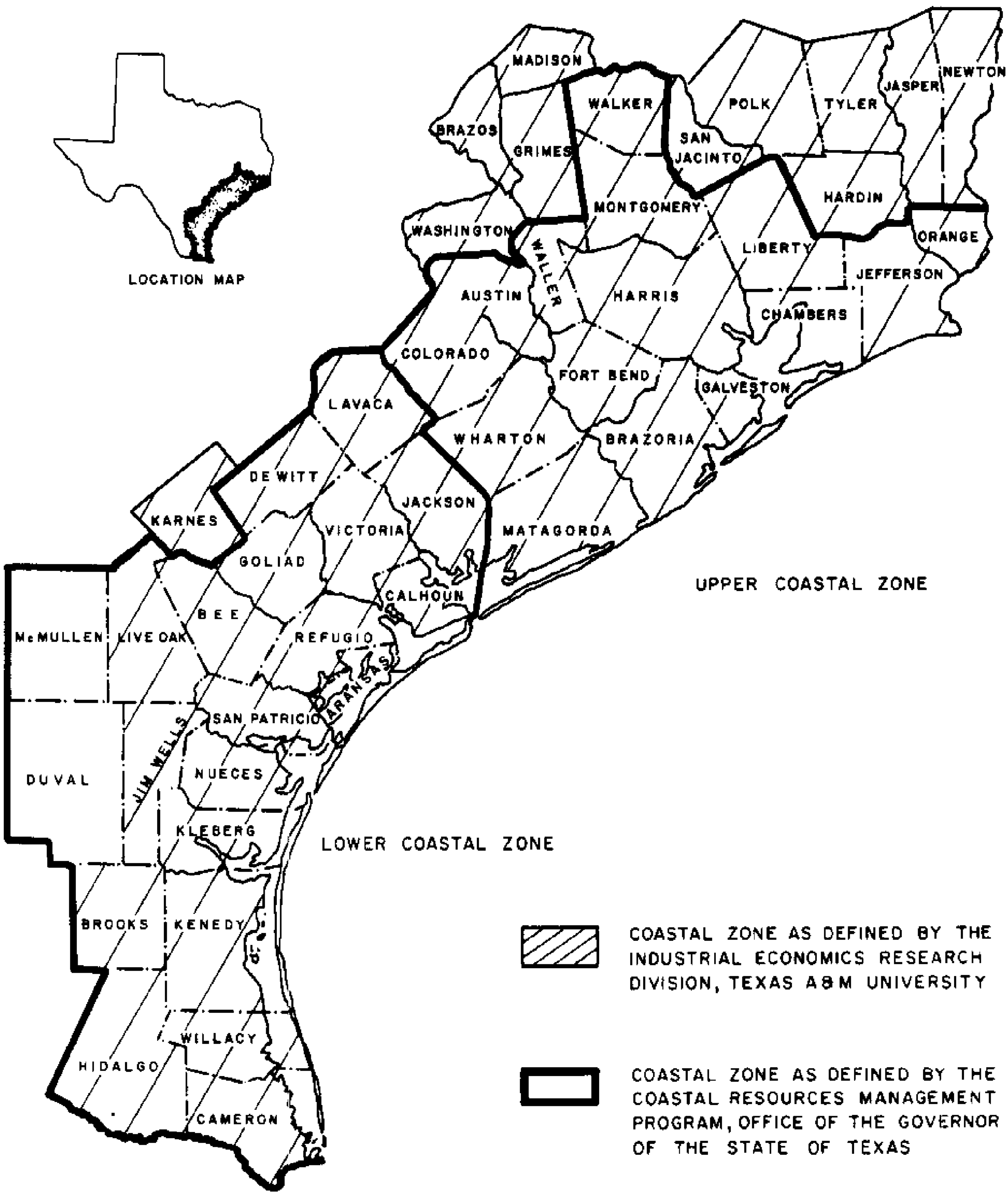
- Estimated data for 1971 show 6,220 "full-time" and 1,000 "part-time" commercial fishermen in Texas.

EMPLOYMENT BY INDUSTRY FOR THE TEXAS COASTAL ZONE*

INDUSTRY	1950	1960	1970	1980	1990	2000
TOTAL EMPLOYMENT	1,106,988	1,379,122	1,642,986	1,956,684	2,262,622	2,680,983
Agriculture, Forestry and Fisheries	155,705	112,162	94,187	83,420	72,071	64,311
Mining	31,099	37,307	48,015	52,477	54,417	56,551
Contract Construction	95,342	103,402	126,294	148,022	168,198	195,552
Manufacturing	168,470	229,842	277,129	329,800	384,411	446,782
Transportation, Communication and Public Utilities	92,742	103,965	109,125	118,049	125,324	128,040
Wholesale and Retail Trade	230,754	295,589	336,881	391,104	440,865	503,042
Finance, Insurance, and Real Estate	34,251	55,067	70,616	88,852	105,924	131,629
Services	207,765	303,669	415,936	555,228	692,871	906,077
Government	90,860	138,119	164,803	189,732	218,541	248,999

(Source: Preliminary Report on Economic Projections for Selected Geographic Areas, United States Water Resources Council, Office of Business Economics, U.S. Department of Commerce, Washington, D.C., 1968 and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.)

*As defined by the Industrial Economics Research Division, Texas A&M University, College Station, Texas.



Texas coastal zone.

L THE FISHERIES POTENTIAL OF THE GULF OF MEXICO

- If one listens to the many "fish stories" of the big ones that "got away", he is inclined to believe that the fisheries potential of the Gulf is indeed great.

- It has been reported that the giant sea bass or great groupers have been known to grow to such weights as 800 to 1,200 pounds. One such grouper was reported to have swallowed a skin diver head first, down to the waist, near Key West, Florida. The diver stabbed the fish with his knife and escaped.

- The biggest Mississippi River catfish on record is one weighing 97 pounds and measuring 57 inches in length.

- On one of the many dives of the Westinghouse submarine, Deepstar 4000, an observer in the Gulf of Mexico reported seeing an unknown fish, a ten-foot rattail.

- There are reports of a sawfish taken off the coast of Galveston, Texas, that weighed 736 pounds.

- Whale sharks have been known to appear off the Philippines or Mexico, Straits of Florida and off Japan, India, Ceylon, Panama, New York and Callao, Peru. One was sighted in 1953 off the coast of Mexico; hours later it was thought that perhaps either the same one or another one was seen not too much farther away.

- Off Mexico's Campeche Bank, one large whale shark has been called Big Ben. Off Sapodilla Cays, British Honduras, one became Sapodilla Tom. These whale sharks, or "elephants", may weigh three to five tons. The biggest to ever come from the sea is a 38-foot specimen caught off Florida, weighing 26,594 pounds (over 13 tons). The world's record elephant weighs only 12 tons.

Concerning the smaller fish

Scientists at the Exploratory Fishing and Gear Research Base at Pascagoula, Mississippi (NMFS) have estimated a two billion pound standing crop of thread herring in the Gulf of Mexico. In addition, there are large quantities of Spanish sardines, scaled sardines and various anchovies.

A program to study the biology of thread herring and other surface schooling species has been recently initiated at NMFS Biological Laboratory at St. Petersburg Beach, Florida.

Scientists at the Exploratory Fishing and Gear Research Base at Pascagoula ,Mississippi believe that yellow-eyed snapper has a potential of being one of the most valuable sources of choice food fish in the Gulf. Recent exploratory work with long lines off the Texas coast at 100 to 200 fathoms, revealed a promising stock of tile fish, a species not considered before as a potential resource of food fish.

Spanish mackerel is presently the subject of offshore aerial photographic reconnaissance for seasonal occurrence of schools. This program involves also the occurrence of offshore surface schooling tunas.

Discovered in commercial abundance in the northeastern Gulf some ten years ago, calico scallops as a fishery of significance has never been developed. Most productive grounds apparently are between Mobile and Apalachicola in about 10-25 fathoms. Because of renewed interest in scallop fishing, the Pascagoula Exploratory Fishing Base plans a reassessment of the beds.

The menhaden fishery in the Gulf of Mexico is second in importance to shrimp.

Texas bays, estuaries and other inland waters along the Texas coast constitute the major spawning and nursery areas for more than 70% of the fish population in the Gulf of Mexico.

M. FOOD FROM THE SEA

- Shrimp

  - Texas A&M University Sea Grant researchers have successfully raised shrimp in ponds which may provide the important evidence needed for the economic feasibility of shrimp farming. Industry is cooperating to study nutritional needs and develop suitable artificial feeds. Twenty research and demonstration ponds have been established in cooperation with industry and the Brazoria County Mosquito Control District in Brazoria County. Additional facilities include twelve demonstration ponds in Orange County in cooperation with a private individual and twenty ponds in Nueces County in cooperation with a power company.

    Personnel of the National Marine Fisheries Service (NMFS) in Galveston have been researching the dynamics of shrimp growth and reproduction for years.

    Periodic surveys to determine population densities, survival rates, migrations and habitat requirements have been conducted by the biologists of the Texas Parks and Wildlife Department.

    At Francis T. Nicholls State College in Thibodaux, Louisiana, research is also being conducted on Penaeid shrimp production in managed, unfed, natural ponds.

    Researchers at the University of Miami are successfully farming the pink shrimp (Penaeus duorarum) under controlled conditions. The shrimp are spawned in a laboratory and grown to full size in artificial ponds.

    Louisiana State University is also conducting shrimp studies at their three research stations: Ben Hur Farms: Houma, Louisiana; and on the campus at Baton Rouge.

- Catfish

  Of the 246,000 acres now devoted to all types of fish farming in the United States, 87,000 acres are for catfish farming which is a growing industry in the South.

  - In Texas, approximately 300 individuals are raising catfish commercially on more than 5,000 acres. These figures do not include the large number of persons raising catfish for personal use. Commercial operations are located throughout the state where water is available. However, the frequency of fish farms is greatest in the Eastern one-fourth of the state and along the coastal plain.

    Live catfish range from 35 to 65 cents per pound and processed fish from 75 to 95 cents per pound, a prime incentive for catfish farming.

In Mississippi, 19,000 acres and in Louisiana, 6,700 acres are devoted to catfish farming.

- Texas A&M University, through the Agricultural Extension Service and Agricultural Experiment Station provides the assistance and technology necessary for this new agricultural industry. Extensive research in this area is also being conducted by Louisiana State University, Auburn University, Mississippi State University, the U. S. Department of Interior and many state agencies.

- <u>Pompano</u>

Pompano mariculture shows great promise to the fish farmers in Florida and along the Gulf coast.

The pompano commands a good market price, grows rapidly, eats many types of food, and is tolerant of changes in salinity, oxygen, turbidity and pH.

In the Tampa Bay area of Florida retail prices of the pompano range from $1.10 to $1.85 per pound; 1967 figures showed that 1.3 million pounds of pompano valued at $783,860 were landed in Florida.

The future of pompano culture depends on the success of artificial spawning, egg-hatching techniques, the development of satisfactory food for larvae and juveniles, cheaper and better construction of impoundments, and 55°F temperature maintenance in the winter.

At Louisiana State University studies are being conducted on the effects of salinity and water quality on the survival and growth of juvenile pompano.

At the University of Miami studies on availability of wild young pompano have emphasized the need to learn how to spawn pompano artificially.

- <u>Thread Herring</u>

Of the many improved techniques of fish farming, much still remains to be done toward raising the fish from its very early stages: the eggs, the larvae or even the very young.

Recently, scientists at Miami succeeded in raising a very high percentage of thread herring, a feat tagged as a "rare and significant achievement."

The significance of the thread herring experiment at Miami was that it is a fish not currently sought by fishermen, but one highly suitable for the making of fish protein concentrate (FPC).

• Other Food Sources

Seaweeds are growing in importance as a food by themselves.

The brown and red seaweeds are used as stabilizers, smoothing agents and colloids in an increasing number of brands of toothpastes, hair lotions, soaps, and skin creams. They are also used as emulsifier stabilizers, smoothing agents or jelling agents in jams, jellies, spreads, puddings, toppings, candies, and dressings.

They make it possible for chocolate to mix smoothly with milk and even help keep a head of foam on a glass of beer.

Kelp is also a source of iodine, may be used in antacid tablets, calamine lotion and aspirin compound tablets.

On the west coast, the brown seaweed (kelp) grows to lengths of over 100 feet. Nereocystis and Macrocystis include the largest and best-known Pacific species.

N FISH PROTEIN CONCENTRATE

The National Marine Fisheries Service has undertaken extensive technnological research into the development of a system for the conversion of fish into FPC (fish protein concentrate) of good quality with a promising market potential.

The process is proving to be highly successful in two relatively large-scale pilot plant operations, one of which is located at Texas A&M University, College Station, Texas; the other at College Park, Maryland.

What is FPC?

It is a tasteless, almost odorless, white or grayish flour containing a minimum of 75% pure animal protein. It is made by processing whole bodies of inexpensive fish, such as hake, sea robins and skate. As opposed to fish meal, FPC is virtually odorless and can be stored indefinitely.

All processes involved in the manufacture of FPC are basically aimed at removing water and fatty substances called "lipids" from ground-up whole fish. At this time, removal of lipids can best be accomplished by solvents.

Early History

The use of fish protein concentrate dates back to 325 B.C. to accounts of inhabitants of the eastern shore of the Persian Gulf using a flour made from grinding dried fish.

Hake Preferred

Pacific hake, frozen and transported from Washington State, has been chosen for use at the Texas A&M plant because the Food and Drug Administration has approved hake and hake-like fish as initial fish for the FPC process.

Process

1. The frozen fish is first ground in a food chopper,
2. Through the use of solvents, the oil and water are removed,
3. The material is then dried.
4. Selective removal of bone particles is used to aid in fluoride control,
5. Finally, 91% of the volume of the solvent used is recovered.

Cost of Production

1. The production cost of FPC varies between 25 and 30 cents per pound.
2. About 15 lbs. of FPC can be produced from 100 lbs. of hake.
3. A ton of fish costs $20 from which 300 lbs. of FPC can be produced. This amounts to a cost of $.067 per pound for raw fish.
4. Preservation, transportation, storage and processing of the raw fish into FPC, with a reasonable allowance for profit-taking, would bring the cost up to the 25-30 cents per pound range.

Purity and Quality Control

Both the National Marine Fisheries Service and the Food and Drug Administration have set certain rigid specifications which must be met regarding:

lipid content
ash content
fluoride content
bacteriological count
crude protein content

Other Investigations

One technique has been developed which allows for the simultaneous preservation and processing of the fish as they are brought aboard the fishing vessel.

Fish Sausage

Researchers at Texas A&M University have also developed a process which reconstitutes FPC into fish-like substances, sausages or meat patties. In contrast to previous FPC materials which are sand-like, the new product will form a gel when water is added. It is odorless and tasteless, but artificial flavoring has been added to the reconstituted material to make a beef-flavored product with a very high protein content of more than 90%.

Small Atlantic croaker, used in the process, are considered "trash" fish by Gulf of Mexico commercial fishermen. It is estimated that 200-500 million pounds of small Atlantic croaker are thrown away each year by Gulf fishermen.

The process, which uses a mixture of two solvents rather than one, has also been used to make FPC from several other species of fish.

O THE MARINE APOTHECARY

The potential of seaweeds is high as:

- a source of food proteins
- a collector of radioactive wastes from bays and other waterways where contamination has been a problem
- an ingredient of dental impression substrates
- for treatment of ulcers
- as a potential killer of Staphylococcus.

Sponges

Produce 15 very important complex alcohols not found in man.

Have been helpful in understanding more complex nervous systems because of their simplified nervous system.

May be used as natural living sentries, guarding against bacterial contamination of our waterways.

Jellyfishes, hydroids, sea anemones and corals

Since this group is notorious for causing irritations to man's skin, efforts are being made to turn their toxins into antitoxins.

In the Gulf of Mexico the Portuguese man-of-war and the sea wasp are two creatures which cause a considerable amount of discomfort.

Starfish, sea urchins and sea cucumbers

Certain chemical substances from these may help medicine to fight viruses, microbes, cancer and nerve disorders.

Research is being conducted into the enzymes, hormones, or genetics that make possible the regeneration of appendages in the starfish in the effort to better understand the chemistry of growth. This may show the way to control the wild proliferation of cells that occurs in some forms of cancer.

Oysters and clams

The oyster shell has been used as a roughage replacer in fattening beef cattle rations.

Clam liver extracts are being used in attacking the cancer problem.

Materials from certain barnacles produce adhesive substances used in dental fillings.

Fish

A biotoxin from the puffer fish is 200,000 times more powerful than the drug curare, used today for blocking nervous activity.

The familiar cod liver oil certainly needs no explanation.

An extract from the sea squirt recently cured 50% of two groups of mice with leukemia, and destroyed human cancer cells in tissue culture experiments.

Fish have long been used as an effective mosquito control.

The venom of the weever fish is undergoing intensive investigation in search for a chemical that slows the heartbeat of animals to a few throbs per minute, therefore acting as a potential aid in surgery.

Doctors have isolated the poison secreted by the stonefish and have found that it reduces blood pressure in animals. The drug may prove useful in treating hypertension. Another marine poison is being used to reduce the coagulating time of blood.

A narcotic for the reduction of severe pain has been developed from the tetrodotoxin from the puffer fish family and is now being used to relieve the agony of terminal cancer.

FISHERIES AND FISHING INDUSTRY OF THE GULF OF MEXICO

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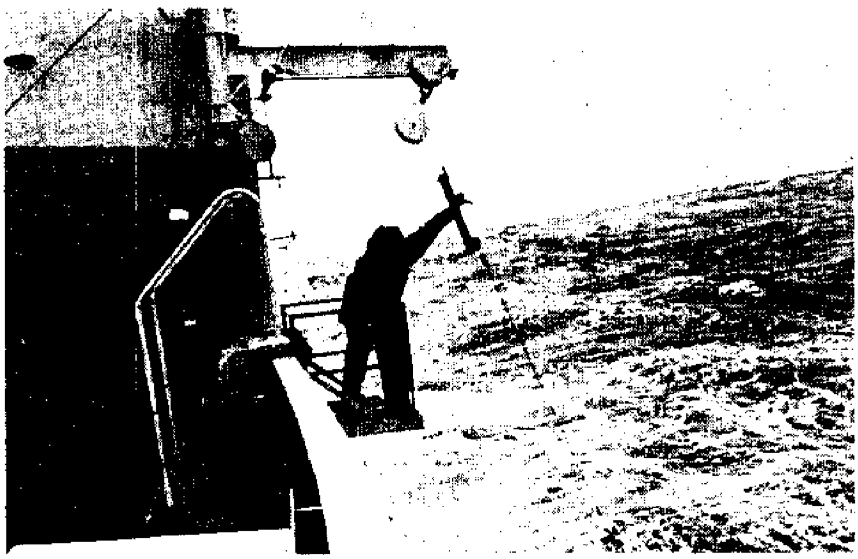
PHYSICAL OCEANOGRAPHY OF THE GULF OF MEXICO

Contents

PHYSICAL OCEANOGRAPHY OF THE GULF OF MEXICO



Attaching a Nansen bottle to a hydrocast from aboard the R/V ALAMINOS of the Department of Oceanography, Texas A&M University

A GULF OF MEXICO - "AMERICAN MEDITERRANEAN"

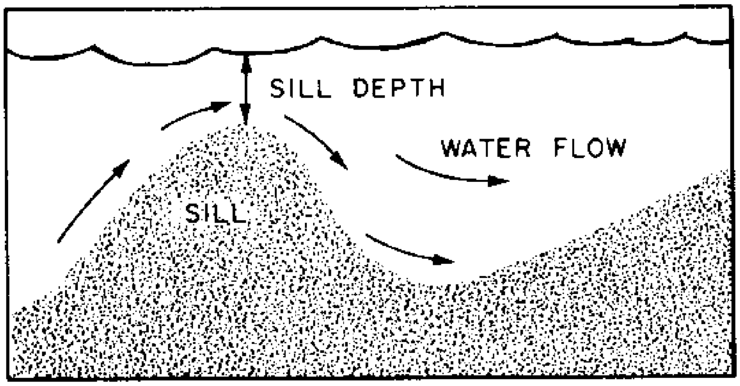
- The Gulf of Mexico is approximately 2-1/2 times the size of the state of Texas.
- The bays, *estuaries* and tidelands, out to 10.4 statute miles from shore, are the property of the state of Texas.
- It is the ninth largest body of water in the world, with an area of 615,000 square miles (1.602 sq. kilometers).
- Together with the Caribbean Sea it forms the "American Mediterranean" (comprised of five major basins), and in this context the Gulf is frequently referred to as the Mexican Basin.
- If all the water in the Gulf basin were drained, it would take 4 years to refill it with the flow from existing currents.

Editor's Note: *Italicized* words are defined in the Glossary. Credit lines for figures refer to selected references.

B WATER MASSES

- A water mass is usually identified by its temperature-*salinity* relationship or chemical content, and normally consists of a mixture of two or more water types.

- The terms water mass and water type have been used loosely and interchangeably in oceanographic literature.

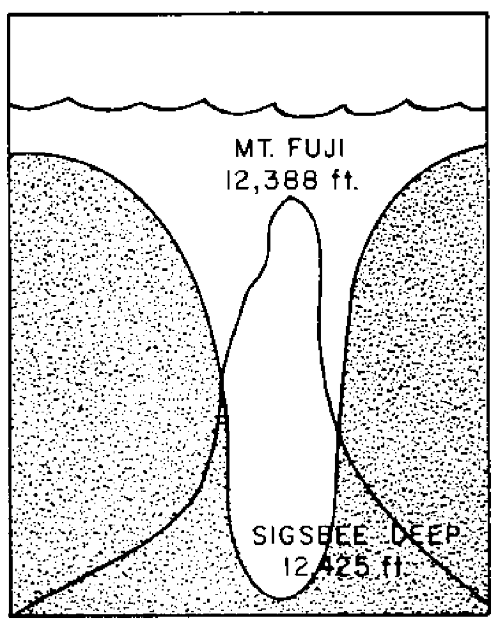


- The water mass takes on some of the characteristics of its surroundings, and as it moves it carries these characteristics with it and loses them rather slowly. This is analagous to the behavior of an air mass. The salinity of the water mass is analagous to the humidity of an air mass.

The principal inflow of water to the Gulf of Mexico is through the Yucatan Channel, which has a *sill* depth of between 1500 and 1900 meters.

Most of the outflowing water passes into the North Atlantic through the Florida Straits, which is the only other passage connecting the Gulf with the open ocean. This flow is the beginning of the Gulf Stream.

- The deepest point in the Gulf of Mexico is Sigsbee Deep in the SW central part, with a depth of 12,425 feet (deeper than Mt. Fuji in Japan is tall).



C CURRENTS

- Energy sources which cause currents are:

  1. wind
  2. heating and cooling

- Currents are also influenced by:

  1. the earth's rotation
  2. topography of the coast and the ocean bottom

In 1967 data gathered by scientists of Texas A&M University from the R/V ALAMINOS provided sufficient information on which to establish positively the existence of a detached *eddy* in the eastern Gulf of Mexico.

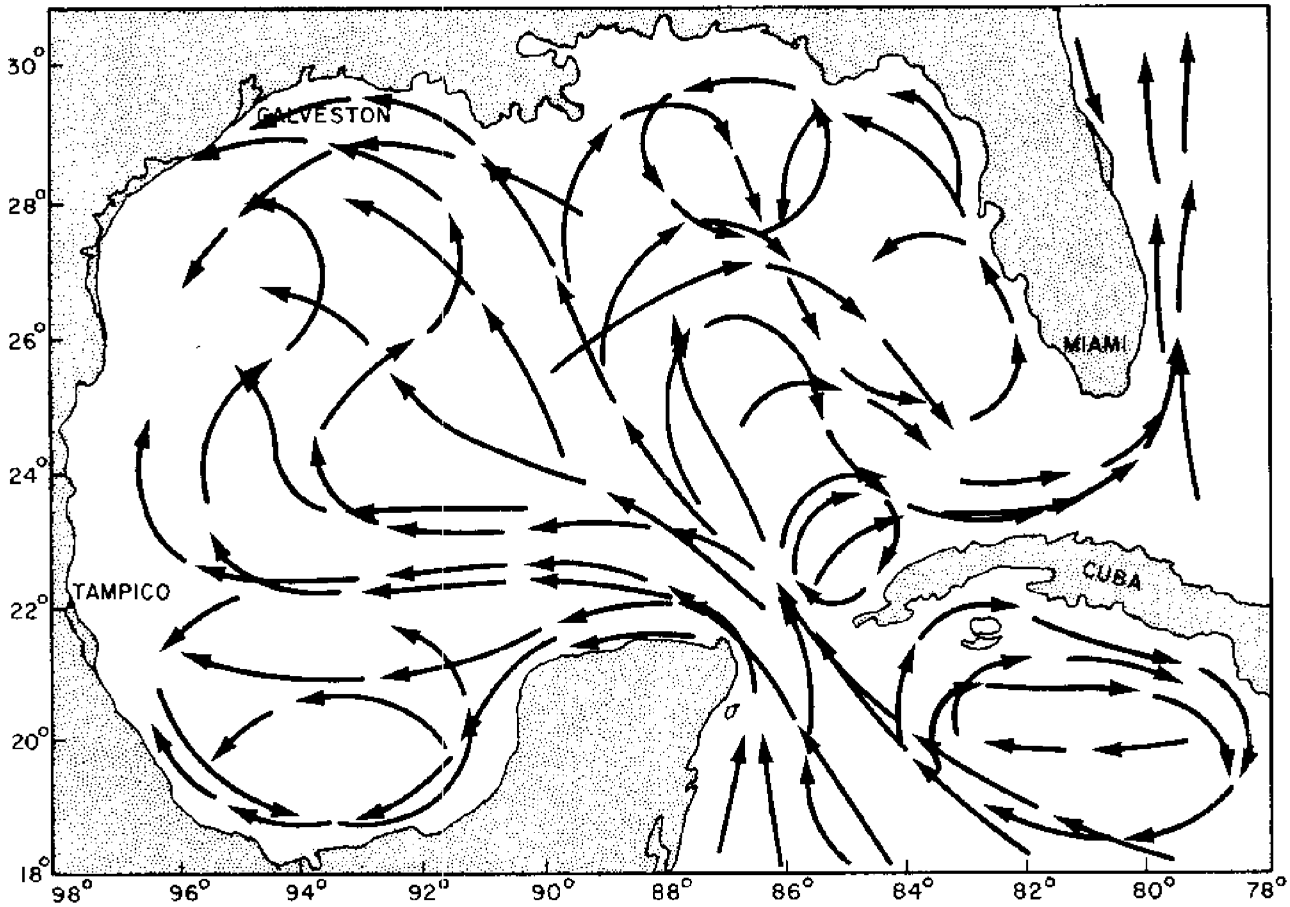
The eddy, which is of considerable size and involves a large volume of water, carries with it all of its properties as it moves into the Gulf.

Definition: *eddy* - a circular movement of water usually formed, where currents pass obstructions, between two adjacent currents flowing counter to each other, or along the edge of a permanent current.

- The *kinetic energy* of the core current of the Yucatan Current would provide sufficient electrical power for the entire world.

Measurements of the Yucatan Current show maximum surface velocities within the core of from 50 to over 200 cm/sec. or 50 statute miles per day. The surface current attains a maximum in early summer and drops sharply during mid-fall to a minimum in October or November.

Currents in the western Gulf, though variable and not well-defined, show a velocity of some 50 cm/sec.

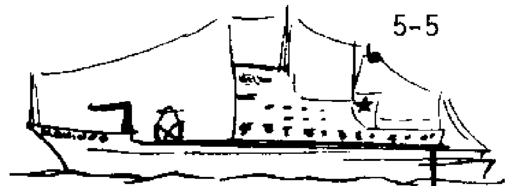


Surface ocean currents in the Gulf of Mexico in December (black) and June (red).

(Source: Leipper 1954)

- One of the fastest currents in the world's oceans passes by and contributes to the Gulf of Mexico through the Yucatan Straits. A loop current is established in the eastern Gulf; circulation in the western Gulf is based upon exchanges of surface and deep waters with the eastern Gulf.

- The Florida Current is the Gulf's major current and is essentially a direct continuation of the current through the Yucatan Channel.



D TEMPERATURES

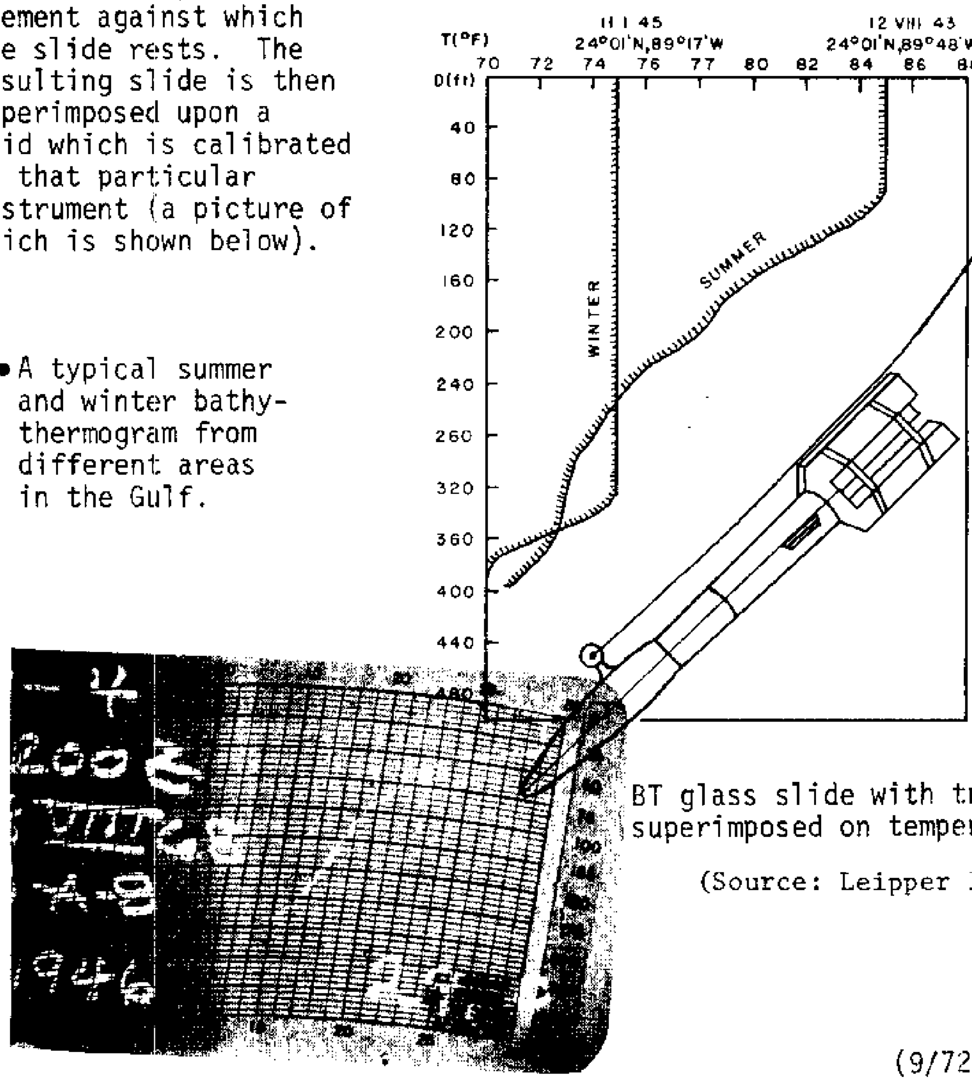
- Water temperatures in the Gulf of Mexico range from 70°F to 75°F during the winter, to 79°F to 87°F during the summer.

- The average surface temperature for the sea as a whole is about 63°F. It is higher in the N. Hemisphere (67°F) and lower in the S. Hemisphere (61°F).

- Temperature measurements versus depths are often taken with an instrument called a *bathythermograph*, or BT.

- A BT is a torpedo-shaped instrument consisting of a stylus which rests against a small smoked glass slide. Movement of the stylus is due to the effect of the water temperature on an attached tube filled with a fluid. Movement of the slide is due to water pressure on a pressure element against which the slide rests. The resulting slide is then superimposed upon a grid which is calibrated to that particular instrument (a picture of which is shown below).

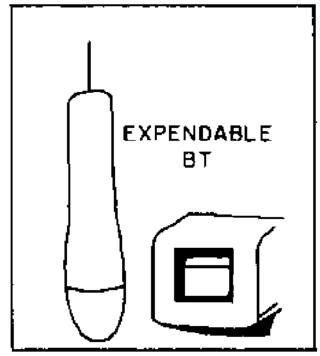
- A typical summer and winter bathythermogram from different areas in the Gulf.



BT glass slide with trace superimposed on temperature grid.

(Source: Leipper 1954)

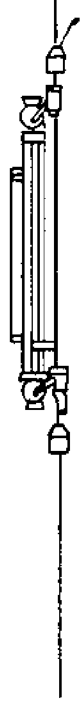
- A ship must slow to 12-16 knots for 15 to 20 minutes while streaming a bathythermograph. The more recently developed expendable BT enables vessels to make BT observations at speeds up to 30 knots. These are capable of measuring temperatures to a depth of 800 meters or 2,624 feet, while the standard BT may only go as deep as 900 feet.



- Another device used by oceanographers, the Nansen bottle, obtains subsurface samples of sea water and subsurface temperatures.

- The "bottle" is lowered by wire from the ship to the desired depth; a tripping mechanism is then lowered on the wire which causes the bottle to turn upside down. This traps a water sample inside it, and the attached deep-sea reversing thermometers simultaneously take a reading of the temperature at that depth.

E SALINITIES OF THE GULF OF MEXICO



Over the central Gulf basin the *salinity* of the surface waters is greater than $36.0^{\circ}/_{oo}$ (36 grams/kg. of water), and generally is within the range of $36.0^{\circ}/_{oo}$ to $36.3^{\circ}/_{oo}$. Average ocean salinity is $35^{\circ}/_{oo}$.

Surface values as great as $36.6^{\circ}/_{oo}$ have been observed in the west central Gulf, north of the edge of the Yucatan Shelf.

The salinity of the nearshore surface waters of the Gulf is greatly influenced by local runoff and river discharge, primarily the Mississippi River.

Because of the Mississippi River runoff, salinities less than $25^{\circ}/_{oo}$ have been reported several miles offshore.

Definition: *salinity* - a measure of the quantity dissolved salts in sea water (see Glossary).

- Salinities in the Laguna Madre of Texas have been known to reach $130^{\circ}/_{oo}$ during droughts.

F DENSITY

Definition: *density* - the weight of sea water relative to that of an equal volume of pure water at 4°C (39.2°F) and at atmospheric pressure. In oceanography, density is equivalent to specific gravity. It is thus dimensionless and expressed in units of sigma-t.

- The average annual sigma-t values for the Gulf of Mexico range from 1.0275 to 1.02775 at 1000 meters depth.

The specific gravity of sea water for salinity of 35°/₀₀ is close to 1.028 at 0°C, but it is greater at lower temperatures and less at higher. It is slightly greater under high pressure.

G PRESSURE

- Pressure in the ocean increases one atmosphere for every 33 feet of depth. It varies from one atmosphere (approximately 15 lbs. per sq. inch) at the surface to nearly 16,000 lbs. per sq. inch at the greatest depth. As a rule of thumb, water pressure increases one pound per square inch with each two feet increase in depth.

Definition: *atmosphere* - approximately 15 pounds per square inch

However, the unit most commonly used to express pressure as encountered in the ocean is the decibar = 1/10 bar. One bar is approximately equal to one atmosphere.

H TIDES AND WAVES

- The average tidal range in the Gulf of Mexico is small, being only one or two feet at most coastal stations.

  The Gulf tide is mostly *diurnal*, i.e., at a given location only one high water and one low water level occur during a lunar day.

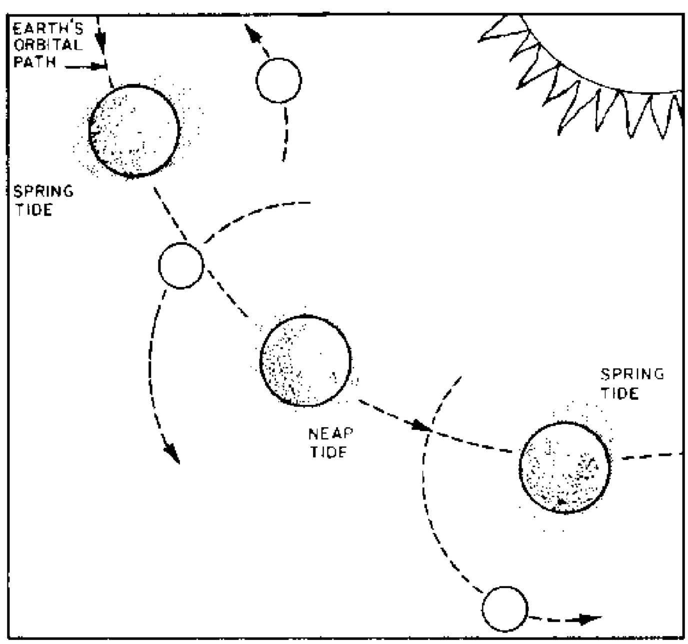
  However, in the coastal region of the Florida Straits, *semidiurnal* (every 12 hours) and mixed tides are observed; the average tidal range seems slightly greater than that along the coasts of the Gulf proper.

- Wind waves generated within the Gulf rarely attain heights over five meters or approximately 16 feet high. The highest wind wave ever reported anywhere in the world oceans was seen from on board FLIP (Floating Instrument Platform) in 1969, north of Hawaii. It was 14.9 meters (49 feet) high.

  A wind wave (sea wave) is generated by friction between wind and the fluid surface. As these waves travel away from the area in which they are formed, the shorter ones die out. The surviving waves increase in speed, becoming larger and flatter. When these waves reach *shoal* water, they become more prominent and are then known as ground swell.

  Storm surges occur more frequently along the northern than along the southern or western Gulf coasts due to the fact that hurricanes entering the Gulf pass through the Yucatan Channel.

- As the earth and the moon whirl around their common center of gravity, centrifugal force pulls every point on the earth away from the moon. The moon, with its gravitational force, pulls everything on the earth toward the center. These two forces, working together, make the ocean tides.



(Source: U.S. Naval Oceanographic Office 1969)

I GULF COAST WEATHER

- Much of the nation's weather is either generated in or moves through the Gulf of Mexico.

  The coastal area is generally humid with temperatures ranging from up to 100°F in the summer to below 30°F during the winter months.

  Of prime concern are the hurricanes which use the Gulf as an access to the coastal regions. They generally follow a west-northwest course across the Gulf of Mexico and curve north after reaching land areas.

- During the 1960s the entire Gulf coast experienced its worst hurricanes. Camille recently destroyed over $1 billion in property and took a large toll in human lives.

  It is estimated that improved weather predictions could save more than $500 million in agricultural programs. An additional $500 million could be saved from improvements in scheduling of fuel production, transportation and storage. Damages of more than $200 million to offshore oil and gas facilities were caused by hurricanes Hilda (1964) and Betsy (1965).

  Origin of Hurricane Names

  - The practice of naming hurricanes femininely began during World War II, when weathermen plotting the movement of the storms identified them alphabetically, using the names of girls.

    The National Weather Service has issued the following names for the 1962 and 1973 hurricane seasons, which begin in June and runs through October.

    1972:

    Agnes, Betty, Carrie, Dawn, Edna, Felice, Gerda, Harriet, Ilene, Jane, Kara, Lucile, Mae, Nadine, Odette, Polly, Rita, Sarah, Tina, Velma and Wendy.

    1973:

    Alice, Brenda, Christine, Delia, Ellen, Fran, Gilda, Helen, Imogene, Joy, Kate, Loretta, Madge, Nancy, Ona, Patsy, Rose, Sally, Tam, Vera and Wilda.

Evacuation Maps

The Department of Commerce's National Oceanic and Atmospheric Administration is collecting material for storm evacuation maps for hurricane-endangered areas on the Atlantic and Gulf coasts.

Maps will soon be available for an area extending from New Orleans, Louisiana to Mobile, Alabama; the Galveston-Houston area and the Corpus Christi area.

- The maps show emergency evacuation routes, areas subject to flooding and elevations which might afford "safety islands" for storm evacuees. They will be distributed to state and local officials and community hurricane preparedness committees by NOAA's National Weather Service.

National Weather Service in Galveston

Established in Galveston on April 19, 1871.

Has a staff of 10 trained weather service specialists.

Provides full 24-hour coverage of the weather seven days a week.

Meteorological Terms Used by Forecasters

weather - the state of the atmosphere mainly with respect to its effects upon life and human activities. It consists of the short-term variations (minutes to months) in the atmosphere. It is thought of in terms of temperature, humidity, precipitation, cloudiness, brightness, visibility and wind.

water conditions - "smooth" - winds less than 5 miles per hour
"slightly choppy" - winds 6-12 m.p.h.
"choppy" - winds 13-25 m.p.h.
"rough" - winds greater than 25 m.p.h.

short-range weather forecasts - covering a time period generally not greater than 18 hours in advance.

long-range weather forecasts - covering a time period greater than 5 days and up to one week in advance. Sometimes called an "extended forecast" or an "extended-range" forecast.

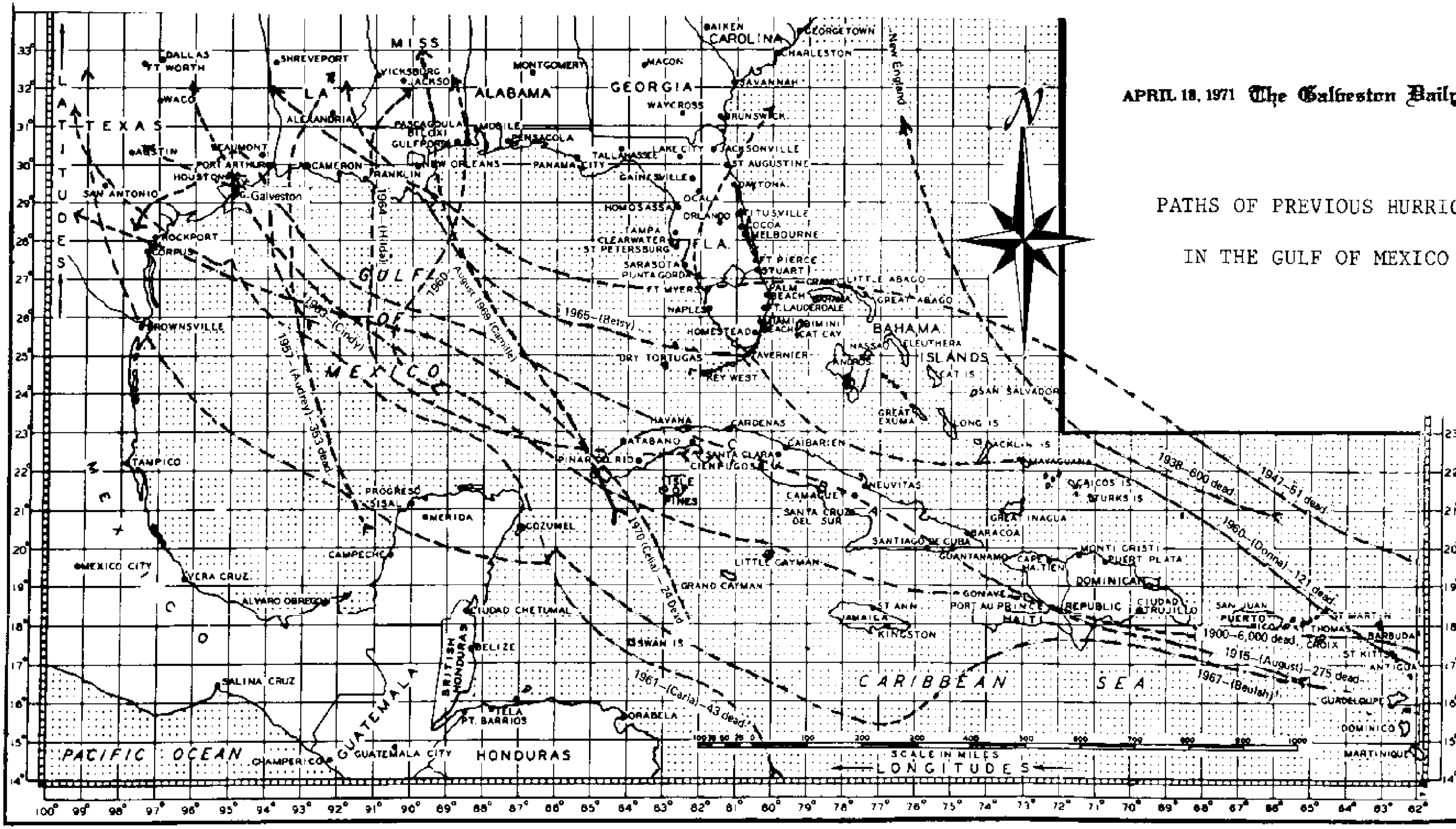
local forecast - weather forecasts of conditions over a relatively limited area, such as a city, county, airport, etc.

cold front - any non-occluded front or portion of a front which moves so that the colder air replaces the warmer air.

warm front - the opposite of cold front.

atmospheric or barometric pressure - refers to the pressure exerted by the atmosphere as a consequence of gravitational attraction. It is measured by many varieties of barometers and is usually expressed in the millibar, or as "inches of mercury."

occluded front - the front formed by a cold front overtaking a warm front and lifting the warm air above the earth's surface.



APRIL 18, 1971 The Galveston Daily News

PATHS OF PREVIOUS HURRICANES

IN THE GULF OF MEXICO

HURRICANE SAFETY RULES

Hurricane advisories will help you save your life . . . but you must help. Follow these safety rules during hurricane emergencies:

1. **Enter each hurricane season prepared.** Every June through November, recheck your supply of boards, tools, batteries, nonperishable foods, and the other equipment you will need when a hurricane strikes your town.
2. **When you hear the first tropical cyclone advisory,** listen for future messages; this will prepare you for a hurricane emergency well in advance of the issuance of watches and warnings.
3. **When your area is covered by a hurricane watch,** continue normal activities, but stay tuned to radio or television for all National Weather Service advisories. Remember, a hurricane watch means possible danger within 24 hours; if the danger materializes, a hurricane warning will be issued. Meanwhile, keep alert. Ignore rumors.
4. **When your area receives a hurricane warning:**
   Plan your time before the storm arrives and avoid the last-minute hurry which might leave you marooned, or unprepared.
   Keep calm until the emergency has ended.
   Leave low-lying areas that may be swept by high tides or storm waves.
   Leave mobile homes for more substantial shelter. They are particularly vulnerable to overturning during strong winds. Damage can be minimized by securing mobile homes with heavy cables anchored in concrete footing.
   Moor your boat securely before the storm arrives, or evacuate it to a designated safe area. When your boat is moored, leave it, and don't return once the wind and waves are up.
   Board up windows or protect them with storm shutters or tape. Danger to small windows is mainly from wind-driven debris. Larger windows may be broken by wind pressure.
   Secure outdoor objects that might be blown away or uprooted. Garbage cans, garden tools, toys, signs, porch furniture, and a number of other harmless items become missiles of destruction in hurricane winds. Anchor them or store them inside before the storm strikes.
   Store drinking water in clean bathtubs, jugs, bottles, and cooking utensils; your town's water supply may be contaminated by flooding or damaged by hurricane floods.
   Check your battery-powered equipment. Your radio may be your only link with the world outside the hurricane, and emergency cooking facilities, lights, and flashlights will be essential if utilities are interrupted.
   Keep your car fueled. Service stations may be inoperable for several days after the storm strikes, due to flooding or interrupted electrical power.
   Stay at home, if it is sturdy and on high ground; if it is not, move to a designated shelter, and stay there until the storm is over.
   Remain indoors during the hurricane. Travel is extremely dangerous when winds and tides are whipping through your area.
   Monitor the storm's position through National Weather Service advisories.

Beware the Eye of the Hurricane

If the calm storm center passes directly overhead, there will be a lull in the wind lasting from a few minutes to half an hour or more. Stay in a safe place unless emergency repairs are absolutely necessary. But remember, at the other side of the eye, the winds rise very rapidly to hurricane force, and come from the opposite direction.

5. **When the hurricane has passed:**
   Seek necessary medical care at Red Cross disaster stations or hospitals.
   Stay out of disaster areas. Unless you are qualified to help, your presence might hamper first-aid and rescue work.
   Drive carefully along debris-filled streets. Roads may be undermined and may collapse under the weight of a car. Slides along cuts are also a hazard.
   Avoid loose or dangling wires, and report them immediately to your power company or the nearest law enforcement officer.
   Report broken sewer or water mains to the water department.
   Prevent fires. Lowered water pressure may make fire fighting difficult.
   Check refrigerated food for spoilage if power has been off during the storm.

Remember that hurricanes moving inland can cause severe flooding. Stay away from river banks and streams.

Tornadoes spawned by hurricanes are among the storms' worst killers. When a hurricane approaches, listen for tornado watches and warnings. A tornado watch means tornadoes are expected to develop. A tornado warning means a tornado has actually been sighted. When your area receives a tornado warning, seek inside shelter immediately, preferably below ground level. If a tornado catches you outside, move away from its path at a right angle. If there is no time to escape, lie flat in the nearest depression, such as a ditch or ravine.

HURRICANE WATCHES MEAN A HURRICANE MAY THREATEN AN AREA WITHIN 24 HOURS.

HURRICANE WARNINGS MEAN A HURRICANE IS EXPECTED TO STRIKE AN AREA WITHIN 24 HOURS

DEPARTMENT OF COMMERCE · UNITED STATES OF AMERICA

PHYSICAL OCEANOGRAPHY OF THE GULF OF MEXICO

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ENGINEERING IN THE GULF OF MEXICO

Contents

ENGINEERING IN THE GULF OF MEXICO

A THE OCEAN ENGINEER

- Concerned with engineering both of and in the ocean
- Constructively interested in problem solving at sea and making things work at sea
- Specially trained to meet the technological problems in the ocean and to assist in the development of marine resources

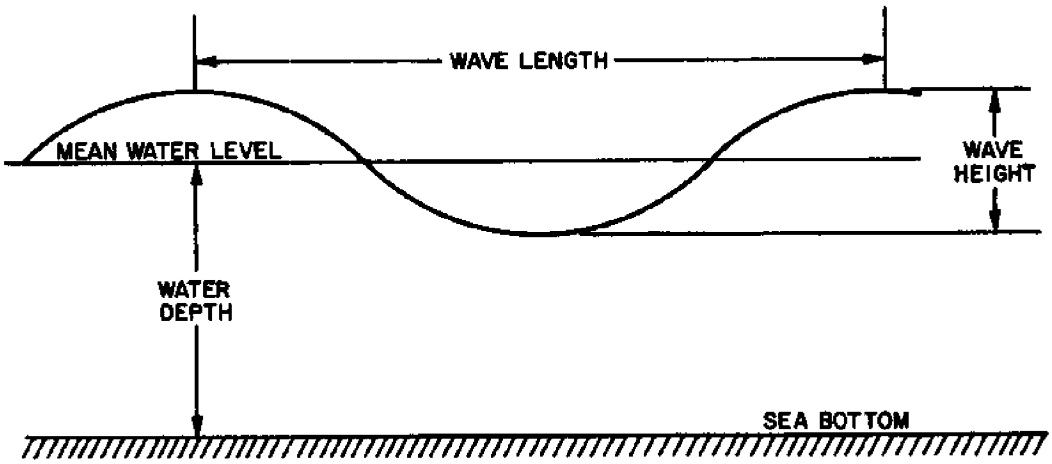
Areas of Specialization

- Ocean and coastal engineering structures - shore, offshore and deep ocean, buoys, pipelines, foundations and cables
- Marine engineering - surface ships, submersibles, and dredges
- Physical phenomena - gravity waves, storms and hurricanes, surges, forecasting and sediment movement
- Instrumentation - transducers, amplifiers for measurement and control manipulation and transmission and recording of data
- Acoustics - communications in and surveying of the ocean.
- Materials and corrosion - metallic and nonmetallic solid materials, laminated and composite materials, chemical corrosion, electrolytical corrosion, and biological fouling
- Pollution - oil, chemical and biological
- Aquaculture - fish, shrimp and seaweed farming

Editor's Note: *Italicized* words are defined in the Glossary.
Credit lines for figures refer to selected references.

B OCEAN STRUCTURES

- Waves - Because of their importance in transporting energy from one location to another thorough knowledge of the types of waves is of prime importance.



Engineering design criteria for structures in an ocean wave environment depend on the type of waves encountered:

1. Shallow Water Waves

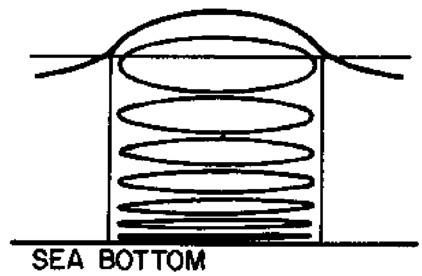
2. Intermediate Water Waves

3. Deep Water Waves

1. Shallow Water Waves - *wave length* is greater than twenty times the water depth. In shallow water, wave shape and speed are governed by water depth.

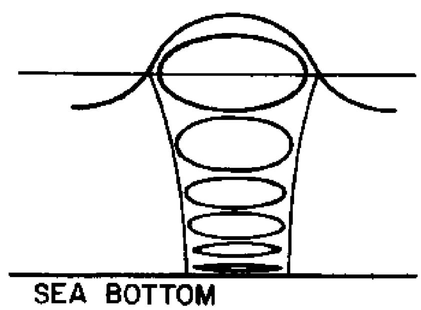
   (Note: d = water depth and
   L = wave length)

$$\frac{d}{L} < \frac{1}{20}$$



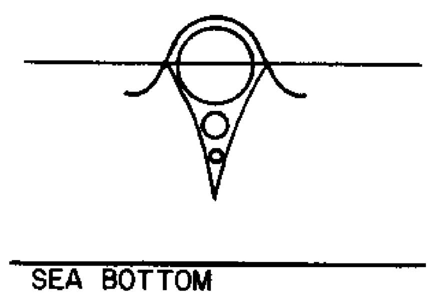
$$\frac{1}{2} \geq \frac{d}{L} \geq \frac{1}{20}$$

2. Intermediate Water Waves - wave length is greater than twice the water depth but less than twenty times the water depth. These waves "feel" the existence of the bottom and exhibit this by changing form and speed.



$$\frac{d}{L} > \frac{1}{2}$$

3. Deep Water Waves - wave length is less than twice the water depth



Small particle motion is in more or less of a circular path in a wave. *Airy wave theory* assumes these orbitals are closed; however, actual wave conditions produce mass transport which signifies open orbitals. The orbital motion, as represented by the ellipses and circles in the above figures, is different for deep and shallow water waves and decreases in magnitude as depth increases.

Accelerations necessary for orbital motions cause forces on the structure located in their paths.

Magnitude of these forces and their related moments is determined by wave characteristics and water depth.

- Forces caused by impact of a wave on a structure also differ according to action of the wave as it passes the structure. This wave action may be:

  nonbreaking

  breaking

  broken

  - Nonbreaking wave conditions exist when coastal structures are located in protected areas where low wave heights will occur and where the water depth at the structure is greater than 1 1/2 times the maximum expected wave height. Forces caused by nonbreaking waves are essentially hydrostatic.

  - Breaking and broken waves exert an additional force because of the dynamic effect of turbulent water. It has been observed that a wave breaking on a vertical wall causes a very intense shock pressure of short duration followed by a low pressure of long duration. Pressure of long duration is nearly equal to the pressure caused by a nonbreaking wave. Shock pressure occurs at the instant the front face of the breaker strikes the wall. Its intensity may be many times the longer duration pressure and have a duration of one-hundredth to one-thousandth of a second. Structures located in areas where ordinary or storm waves may break should be designed to resist greater forces than those structures which would only encounter nonbreaking waves.

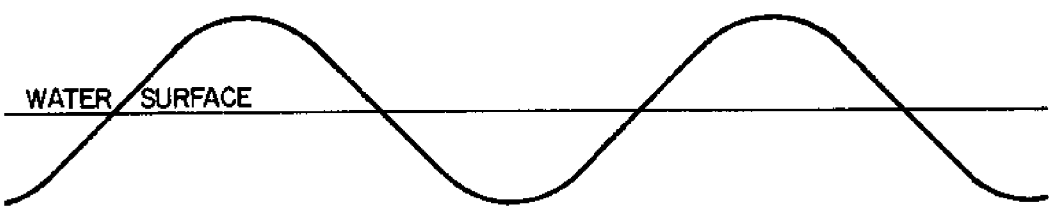
Wave Theories - Important engineering tools in evaluation of forces and moments on offshore structures are the various wave theories. These mathematical theories calculate important wave characteristics: wave speed (celerity); wave length; wave amplitude; horizontal particle displacements, velocities, and accelerations; and vertical particle velocities, displacements and accelerations.

Of the many wave theories in use today, the Airy wave theory is considered by many ocean engineers to be the most useful.

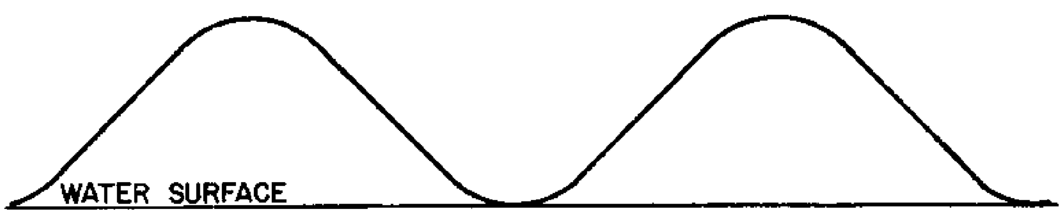
- Airy Wave Theory - deals with ideal wave motion.

  Ideal waves - a long wave with a small amplitude and sinusoidal shape.

  Permanent form - following the wave at the phase speed (celerity), the fields of motion, pressure distribution, and surface evaluation remain constant.



An example of a sinusoidal wave as compared with the solitary wave shown below:



In the design of any coastal structure, such as a breakwater, jetty or harbor facility, the phenomena of wave shoaling, refraction, reflection and diffraction must be considered because they will affect characteristics of incoming waves. These factors may cause waves to be higher than expected in the area of the structure.

- Reflected Wave - The wave returned seaward when a wave impinges upon a very steep beach, barrier or other reflecting surfaces.

- Refraction of Water Waves - The process by which direction of a wave moving in shallow water at an angle to the underwater bottom contours is changed. The part of the wave advancing in shallow water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with underwater contours.

- <u>Diffraction of Water Waves</u> - The phenomenon in which energy is transmitted laterally along a wave crest. When a train wave is interrupted by a barrier, such as a breakwater, diffraction is manifested by propagation of waves into the sheltered region with the barrier's geometric shadow.

<u>Engineering Structures</u> encountered in the coastal zone include:

- <u>Groin</u> - Protective structure (usually built perpendicular to the shoreline) to trap *littoral drift* or retard shore erosion. It is narrow and its length may vary from less than one hundred to several hundred feet (extending from a point landward of the shoreline into the water). Groins may be permeable or impermeable. Impermeable groins have a solid or nearly solid structure; permeable groins have openings that permit passage of appreciable quantities of littoral drift.

(Source: U.S. Corps of Engineers 1966)

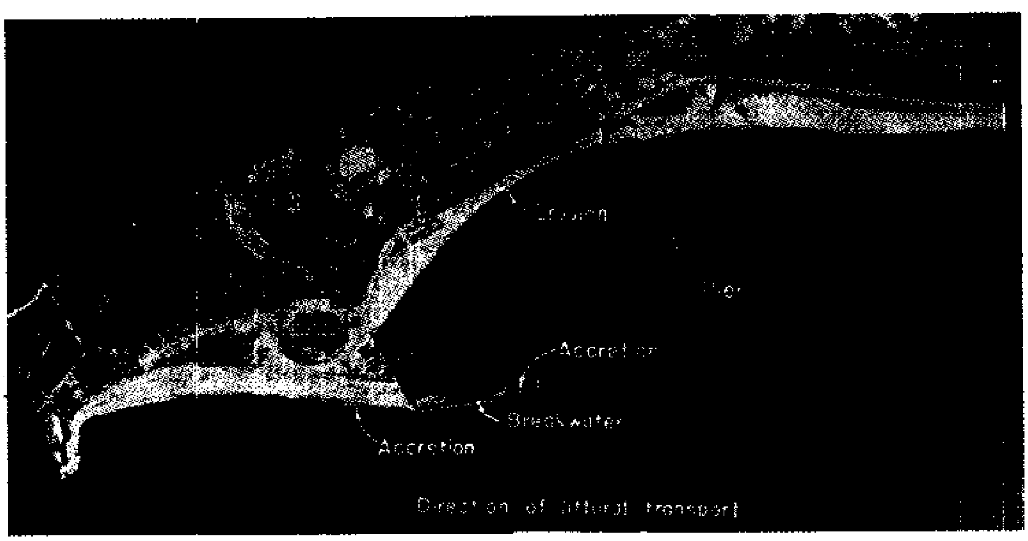
Groins differ from jetties structurally and functionally in that jetties generally are larger with more massive components, and are used primarily to direct and confine the stream or tidal flow at the mouth of a river or inlet to a bay and prevent littoral drift from shoaling the channel. In some sections of the country, groins are mistakenly referred to as jetties.

(Source: U.S. Corps of Engineers 1966)

- Jetty - A solid structure built on open seacoasts which extends into a body of water to prevent shoaling of a channel by littoral materials and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river or tidal inlet to help deepen and stabilize a channel.

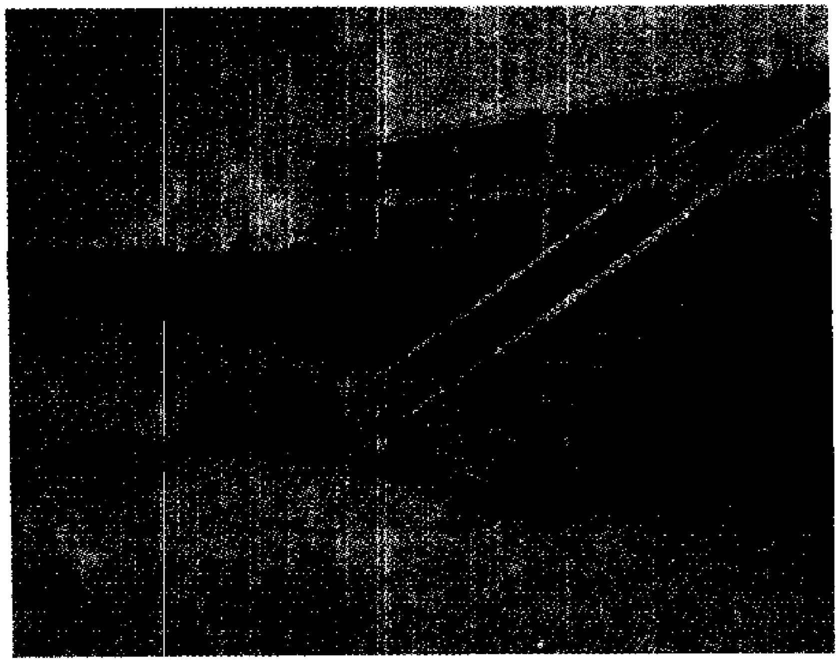
- Pile - Long, slender piece of wood, concrete or metal driven into the ground to carry a vertical load.

- Levee - An embankment bordering one or both sides of a seachannel or the low-gradient seaward part of a canyon or valley.



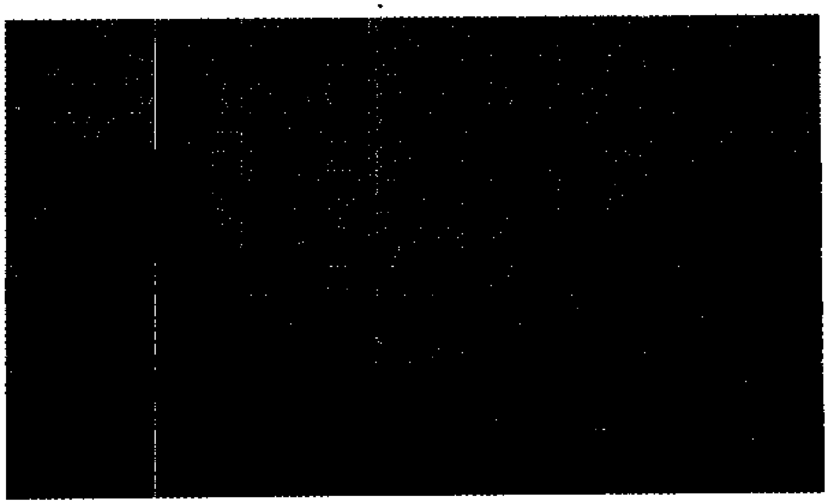
(Source: U.S. Corps of Engineers 1966)

- Breakwater - A structure protecting a shore area, harbor, anchorage or basin from waves.



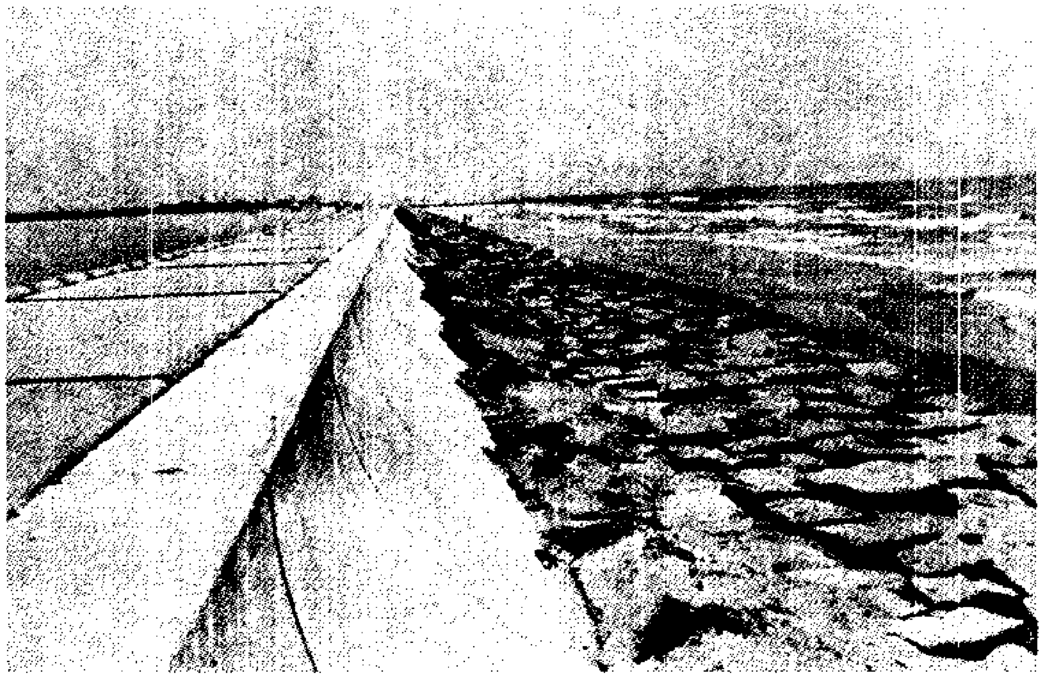
(Source: U.S. Corps of Engineers
1966)

• Bulkhead - A structure separating land from water, primarily designed to resist earth pressures.



(Source: U.S. Corps of Engineers
1966)

• Revetment - A facing of stone, concrete, etc., to protect an escarpment, embankment or shore structure against erosion by wave action.



(Source: U.S. Corps of Engineers 1966)

- Seawall - A manmade structure of rock or concrete built along a portion of coast to prevent wave erosion of the beach.

C SEDIMENTS

Sediments transported by rivers and currents affect river transportation, can completely block tidal inlets and fish passes and can create high maintenance costs for navigation channels.

Sediments are carried by rivers and deposited near the mouth or other points where lower water velocities occur. *Flocculation* occurs when proper conditions exist for the deposition of sediments.

- Flocculation takes place when small soil particles of negative charge carried in fresh-water are mixed with salt-water (as in the tidal river channel). The negative charge which keeps the particles apart is then neutralized by positive ions in the salt water. The particles flock together and gain enough weight to fall out. Hence, where salt water and fresh water mix, sediment build-up can be anticipated.

Sediments are also carried by the *longshore current*. This sediment transport is referred to as littoral drift.

Sediments are also carried by the longshore current produced when waves move forward, pushing water ahead in the same direction. The resulting current running parallel to the shoreline is the longshore current.

- The mechanics of littoral drift are currently being studied at Texas A&M University's Coastal and Ocean Engineering Department.

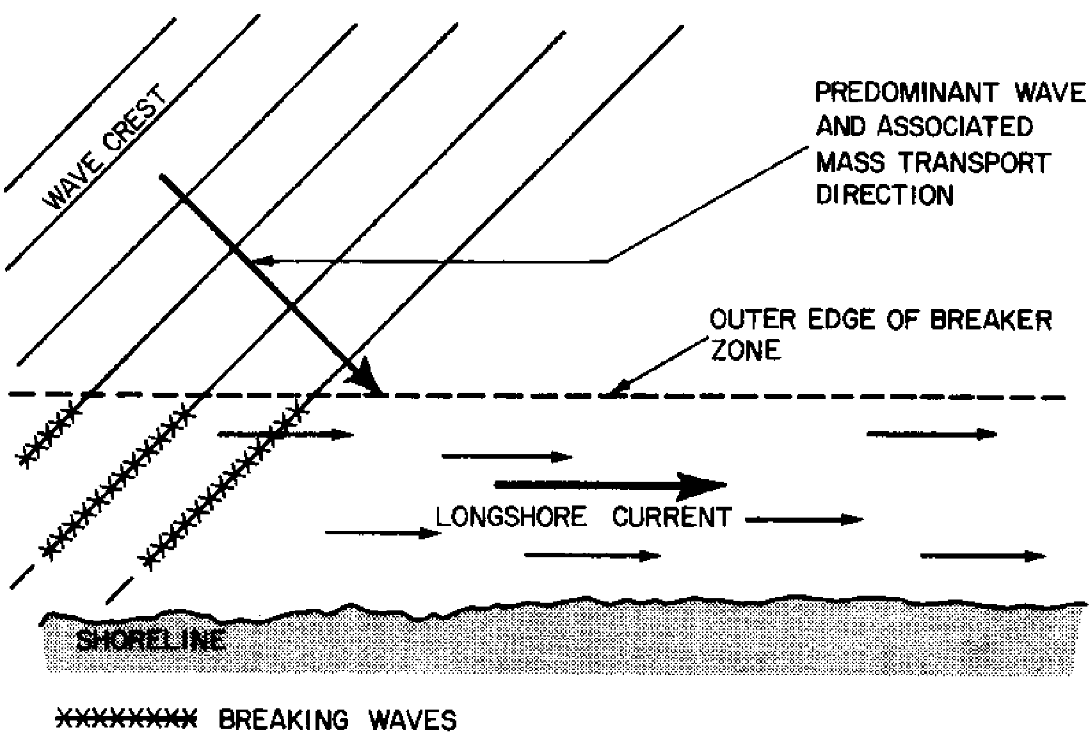
- The gross littoral drift rate at Freeport has been estimated to be 703,000 cubic yards per year. Other gross estimates range around 300,000 cubic yards per year.

Littoral drift carried by the longshore current is considered in the design of any strucutre that will interfere with the current or with waves causing the current.

Structures which stop littoral drift will have a continuous accumulation of sediments on the up-drift side and erosion on the down-drift side. Segments of beach where some coastal structure has stopped the supply of sediments and where the longshore current has picked up again can have serious erosion problems.

Breakwaters interfere with wave action, slowing the longshore current and allowing deposition of sediments behind the breakwater. Erosion on the down-drift side can be expected.

Longshore currents occur in a band between the shoreline and the outer edge of the zone of breaking waves (see figure).



D DREDGING

The huge volume of sediment carried by rivers and currents and deposited in navigational channels is removed by *hydraulic dredging*.

Hydraulic dredging is the transportation of solid material by mixing solids with water and pumping this liquid mixture with special hydraulic pumps. The unlimited water supply and the existing mixture of solid material and water make hydraulic dredging a convenient method of soil-sediment removal in the marine environment.

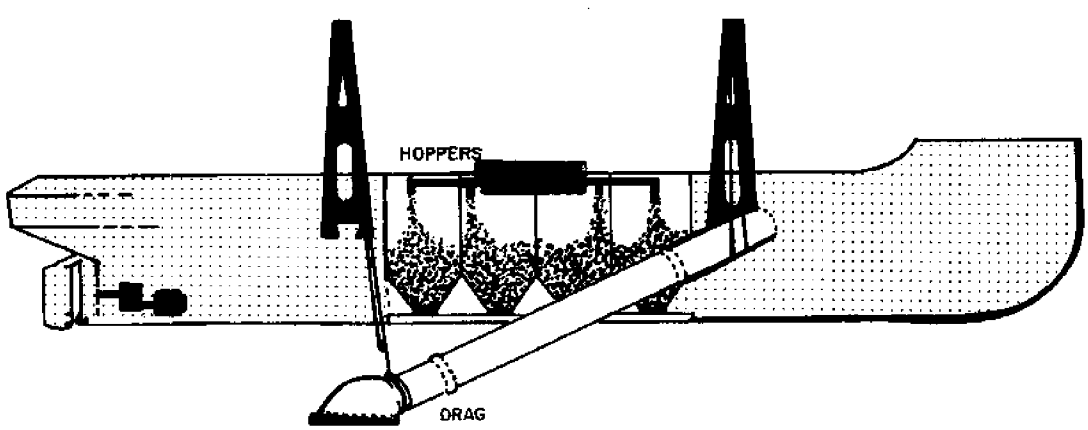
The region to which dredged material is pumped is called the *spoil area*. Spoil areas must be carefully located close to the dredging site. They must be large enough to accommodate the volume to be moved and must be located with consideration for their ecological effects.

- The Port of Houston alone reports an annual dredging volume for the Houston Ship Channel of 3 million ± cu. yds. at a cost of $1.1 million.

Three basic dredges are used in Texas:

1. Hopper dredge - Seagoing with molded hull and lines of an ocean vessel and, in addition to propulsion machinery, is equipped with dredge pumps, suction pipes and other special apparatus needed for dredging material hydraulically from a channel bottom or ocean bed. The dredge material is discharged into built-in hoppers and transported and dumped at the spoil area.

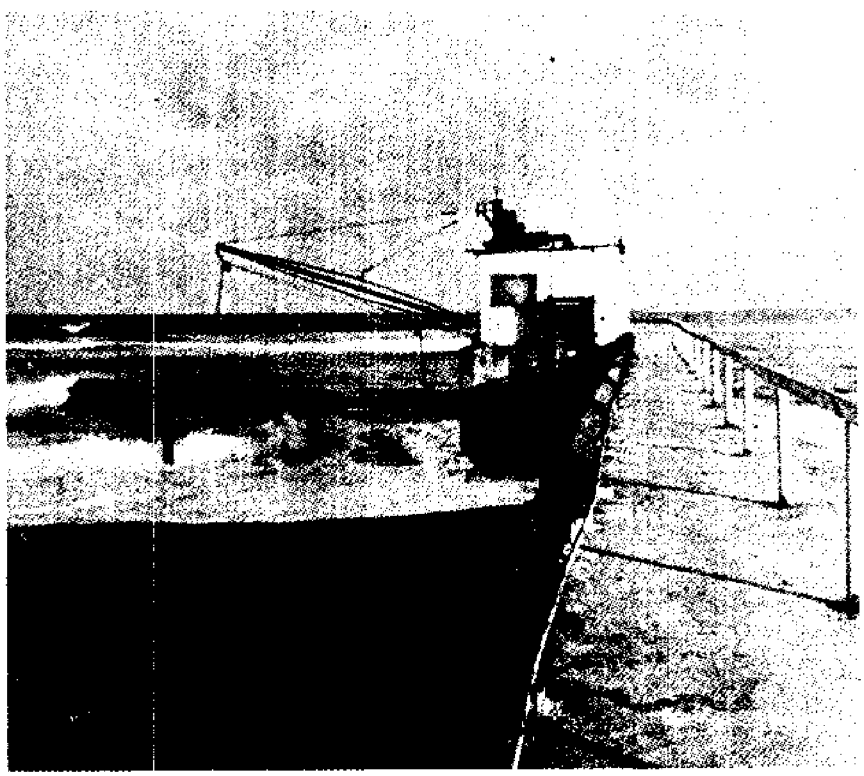
THE "A. MACKENZIE"



(Source: U.S. Corps of Engineers)

2. Cutterhead dredge - Familiar river dredge which incorporates a hydraulic dredge pump mounted on a large barge-shaped hull. The suction line is supported by a special frame called the "ladder" which extends down into the water. At the end of the ladder just ahead of the suction line is the rotating cutterhead. The cutterhead loosens compacted material, which is then pulled into the suction line.

3. Stationary dredge - Used where man-made structures interfere with natural sediment transport. For example, jetties which extend out into the water from shore often capture sediments on the up-drift side, creating a build-up there and erosion on the down-drift side because the sediment supply is cut-off. Installing a stationary dredge station is a practical method of bypassing sand around the jetties. Consists of a moveable suction line, stationary dredge pump and a discharge line running under the inlet to the down-drift side. Sediments deposited on the up-drift side of the jetty are pumped to the down-drift side where the littoral current will transport them along the coast. This stabilizes the shoreline in the vicinity of the jetty.



(Source: U.S. Corps of Engineers 1966)

E INLETS

- Barrier islands are found along 80% of the Texas coast.

- Texas coastal inlets range in width from a few hundred feet to nearly a mile.

Bays and estuaries located behind these islands are connected to the open sea by water passages called "inlets" or "passes". These play an important role in the ecology of the Texas coast.

- Inlets have three important functions:

  1. Controlling estuary salinity and pollution by allowing circulation with the open sea

  2. Providing pathways to estuarine nursery and breeding grounds for marine life

  3. Allowing passage of ships and boats to inland ports

Inlets are classified as either stable or unstable, depending on ability of the inlet to hold its configuration.

The flow of water through the inlet which causes changes in its configuration is the result of differences in water levels between the ocean and inland bays. These differences are normally caused by tides, rainfall and *wind set-up* of water.

Coastal engineers can design a stable inlet or stabilize an unstable one.

Basic to inlet design is the consideration of these factors:

1. Tidal range and differential between the sea and bodies of water behind the inlet.

2. Net and gross littoral drift carried along the shoreline past the inlet.

Important: Sediments are not only carried out from inland waters to the sea, but during the rising tides the littoral drift, proceeding along the coast, is swept into the inlet. These sediments are deposited in the inlet itself or are deposited as shoals in bays beyond the inlet.

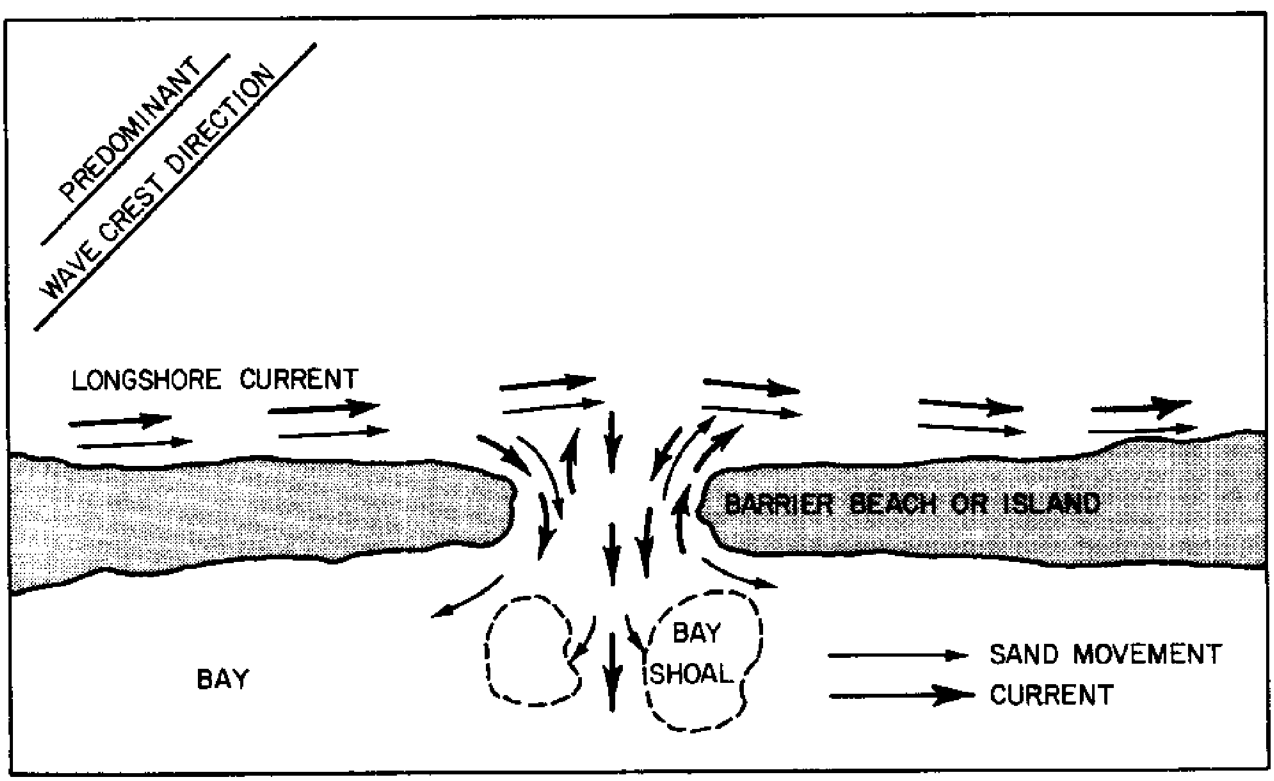
• Factors which may determine the design of an inlet:

1. littoral drift
2. wave action
3. prevailing winds
4. orientation of other inlets in region

Assessment of these factors leads to the determination of velocities high enough to keep the inlet flushed of deposited sediment and yet low enough to prevent erosion of the inlet.

The investment in the engineering design of an inlet will be returned in lower initial construction costs and lower future maintenance costs.

• Rollover Pass on Bolivar Peninsula was constructed during 1954-55 at an initial estimated cost of $121,000. Lacking proper design, erosion of the inlet occurred. $30,000 was spent for a study of of the problem which ultimately cost $600,000 to correct.



F OFFSHORE PORTS

- Only three Texas ports - Houston, Beaumont and Port Arthur - can handle ships with drafts of as much as 40 feet, which limits them to tankers of less than 80,000 deadweight tons.
- By 1983 more than 1,400 of the projected world tanker fleet of 4,384 ships will be unable to enter Texas ports.
- One method for providing deep water facilities is the construction of offshore ports.

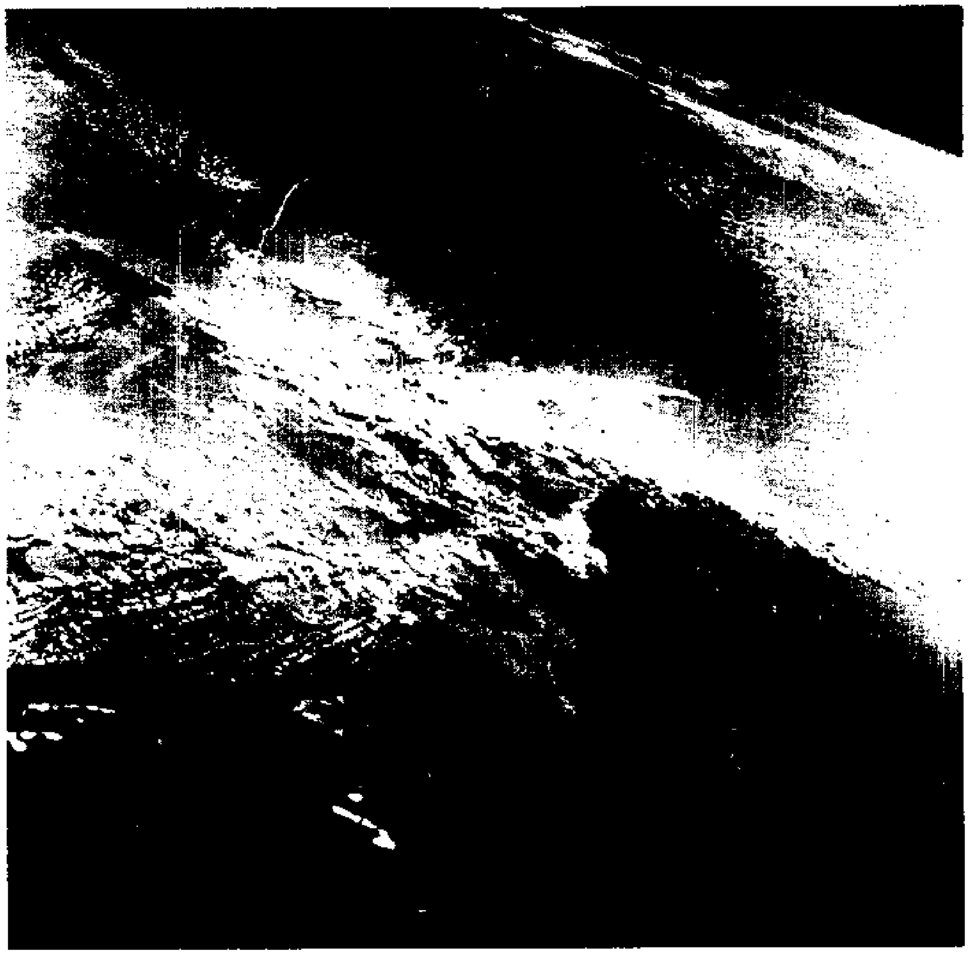
<u>Advantages</u>:

1. provides adequate depth to accommodate the greater draft ships
2. is free from expensive dredging
3. provides ease of navigation in open waters
4. allows reduced transportation costs, reflected in lower prices for raw materials for industry
5. provides short turn-around time
6. keeps present shallow-water ports from over-extending themselves in attempting to dredge deeper channels at prohibitive costs.

<u>Disadvantages</u>:

1. offshore ports are exposed to full force of wind and wave environment with minimal protection for ships loading or unloading unless special equipment is available.
2. adequate mooring systems have not been developed to reduce the stress occurring in the ocean environment
3. not only would adequate pipelines be required for the transferral of liquids and solids which can be mixed with water to points of distribution, but bulk and container cargo would also require transferral to smaller ships which in turn would transport cargo to distribution points
4. electrical power must be supplied by generators on the port or cabled in from power stations onshore

G REMOTE SENSING IN THE GULF OF MEXICO



Aerial view of the Mississippi Delta taken by GEMINI IX. The view is looking east along the Gulf coast and was taken at an altitude of 160 miles on June 3, 1966. Note the pronounced westerly flow of the discolored river discharge.

(Source: NASA 1966)

- Great potential in the study of the oceans from space has been recognized by the public since the appearance of Gemini photography. Added to the general vocabulary were such words as:

Remote sensing	*Metric cameras*	*Thermal gradients*
Panoramic photography	*River effluence*	*Infrared sensors*
Radar sensors		

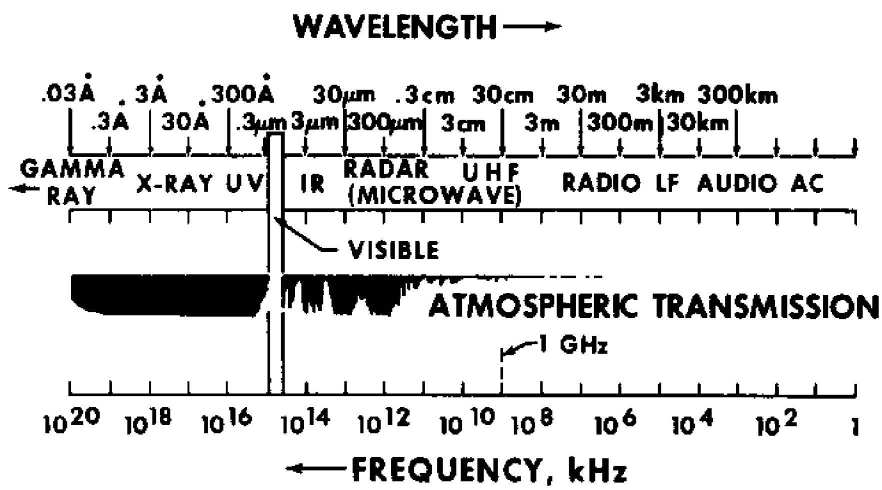
As these data became more available for study, the importance of remote sensing increased.

• Definition - *remote sensing* - the gathering and recording of information without actual contact with the object or area being investigated.

All remote sensing depends upon the property of all materials to radiate or reflect *electromagnetic energy*.

NASA-S-70-14824-S

CHARACTERISTICS OF THE ELECTROMAGNETIC SPECTRUM WHICH ARE OF SIGNIFICANCE IN REMOTE EXPLORATION



The electromagnetic spectrum shown here extends from direct current frequencies to cosmic rays and beyond.

(Source: NASA-S-70-14824-S)

Several varieties of instruments, in the different spectral regions, are used aboard aircraft and spacecraft. These fall within the following categories:

1. Photographic sensors (cameras)
2. Infrared sensors
3. Radar sensors
4. Passive microwave sensors
5. Laser sensors

Photographic sensors (cameras)

- Through various combinations of films and filters, oceanographers are able to study sea-ice patterns, ocean currents, ocean color, river *effluence* , oil spills, and many other features visible to the camera lens.

- The hydrographic cartographer finds this form of photography a real boon in that photography of such large water masses enables the updating of shipping charts. The action of tides, currents and storms often creates new hazards to navigation, making existing charts obsolete within a short period of time.

- Film types used are:

  Panchromatic - Most black-and-white aerial film ranges in spectral sensitivity from 0.36 to 0.72 microns.

  Infrared film - Has a spectral sensitivity of from 0.36 to 0.9 microns.

  Color film - 1. color positive
  2. color infrared
  3. color negative
  4. false color infrared

  Limitations: must be used in daylight and during good weather conditions.

- The Gemini photography is a good example of use of the above film types.

- The Mississippi Delta area represents an ideal oceanographic test location for remote sensors. It empties one of the largest river systems in the world. As a meeting place for oceanic and river waters involving vast quantities of fresh water and sediments, it becomes the stage for an enormous display of relatively large changes visible even to the naked eye.

For the past several years, it has been considered one of the prime test sites of remote sensing instrumentation for the Earth Resources Program of the National Aeronautics and Space Administration (NASA). Overhead flights with NASA aircraft equipped with certain sensors have been correlated with oceanographic research vessels in the area so that ship data (so-called "ground truth") could be compared with that obtained from the aircraft.

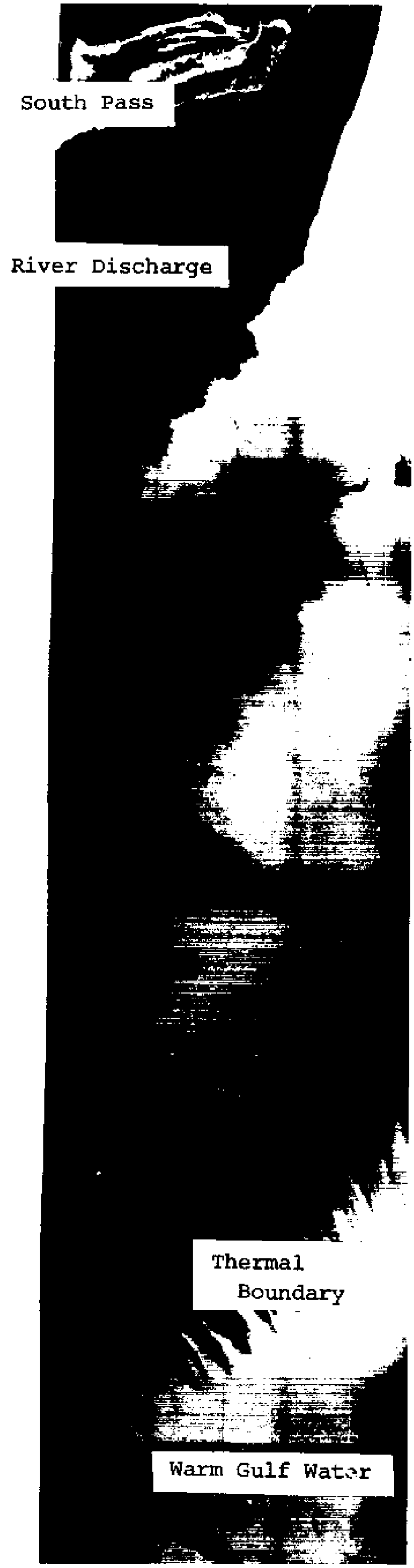
Non-photographic sensors

- Infrared sensors - The imagery provided by an infrared imager or scanning system gives much information not available from ordinary photography. The brightness with which an object appears on an infrared (IR) image increases along with increases of temperature. Radiant temperature depends largely on the chemistry, grain size, surface roughness, and thermal properties of the material. (Note: the image is nearly a reversal of conventional photography in that black represents cold areas and white signifies hot areas).

  Infrared sensing is valuable in determining sea surface temperature, thus distinguishing cold water from warm water masses. Since the thermal status of the oceans is a major factor controlling weather, increasing our synoptic knowledge of its thermal structure is vital. Microwave radiometry has been shown to be theoretically capable of this remote measurement through overcast and the atmosphere.

  Limitations: provides year-round capabilities of photography, but not useable through heavy clouds.

IR Imagery of the South Pass of the Mississippi Delta



This is an example of IR imagery obtained with an infrared scanner aboard a NASA aircraft. The area shown is the South Pass of the Mississippi Delta and was made in June 1967. The direction of the flight is north, or lengthwise as the photograph is viewed. The land mass in the upper left of the photograph is the tip of South Pass. The black area adjacent to the land mass is the cold river water discharge. The varying shades from dark to light represent the varying temperatures from cold to hot.

The crosstrack lines are scanning lines, caused by the movement of the imager from left to right and back again.

- Radar Imaging - This imager relies upon its own illumination -- radio waves. It is particularly useful in the surveillance of ice and shoals, coastal mapping, sea surface roughness, water pollution, ground water discharge, geological studies, geographic and agricultural studies.

  Other imaging systems used may be a scatterometer and microwave radiometer.

  Limitations: nearly all weather capabilities, but limited in resolution (image detail).

- Passive Microwave Instrumentation - This instrumentation measures the total reflective-emission of materials and natural microwave radiation emanating from observed objects.

  A picture is constructed that relates the light and dark intensities on the image to the amounts of microwave imagery radiated by the objects in the scene.

  In the microwave region, the intensity of radiation is directly proportional to the temperature and the emissivity of the object. For example: ice has a higher emissivity than water and, therefore, has a higher apparent temperature than water.

  Limitations: nearly all weather capabilities, but limited in resolution.

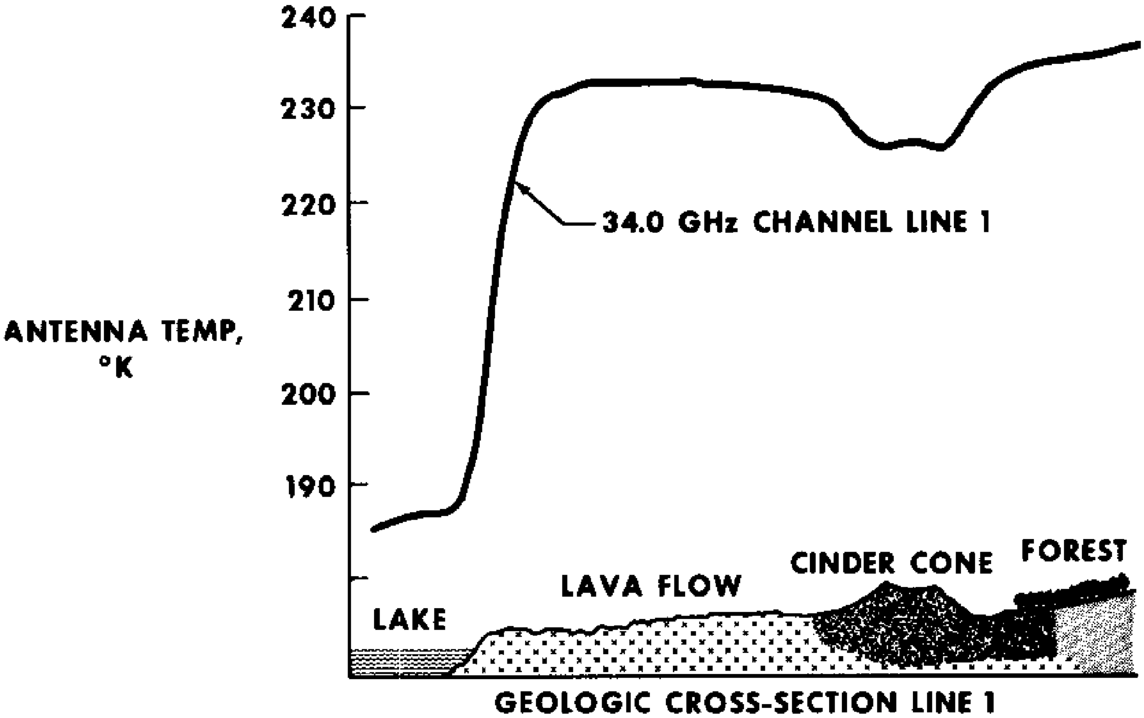
  The microwave radiometer may be used to determine the thermometric water temperature, the sea surface roughness spectrum, the total heat flow from the sea surface, and the thickness and distribution of ice.

- Infrared spectrometer/radiometer - This instrument measures the spectrum of emitted heat directly radiated from the earth's surface. The radiometer will serve as a monitor for changes in radiant emittance during the time or spectral scan, and will use the same optics as the spectrometer. With this information, it is then possible to determine, at low altitude, the surface temperature to about 0.1°F.

  This instrument has uses in the areas of oceanography, hydrology, geology, geography and agriculture.

NASA-S-70-12650-S

AIRBORNE RADIOMETER SCANS ALONG WATER, LAVA, CINDER, AND FOREST



In this microwave region of the spectrum, one can observe thermal emission which is proportional to the product of temperature and emissivity.

(Source: NASA-S-70-12650-S)

- Laser Sensors - The development of laser instrumentation has enabled accurate determination of wave profiles when measured from aircraft. The modulated light source of the laser is reflected from the ocean surface and the time of travel is measured. As the aircraft flies a course normal to the wave direction, a profile of the ocean surface is obtained. The present state-of-the-art allows aircraft to fly at low operational altitudes and obtain satisfactory results.

Use of Satellites in Remote Sensing

- Since it is felt that the ever-increasing demand for fishery products will soon exceed the supply, fishery biologists are looking to the manned and unmanned orbiting satellites for assistance in gathering valuable data which will help to gain the increase in supply needed.

- The use of satellites to help locate, with sufficient precision, large fish concentrations has opened the possibility of more profitable fishing activities. The need is not in the location of fish which normally school on the surface, but in the location of those stocks of pelagic fish such as tuna and billfish in areas where conventional visual observation is not adequate.

- The use of satellites will be of limited value, however, unless a corresponding sophistication is developed in the design of fishing vessels.

- In addition to the above, using moored or unmoored buoys in the sea equipped to sense various oceanic features such as temperature, current and surface winds, and eventually sending this information to the fishermen via satellite, will help the entire fishing industry, as well as increasing knowledge of the oceans.

- Spotting fish schools by airplanes alone has made a great contribution. Experiments have been conducted by scientists of the National Marine Fisheries Service at Pascagoula, Mississippi, where a number of significant characteristics of fish and their environment have been observed through the use of various remote sensors mounted on aircraft.

ANTICIPATED OCEANOGRAPHIC APPLICATIONS OF REMOTE SENSORS	Sea Surface Thermal Mapping	Ocean Waves	Shoals & Coastal Mapping	Currents	Ice Surveillance	Coastal Marine Processes	Biological Phenomena	Air/Sea Interactions	Sea Level and Sea Slope	Water Color Analysis	Volcanic Activity	Subsurface Structure
1. Metric Mapping Camera		•	•	•	•	•	•	•		•		
2. Panoramic Camera		•	•	•	•	•	•	•		•		
3. Multiband Synoptic Camera		•	•	•	•	•	•	•		•	•	
4. Radar Imager		•	•		•	•		•				
5. Radar Scatterometer		•			•			•	•			
6. Infrared Imager	•		•	•	•	•	•	•			•	
7. IR Radiometer/Spectrometer	•		•	•	•	•	•	•			•	
8. Microwave Imager	•	•	•	•	•	•		•			•	
9. Microwave Radiometer	•	•	•	•	•	•		•			•	
10. Laser Altimeter		•	•		•			•	•			
11. Magnetometer			•								•	•
12. Gravity Gradiometer			•								•	•
13. Absorption Spectroscopy							•	•		•	•	
14. Radio Frequency Reflec.					•							
15. Viewfinder			•	•	•	•	•				•	
16. Telemetering Buoys/Ships	•	•	•	•	•	•	•	•	•	•	•	•

Anticipated oceanographic applications of remote sensors.

(Source: U.S. Geological Survey)

H SUBMERSIBLES IN THE GULF OF MEXICO

- Within the past five years more than 30 submersibles have been christened and sent off to sea. These have ranged in depth capabilities from 150 feet to 10,000 feet. It has been estimated that this fleet is worth well over $100 million.

- In 1954, the Cousteau Diving Saucer gave over 75 scientists their first look through a small port at the world a thousand feet below sea level.

- Submersibles date back as far as the seventeenth century.

- Two men from the mid-twentieth century probably are entitled to the distinction of being the "fathers" of the modern day research submersible:

  August Piccard - A Swiss physicist
  Jacques Cousteau - Renowned oceanographer

- Piccard and Don Walsh, then Lieutenant of the U.S. Navy, made their plunge in the TRIESTE 35,800 feet in the Marianas Trench, the greatest depth of the ocean. This is the deepest dive so far recorded.

- The present U.S. Navy Deep Submergence Program is a direct derivation of the TRIESTE dives.

- A submersible has been defined as an undersea diving vehicle that requires surface tending or support as opposed to the submarine, which is wholly independent of the surface.

- There are at least 60 and perhaps 100 submersibles in existence around the world. Probably 40 of them are in the United States.

Applications

Geology - Observation of processes thought to be responsible for submarine canyons and sedimentary movements on slopes.

Biology - Population studies of both the pelagic and benthic regions.

Fisheries - Determination of the relationship between the distribution of fishes and sea floor topography as well as geologic and physical factors affecting the fishing grounds.

Physical/Acoustical Oceanography - The submersible is an ultra-quiet platform for making measurements, removed from noisy ships and sea surface disturbances.

Measurements of temperature, salinity and pressure.
Excellent measurements and observations of slow-speed currents on the bottom have been obtained with a Savonius rotor.

Geophysics - Ideal platform for gravity measuring instruments because of stability.

Engineering and other test evaluations - Site surveys prior to bottom installation or subsequent operations.

Nonscientific - Military tasks such as torpedo, bomb, missile and aircraft wreckage recovery.

• The Deepstar 4000

In 1967 the Underseas Division of Westinghouse Electric Corp. brought the Deepstar 4000 to the Gulf of Mexico to demonstrate its Cacholot saturation divising system. Three series of dives were conducted. The first, off Panama City, Florida, was to observe the behavior and distribution of marine organisms. The second series was made to study the geological formations in the DeSoto Submarine Canyon, and the final series was to demonstrate the Cacholot system on an isolated knoll on the W flank of the Mississippi Trough, one of the few locations of about 600 foot depth in the vicinity of the Mississippi Delta where there was a chance of having relatively clear water. Five biological and six geological dives were made.

The Deepstar 4000 is 18 feet long, 7 feet high and 11 feet wide. Its weight is 18,534 pounds. the submersible can accommodate three observers for up to 10 hours underwater. It is capable of attaining depths of 4,000 feet.

• Shelf Diver

In 1969, Perry Oceanographics (Florida) demonstrated the Shelf Diver in the Gulf. Purpose of the dive was to demonstrate its usefulness as a mobile observation platform for visual inspection, photography and video-taping.

The lock-out feature of the Shelf Diver was also demonstrated. This permits a diver to leave the sub for outside activities and then to re-enter the submarine in any depth down to the working capacity of 600 feet.

The Shelf Diver is 23 feet long. Its weight is 17,000 pounds. It can accommodate four observers for up to eight hours under water. It is capable of attaining depths of 800 feet.

ENGINEERING IN THE GULF OF MEXICO

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TEXAS COASTAL ZONE

Contents

TEXAS COASTAL ZONE

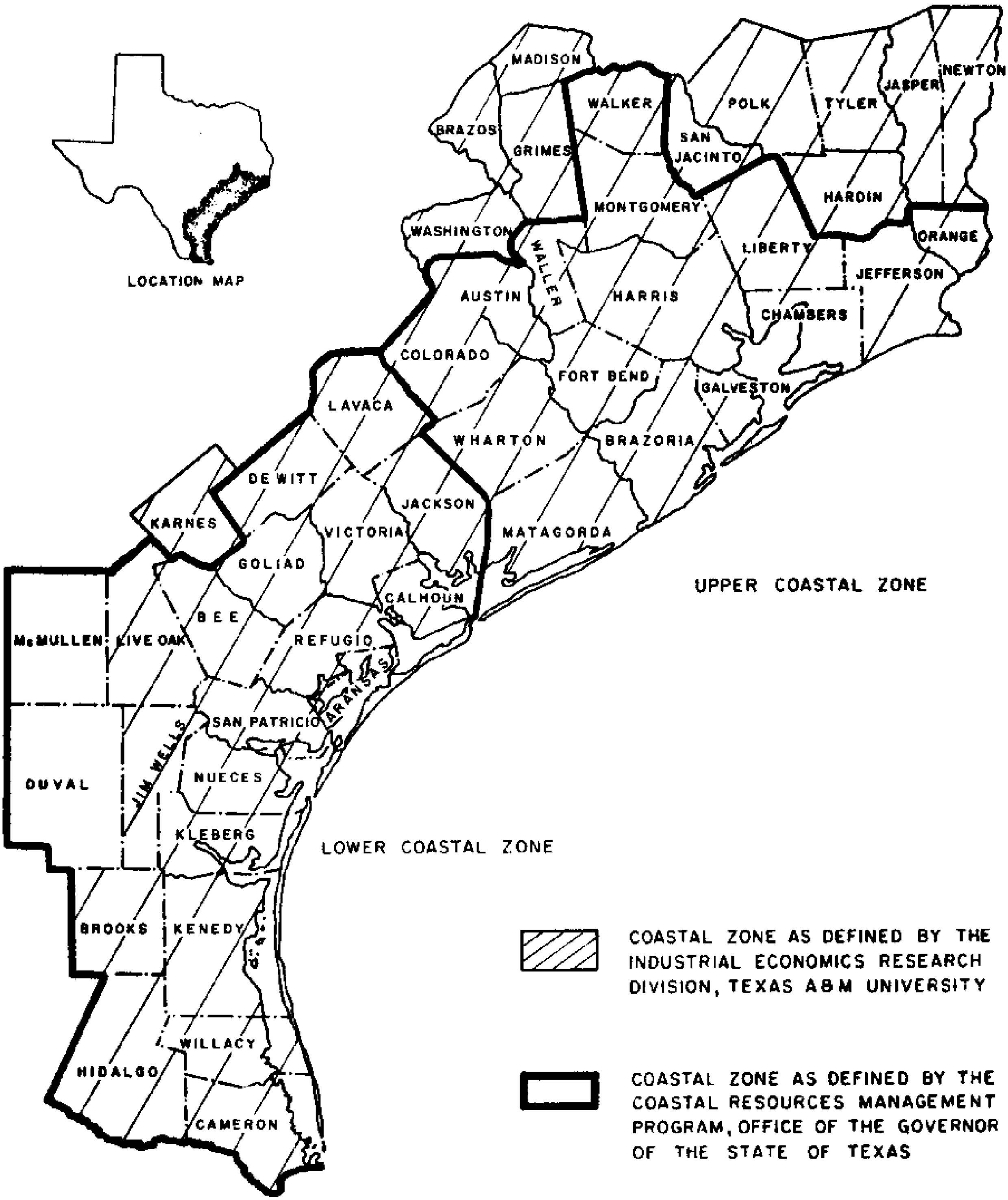
A FACTS ABOUT THE GULF COASTAL ZONE

- Five coastal states--Alabama, Florida, Louisiana, Mississippi and Texas--have 17,141 miles of tidal shoreline, comprising 18% of the continental U.S.

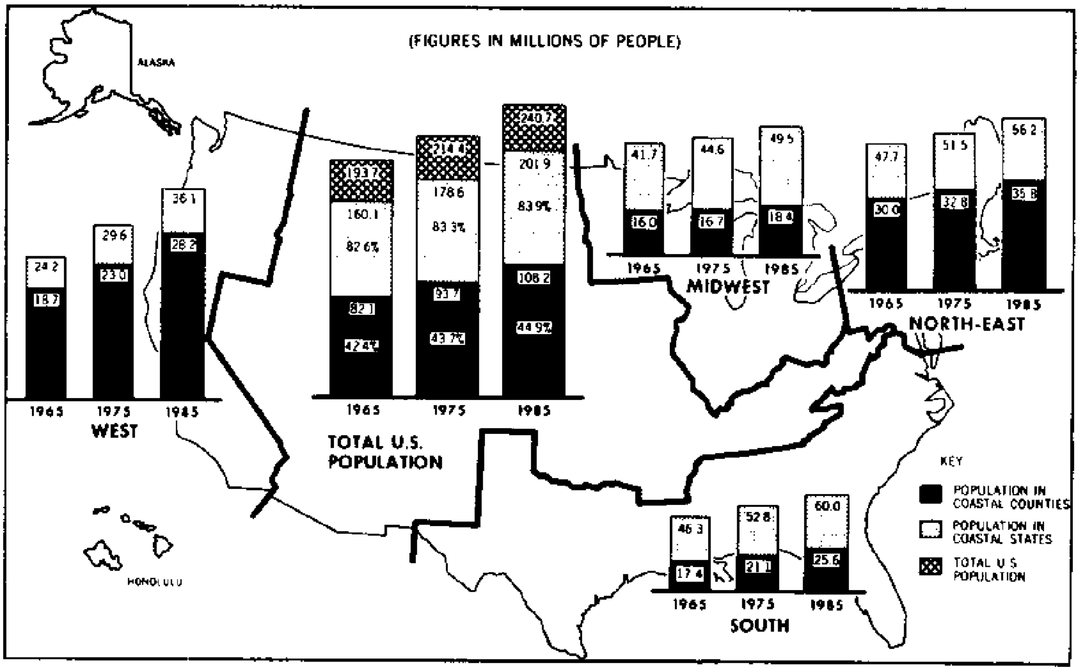
- Within the five Gulf coast states are 33 bay systems, such as Tampa, Barataria, Mobile, Mississippi Sound and Corpus Christi Bay, averaging 550 square miles in area, each ringed by vast concentrations of human population.

- The Gulf of Mexico probably contains more shore and offshore observation facilities combined than any other coastal segment of the continental United States.

Editor's Note: *Italicized* words are defined in the Glossary. Credit lines for figures refer to selected references.



Texas coastal zone



Population growth in nation's coastal zone.

(Source: Miloy and Copp 1970)

B THE TEXAS COASTAL ZONE

- The coastal zone as defined by the Texas Coastal Zone Management Program, Office of the Governor of Texas, includes 36 counties (33,223 sq.mi.) and extends seaward to 10.35 miles.
- Elevation in the Coastal Plain rises from sea level along the Gulf coast to more than 500 feet at the Balcones Escarpment.
- Coastal prairie is largely a thick accumulation of sediments.
- Belt of coastal lowland, some 50 to 75 miles wide, is the most recently emerged portion of the Texas continental shelf.
- Quite level for some distance inland, the Coastal Prairie rises rapidly to about 100-175 feet along its inland edge.
- Except for the steep-sided channels of traverse streams, the Coastal Prairie is a clay plain almost unrelieved by erosional features.

- Texas has 1,081 miles of shoreline suitable for recreation including more than 301 miles of beach shoreline. The remainder is:

  bluff shore - 421 miles
  marsh shore - 359 miles
  public recreation areas - 5 miles
  restricted shore areas - 18 miles

- Texas has almost continuous offshore barrier islands paralleling the mainland shore. They include:

  Padre Island (extends 113 miles and is the longest barrier island in North America)
  Matagorda Island
  Matagorda Peninsula
  St. Joseph's Island

- Texas bays include:

Galveston	Aransas
Matagorda	Nueces
San Antonio	Corpus Christi
Espiritu Santo	Baffin
Copano	Laguna Madre
Lavaca	

- There are more than 1.8 million acres of wetlands in the Gulf coastal area.

- Two-thirds of the state's total value added in manufacturing emanates from industries located within the coastal area.

There are 25,394,003 acres of uplands, submerged lands, islands of which 80% are private, 16% state-owned and 2% each in Federal or local government hands.

There are 760 square miles of marshland, 2100 square miles of bays and estuaries, 200 square miles of formal Wildlife Refuges and 35 square miles of made-land and spoil.

There are 1890 miles of waterfront of which 1419 are bayfront and 373 front on the open Gulf.

- The coastal zone contains more than 345 historical sites.

Estuaries are 20 times as fertile as the open Gulf.

- The region contains more than 50% of the nation's petrochemical industry and 25% of its refining capability.

One-third of the State's economy is concentrated in the 1/20th of its area that is within the coastal zone.

- Mineral production in the coastal zone exceeds 1.3 billion dollars per year. Oil reserves exceed 3.5 billion barrels and gas reserves are 50 trillion cubic feet.

A hurricane hits the coast on the average of once every two years, often bringing 150+ mph winds and 15 foot tides, which have flooded more than 3200 square miles with salt water.

Seventy-five percent of the 550 water supply systems are not approved by the State Department of Health.

Over half of the area is not covered by full-time health departments.

Municipal and industrial wastewaters contribute to our estuarine systems: 162,600+ million gallons per day; 1,269,200+ pounds of biochemical oxygen demand per day; 1,449,400+ pounds of suspended solids per day; 59,300+ pounds of phosphates per day; and 4,876,800+ pounds of chemical oxygen demand per day.

The effluent from 2/3 of 368 waste treatment plants in the coastal zone does not meet state standards. Likewise, 90% of 171 solid-waste disposal sites do not meet state standards.

A Brief History of the Texas Coastal Zone

The Texas "Industrial Revolution" began with the discovery of oil and natural gas along the state's coastal region and the development of port and harbor facilities along the eastern half of the Texas coast.

The demand for petrochemical products, along with the increased requirements for oil and natural gas during and following World War II, stimulated large-scale investments in coastal refining and processing facilities.

- The Texas Gulf Coast is currently the location for the world's largest petrochemical complex in terms of output and investment.

- The Texas Gulf Coast is the most important source of natural gas in the United States and contains reserves of more than one trillion cubic feet.

The Texas offshore oil and gas industry is now concentrated from the Galveston Bay area to the Louisiana border.

The Houston area is one of the world's major offshore exploration and supply centers for maintenance and supplies for offshore platforms and exploration vessels.

Industries found within the coastal zone of Texas alone:

Agriculture
Forestry and Fisheries
Mining
Contract Construction
Food and Kindred Products Manufacturing
Textile Mill Products Manufacturing
Apparel Manufacturing
Lumber, Wood Products, Furniture Manufacturing
Printing and Publishing Manufacturing
Chemicals and Allied Products Manufacturing
Electrical and Other Machinery Manufacturing
Motor Vehicles and Equipment Manufacturing
Other Transportation Equipment Manufacturing
Miscellaneous Manufacturing
Railroads and Railway Express
Trucking and Warehousing
Other Transportation
Communications
Utilities and Sanitary Service
Wholesale Trade

Food and Dairy Products Stores
Eating and Drinking Places
Other Retail Trade
Finance, Insurance and Real Estate
Hotels and Other Personal Services
Private Households
Business and Repair Services
Entertainment, Recreation Services
Medical, Other Professional Services
Public Administration
Armed Forces

TEXAS BAYS

Bay	Depth	Bottom Composition	Salinity	Mineral and Energy Resources
Galveston	6-12 ft.	Made land and spoil, properties highly variable, mixed mud, silt and sand	Avg. sfc.: 10-26°/oo During periods of relatively high rainfall and runoff: 1-14°/oo During periods of relatively low rainfall and runoff 20-32°/oo	Oyster reefs both live and dead Oil or gas fields Salt dome oil fields
Copano Bay (& Aransas Bay)	5-12 ft.	Shell, mud, some sand, marginal grass flats, variable, abundant reefs	Avg.: 24-30°/oo High runoff: 4-26°/oo Low runoff: 33-35°/oo	Oil and gas field Abundant oyster reefs (live and buried)
San Antonio Bay	4-6 ft.	Shell, reefs, mud, sand, marginal grass flats, spoil, variable, delta mud	Avg.: 6-26°/oo High runoff: 1-16°/oo Low runoff: 24-35°/oo	Oil and gas field Oyster reef (live and buried)
Matagorda Bay	6-13 ft.	Shell, mud, sand, marginal gass flats, local reefs, variable, spoil	Avg.: 20-28°/oo High runoff: 2-22°/oo Low runoff: 24-38°/oo	Oil and gas field Oyster reefs; some live, abundant buried
Lavaca Bay	4-7 ft.	Shell, mud, sand, delta mud, grass flats, local reefs, spoil, variable	Avg.: 12-22°/oo High runoff: 2-10°/oo Low runoff: 30-34°/oo	Oil and gas field Oyster reefs; some live, abundant buried

TEXAS BAYS (Continued)

Bay	Depth	Bottom Composition	Salinity	Mineral and Energy Resources
Laguna Madre (North and South)	6-18 ft.	Spoil, extensive, hypersaline, grass flats, sand, mud, shell, locally oolites, spoil, serpulid reefs, variable	Avg.: 34-44°/₀₀ High runoff: 4-20°/₀₀ Low runoff: 42-58°/₀₀	Oil and gas fields
Trinity Bay	6-12 ft.	Mud, sand, shell, spoil, local grass flats, reefs, variable, delta muds	Avg.: 10-16°/₀₀ High runoff: 1-2°/₀₀ Low runoff: 20-24°/₀₀	Oyster reefs (live and buried) Oil and gas fields
East Bay	6-12 ft.	Mud, sand, shell, reefs, marginal grass flats, spoil, variable	Avg.: 14-20°/₀₀ High runoff: 2-8°/₀₀ Low runoff: 24-28°/₀₀	Oyster reefs (live and buried) Oil and gas fields
West Bay	6-12 ft.	Mud, sand, shell, reefs, marginal grass flats, spoil, variable	Avg.: 24-28°/₀₀ High runoff: ≃14°/₀₀ Low runoff: 32-34°/₀₀	Oyster reefs (live and buried) Oil and gas fields
Corpus Christi	6-13 ft.	Mud, sand, shell, marginal grass flats, spoil, variable	Avg.: 31-38°/₀₀ High runoff: 2-11°/₀₀ Low runoff: 42-45°/₀₀	Oil and gas fields Reefs (mostly dead or buried)

Source: Dr. W.L. Fisher, Bureau of Economic Geology, The University of Texas at Austin.

(9/72)

Population Facts About The Texas Coastal Zone

- More than 50% of the residents of Texas are located within a radius of less than 100 miles from the coastline. By the year 2000 it is predicted that more than 12 million Texans will live in the coastal zone, a population equivalent to that of the entire state in 1970.

  The upper half of the coastal zone is the export center for marine-related machinery and equipment, transportation and mining.

  The lower half is the state's center for fishery production and processing and mining.

  The upper half of the coastal zone also accounts for most of the direct marine-related income generated by 10 industries.

- More than 75% of the state's population lives within 4-1/2 hours driving time from the coast.

- The population of the coastal zone increased 20% between 1960 and 1970.

- Total employment in the Texas Coastal Zone in 1970 is estimated to be 1.6 million. By the year 2000, 2.6 million persons will be working in the coastal zone.

POPULATION OF THE TEXAS COASTAL ZONE

YEAR	POPULATION	PERCENT INCREASE
1940	2,306,737	--
1950	3,068,516	33.0
1959	3,886,505	26.7
1962	4,206,760	8.2
1970	4,457,150	6.0
1980	5,148,566	15.5
1990	5,989,750	16.3
2000	6,943,745	15.9

Source: Preliminary Report on Economic Projections for Selected Geographic Areas, United States Water Resources Council, Office of Business Economics, U.S. Department of Commerce, Washington, D.C., 1968 and the Industrial Economics Research Division, Texas A&M University, College Station, Texas.

Recreation in the Texas Coastal Zone

- More than 1,000,000 salt water anglers spent about $85 million and caught 89 million fish. They used about one million pounds of bait shrimp costing $2 to $3 per quart.

  In the Gulf coastal waters of Texas, each day that a deepsea fishing yacht spends at sea represents a minimum expenditure of $100 for fuel, bait, ice, ship rental and food.

- During 1970, coastal recreation and tourism brought over 4.3 million tourists to the coast of Texas, resulting in expenditures of over $190 million.

  Most of the out-of-state visitors come from California, Florida, Louisiana, Oklahoma, Missouri and Illinois. Their preferences for coastal marine recreation were ranked as follows:

  a. Fishing and hunting
  b. Climate
  c. Swimming
  d. Padre Island
  e. Boating and sailing
  f. Surfing
  g. Scenery
  h. Water skiing
  i. Golf and tennis
  j. Birds and wildlife

  Other desired activities include vacation home development, underwater recreation (glass bottom boats), sight-seeing, pleasure driving, local commercial entertainment, local industry attractions and use of local historical and archeological sites.

- Over 2 million sport fishermen fished in the Gulf of Mexico during 1970.

  The leisure industry is the third largest in the nation as well as in the State of Texas.

  Of all outdoor recreational activities, water-related activities are the most popular. Water is the magnet. Of these recreational boating is one of the fastest growing activities.

Land and Water Acreages in Texas

	Acres	Sq. Miles
Fresh water rivers; 30 feet wide and navigable,	1,000,000	1,562
Fresh water lakes and reservoirs, small streams,	1,879,360	2,937
Salt-water bays and inlets to the Gulf beaches,	1,537,000	2,402
Gulf - within three marine leagues, or 10.35 miles, or a grand total of water surface	2,600,000	4,062
	7,016,360	10,963

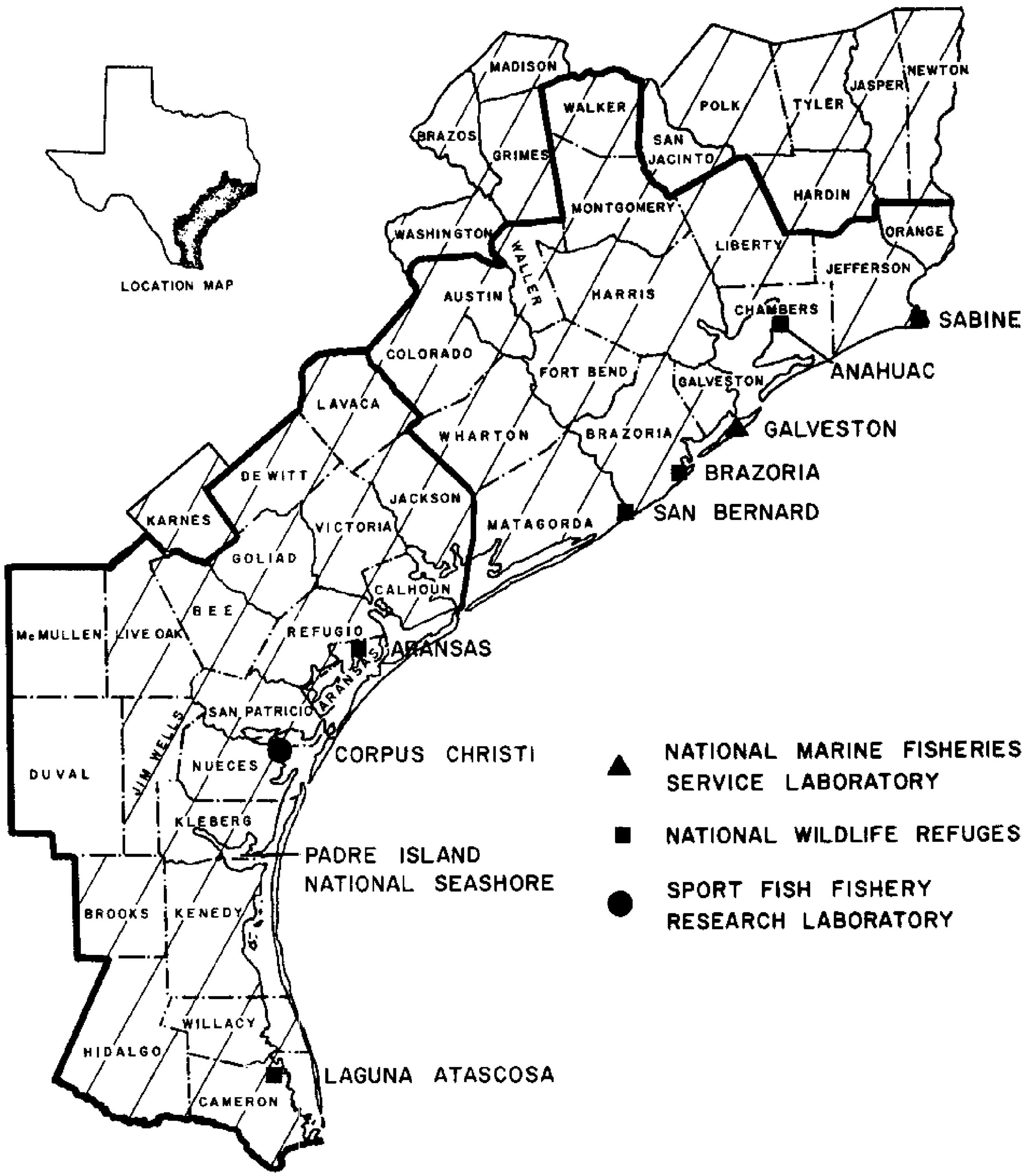
	Acres	Sq. Miles
Total land (1970 census)	168,217,600	262,840
Total fresh water	2,879,360	4,499
Total land & total inland fresh water:	171,096,960	267,339
Total land, total inland fresh water, and total inland bay salt water:	171,096,960	267,339
	1,537,000	2,402
	172,633,960	269,741
Total land and total inland fresh water and total inland bay salt water,	172,633,960	269,741
with Gulf water within three leagues	2,600,000	4,062
(10.35 miles)	175,233,960	273,803
Total land,	168,217,600	262,840
Total water, fresh & salt, within three leagues,	7,016,360	10,963
TOTAL TEXAS DOMAIN	175,233,960	273,803

Source: General Land Office of Texas, Austin, Texas

(9/72)

FRESHWATER FISHING IN TEXAS

Best Known and Most Popular	Location
Bass, large-mouthed	In most waters
Bass, spotted	As far west as Central Texas
Bass, calico (or strawberry)	Nonalkaline waters of East Texas, Many West Texas streams
Crappie (white perch)	(Same as calico bass)
Bluegill (or Blue bream, blue sunfish, coppernosed sunfish)	Throughout the State
Sunfish, red-eared	Lowland streams and ponds
Sunfish, blue-spotted	Small streams
Sunfish, green	Small streams
Sunfish, long-eared	Clear running streams
Goggle-eye, warmouth	Sluggish streams & mud-bottom ponds
Bass, rock (or red-eye, goggle-eye)	Large & small bodies of clear water
Bass, yellow	Lower reaches of Trinity River, San Jacinto & other East Texas rivers
Bass, white	Caddo Lake and along E. Texas border
Catfish (11 or more species are found, but the following are more common)	
Catfish, blue or blue cat	Large streams, especially along coast
Catfish, channel (or spotted cat)	Larger streams
Catfish, yellow (or mud cat)	Large streams, preferring sluggish waters
Catfish, spoonbill (or paddle fish)	Lowland streams & ponds of E. Texas
Pickerel, little	East Texas
Perch, bullhead (or bull-nose)	South Texas
Buffalo fish (mullet, red horses, buffaloes)	Larger Texas streams
Gaspergou (or freshwater drum)	Generally in Texas
Shad, gizzard (or hickory shad)	Sluggish waters of lower streams & brackish waters of Gulf bays
Bowfin (or grindle of dogfish)	East Texas
Gar Pike, short-nosed	Fresh & brackish waters along coast
Great Alligator Gar	Same as Gar Pike
Top minnow (mosquito fish)	Same as Gar Pike



Federal marine research laboratories and coastal
wildlife refuges in Texas

(Source: Miloy and Copp 1970)

COASTAL STATE PARKS ADMINISTERED BY
TEXAS PARKS & WILDLIFE DEPT., 1972

NAME	LOCATION	ACRES	RECREATIONAL OPPORTUNITIES
Bentsen-Rio Grande Valley State Park	Near Mission	600	Area set aside to preserve native flora and fauna of Lower Rio Grande Valley. Offers camping, picnicking, rest rooms, showers, group shelter, fishing, bird-watching and nature study.
Brazos Island State Park	Near Brownsville	216	Undeveloped beach on the Gulf of Mexico. No facilities but activities include camping, surfing, fishing, swimming, picnicking and nature study.
Velasco State Park	Near Freeport on Gulf Coast		Actually a shoreline on Gulf of Mexico; undeveloped beach has no facilities except chemical rest rooms, but offers opportunities for swimming, fishing and beach camping.
Port Lavaca Causeway State Recreation Park	Near Port Lavaca on Gulf Coast	2	Offers swimming, boating and salt-water fishing. Facilities include snack bar, bait stand and rest rooms. Boat ramp, camping and picnicking facilities also available.
Lake Corpus Christi State Park	Near Mathis	14,187	Facilities include trailer camps with electricity, water sports, swimming, fishing, boat rentals, groceries and snack bar, rest rooms and showers, campsites, picnicking and screened shelters.
Goose Island State Park	Near Rockport on Gulf Coast	307	Rest rooms, showers, picnic sites, open shelters, children's play area, fishing pier, fish cleaning table, boat ramp. Tent and trailer camping permitted.
Copano Bay Causeway State Park	Near Rockport		Fishing piers, concessions and public boat ramp.

Source: Texas. Texas Highway Department, Travel and Information Division, Austin, Texas. 1972. 208 pp.

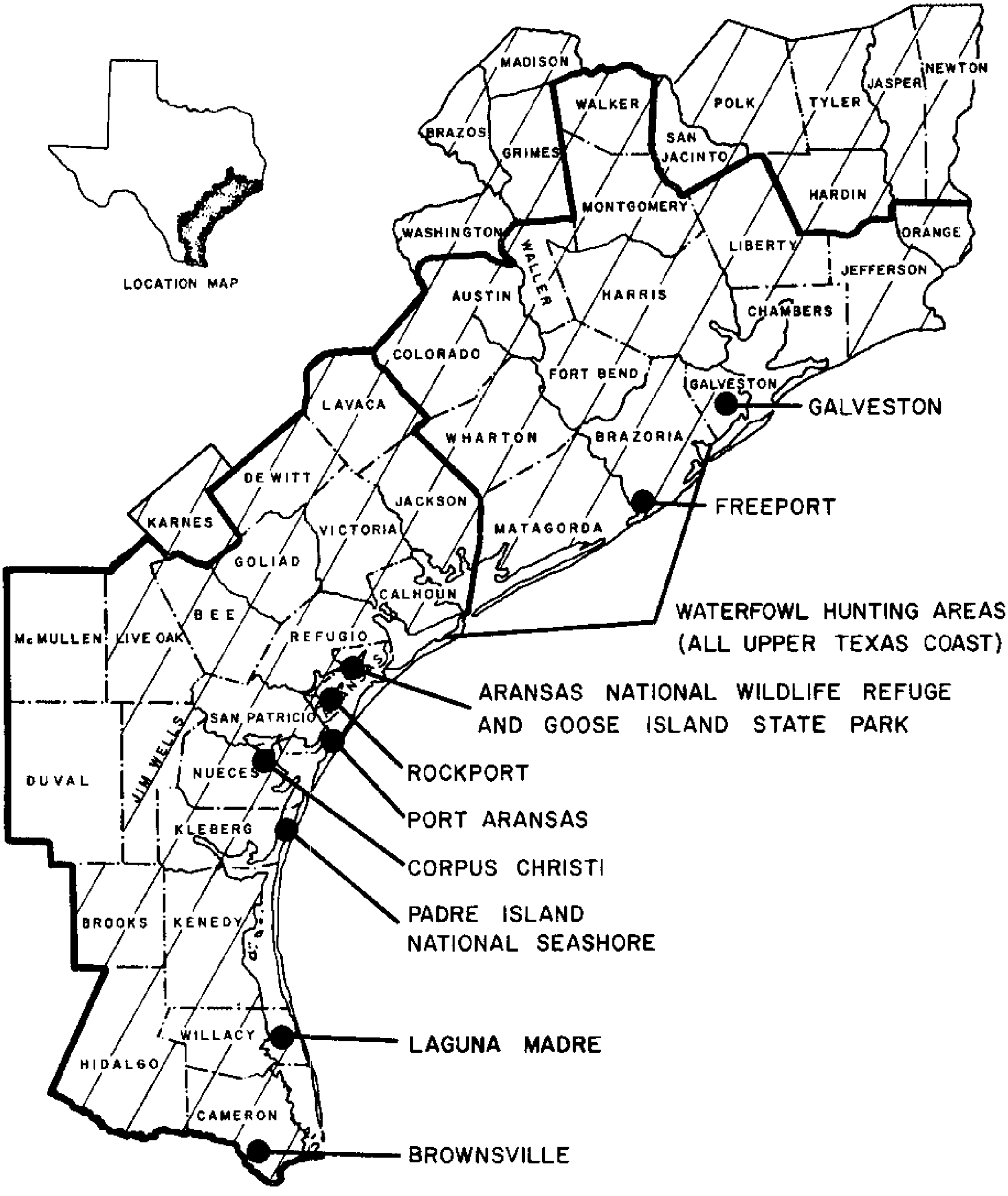
POPULAR RECREATIONAL SITES IN THE TEXAS COASTAL ZONE

SITE	LOCATION	ATTRACTIONS
ANAHUAC NATIONAL WILDLIFE REFUGE	18 miles southeast of Anahuac (9,837 acres)	Excellent opportunities to observe waterfowl and water birds in season. Sightseeing, nature observation and photographing. Visitor facilities limited to primitive roads. Public hunting pending approval.
ARANSAS NATIONAL WILDLIFE REFUGE	7 miles south of Austwell (47,261 acres)	Wintering ground for the rare whooping cranes (59 in the wild; 21 in captivity). A host of other attractions, including alligator, javelina, wild turkey, white-tail deer and assorted species of water-fowl. Sightseeing, nature observation, hiking and photography.
CORPUS CHRISTI	Located in the coastal bend area on the Gulf	Leading recreational center because of the Gulf, Padre Island National Seashore Area and attractive climate. Population - over 286,000 Other points of interest include: Ocean Drive, U.S. Navy's largest Air Station Corpus Christi and South Texas Art Museums Lake Corpus Christi Goose Island State Park Famed King Ranch

SITE	LOCATION	ATTRACTIONS
		Port of Corpus Christi Tourism generates over $135 million annually. Lake Corpus Christi has more than 714,000 visitors annually.
GALVESTON	Upper coastal zone on the Gulf	Galveston ranks sixth in the State of Texas as a Convention Center. Galveston's population (over 172,000) is derived from: Port of Galveston University of Texas Medical Branch Tourism It is estimated that revenue from the Port amounts to $61 million annually, and from the medical branch $25 million annually. Revenues from tourism exceeded $180 million in 1971. Marinas, fishing facilities, historical attractions, and beach sport facilities are among the main attractions at Galveston. During 1971, over 2.5 million tourists visited Galveston, 93,000 of which were convention delegates.
GOOSE ISLAND	Located in Corpus Christi Area	State operated; one of the more developed state parks.

HOUSTON	50 miles northwest of Galveston	Largest city in Texas
		Its population exceeds 1.8 million, and its payroll exceeds $1.9 billion in the metropolitan areas.
		Over 1.9 million tourists visited the city in 1971, spending approximately $82.4 million dollars.
		In 1971, over 766,055 convention delegates visited, spending approximately $116 million dollars.
		Has the largest total number of square footage of exhibition area in the state - totaling over 1 million square feet available from: Albert Thomas Convention Center Astrohall Sam Houston Coliseum
		Four restored historic homes in the city; other historic sites include Allen's Landing Park where the first settlers in the Houston area landed, San Jacinto Monument - site of the famous battle for independence, National Aeronautics and Space Administration Manned Spacecraft Center, and fishing and saltwater activities.
		Contains over 22 universities and over 49,033 students within the county.
		Houston also claims over 2,500 manufacturers in diversified fields, and over 200 firms active in underwater, offshore activities.

LAGUNA ATASCOSA NATIONAL WILDLIFE REFUGE	25 miles northeast of San Benito (44,700 acres)	Tour roads, trails and blinds for nature study, photography, sightseeing, fishing, boating, and camping are among the main features. Because it is mainly a wintering area for ducks and geese, no hunting is permitted.
PADRE ISLAND	An 80-mile section of the 113-mile island, stretching from near Corpus Christi to to Mexico is a National Seashore. (134,000 acres - 34,000 acquired as of 1965).	Classified as a National Seashore. It is the largest of the nation's seven national seashores. Windformed sand dunes, shell beaches, wintering region for waterfowl are only a few of its attractions. Facilities include camping, picnicking, sanitation. Plans call for additional development of bathhouses, beach safety patrols, marinas, interpretive devices, park ranger stations and visitor centers. 721,243 persons visited the National Seashore at Padre Island in 1970 with 64,335 of these visitors being campers. This represented an increase of 3% since 1969. During its first year of operation, more than 152,000 visits were made to this National Seashore.
PORT ISABEL	Gateway to Padre Island	In 1968 Port Isabel registered 14,700 visitors.



Selected major marine recreation and tourist areas
(Source: Miloy and Copp 1970)

- Outboard motor sales nationally have increased 5 times faster than the rate of population increase in the past 25 years.

- Boat registrations in Texas have increased 4 times faster than population during the past five years. Registration figures do not include all boats operated by residents.

Fishing popularity has been steadily increasing in past years. Water impoundments are creating fishing opportunities never before envisioned in Texas.

Today about 3,200,000 acres of land and water are administered in Texas for outdoor recreation by four Federal agencies, the Parks and Wildlife Department, river authorities and special water districts.

Two important agencies toward this development are:

1. Parks and Wildlife Department
2. Bureau of Outdoor Recreation

Most of the natural resource base in Texas is privately owned. Ninety-five percent of the land area and much of the high-quality shoreline of the Gulf coast and inland waters fall in this category.

NUMBER AND EXPENDITURES OF OUT-OF-STATE TOURISTS VISITING THE TEXAS COAST

YEAR	NUMBER OF TOURISTS	TOTAL EXPENDITURES
1964	2,116,260	$ 94,453,020
1965	2,283,840	110,366,640
1966	2,548,260	130,292,460
1967	2,735,640	145,434,960
1968	2,983,680	182,916,000
1969	2,925,000	190,800,000
1970	2,869,000	185,465,460

Source: Travel and Information Division, Texas Highway Department, Austin, Texas

- Eighteen percent of the visitors from out-of-state cited the "coastal area" or coastal cities as their destination.
- Houston and San Antonio were listed as major attractions by out-of-state tourists.
- As of November 30, 1971, 103,015 pleasure boats were registered in the Texas Coastal zone.

C POLLUTION

Man's Effect on the Gulf

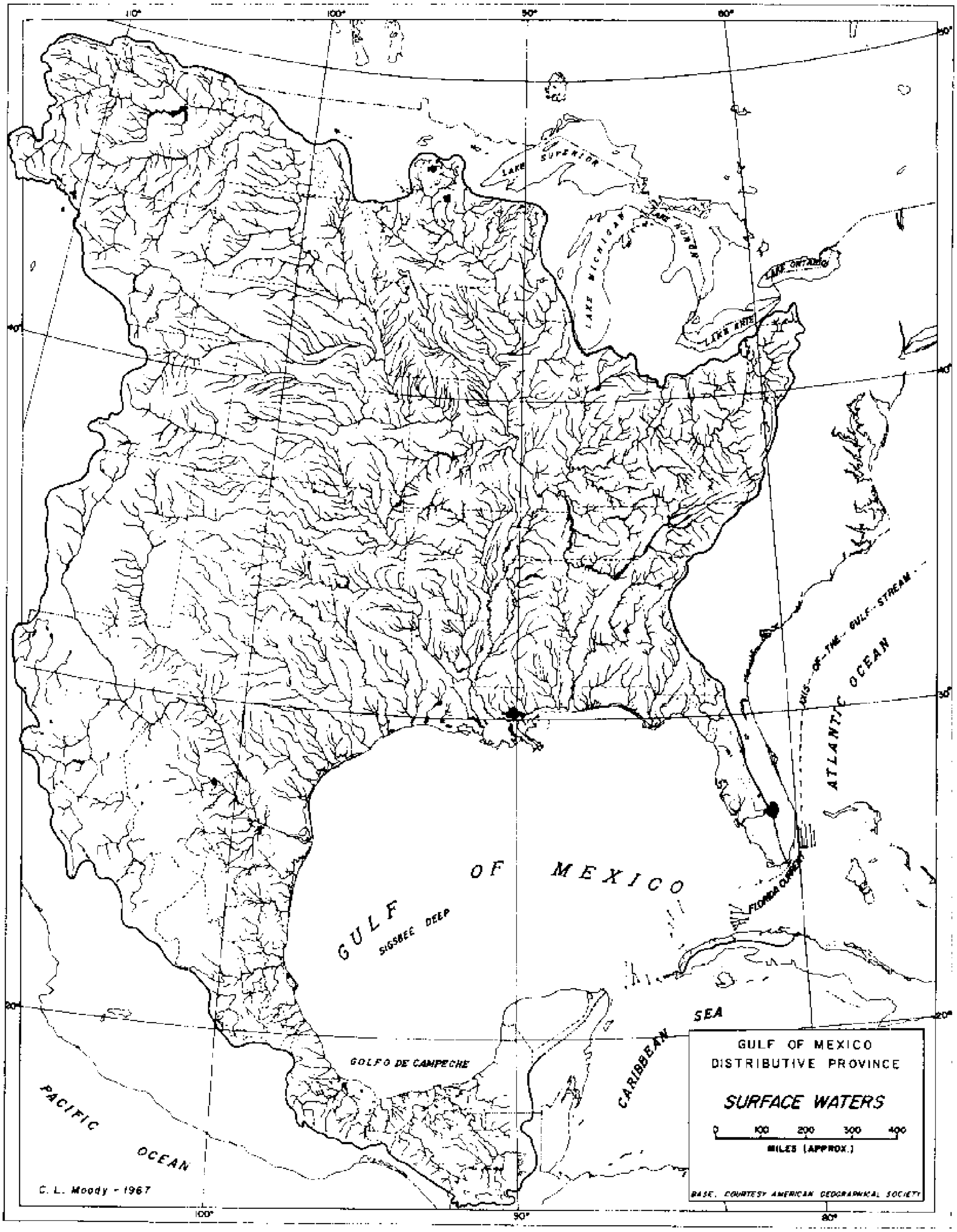
Much concern has been expressed by such notables as Jacques Yves Cousteau and Thor Heyerdahl over the deplorable state of the world oceans. Cousteau recently remarked, "The oceans are dying. Pollution is general."

- Some scientists believe that the world ocean has become an unmonitored dumping ground for wastes, thermal and bacterial pollutants, industrial wastes and an innocent bystander to our unconcern for erosion, dredging and filling and many other such abuses.
- In 1969 more than 350,000 barrels of oil were spilled in U.S. territorial waters alone.
- In the U.S., we consume 560,000 million tons of water per year.

  240,000 million tons -- irrigation (40% is recycles or goes directly into waste; 60% is absorbed by plants or is evaporated and becomes a gaseous residual)

- Of the 560,000 million tons of water per year used:

  160,000 mil. tons (30%) can be expected to evaporate
  400,000 mil. tons (70%) remains liquid and eventually becomes a waste problem.



Almost two-thirds of the natural sediments and industrial pollutants of the United States are dumped into the Gulf of Mexico.

(Source: Moody 1967)

Threats to the Coastal Zone

Sudden changes in temperature, the introduction of toxic substances, of the depletion of oxygen can kill coastal zone life.

(Source: American Littoral Society 1970)

1. Dredging

Releases silt which smothers shellfish and cuts down penetration of sunlight into the water; changes water current patterns.

Creates detritus traps and low oxygen conditions.

The dredged material, called spoil, is often dumped on productive marshland.

From 1950 to 1969, a total of 426,700 acres (5.1% of total) of estuarine habitat important to shrimp, fish and other wildlife in the Gulf of Mexico were lost through dredging and filling. During the same period, 68,100 acres (8.2%) of Texas' estuarine habitat were lost.

2. Coastal Zone Mining and Drilling

   The major threat is the leakage of oil and gas up through the drill pipe and into the water.

3. Tidelands Real Estate Development

   Development usually involves three basic steps:

   a. Placing of bulkheads either at the edge of the tidal marsh or out into the tidewater area,
   b. Dredging or pumping tidelands on the seaward side of the bulkhead,
   c. Using dredged material to fill land behind the bulkhead.

   This development can damage estuaries three ways:

   a. by destroying marine habitat on the bottom
   b. by destroying salt marsh
   c. by polluting water with silt.

4. Beach Erosion

   Much dune sand has been used as fill for construction.

   The use of beach sand catchers (groins, bulkheads and jetties) can often destroy beaches.

5. Water Pollution

   Three major water pollutants:

   - a. domestic sewage (human wastes)
   - b. industrial sewage (primarily chemicals)
   - c. thermal pollution

   In our own backyard - the Gulf - the following has been observed:

   - Industrial firms are dumping waste materials off the Texas coast which consist of:

     liquid caustics
     chlorinated hydrocarbons
     epoxy resins
     herbicide and fungicide wastes
     ammonium sulfate
     other organic materials

- Texas wastes must be unloaded beyond the 100-fathom curve, the edge of the Continental Shelf, which lies about 110 miles off Galveston.

- Preliminary figures from a study of the U.S. Bureau of Solid Wastes show that industrial waste disposals off the three coasts in 1968 amounted to:

Atlantic	-	3,013,200 tons
Pacific	-	981,300 tons
Gulf	-	696,000 tons

- According to the National Marine Fisheries Service, approximately 225,000 pounds of DDT and its derivatives drain into the Gulf yearly.

What Are We Doing About It?

The U.S. Corps of Engineers is prepared to invoke the 1899 Refuse Act against industrial polluters. This means:

1. Applicants for permits will have to identify the nature of their discharges and furnish data on chemical content, water temperature, toxins, sewage, amount of solids and the amount and frequency of discharges.

2. Penalties under the Refuse Act will range from fines of $500 to $2,500 for each violation, with the added threat of imprisonment up to one year. (A bill is under consideration for raising the maximum fine to $100,000 for each violation).

3. Additional inspectors are being requested to help enforce these measures.

At Texas A&M University researchers in the Environmental Engineering Division of the Civil Engineering Department have been conducting a study of the Houston Ship Channel. They have found that:

1. The channel is one of the most polluted bodies of water in the nation.

2. The channel receives heavy pollution loadings comprised of both domestic and industrial wastes. These waste loads together with the sluggish flow characteristics of the waterway have overloaded the natural purification capability of the estuary resulting in a severe pollution problem.

3. The oxygen content of the Houston Ship Channel is dangerously low.

4. Pollution from the channel has spread to nearby streams and bays, contributing to the closing of half of the oyster reefs in Galveston Bay.

5. 4,300 ships pass through the channel every year, sometimes dumping their wastes and refuses.

6. $100 million worth of industrial and $10 million worth of city waste treatment plants have either been built or are planned which, when completed, are expected to reduce the pollution by 75%.

- An example of what citizens can do to abate pollution problems in a large industrial complex is the Bay Drilling Committee in Corpus Christi. The Port of Corpus Christi is the ninth largest seaport in the United States. The Corpus Christi Bay fields and other nearby fields harbor 630 producing wells -- 363 oil wells and 267 gas wells. Total production from the oil wells is 8,500 barrels per day.

In the bay directly out from the city and within the city limits, there are 80 gas wells and seven oil wells.

There are seven refineries in Corpus Christi with a capacity of 293,000 barrels per day.

Nearby producers include Red Fish Bay with an annual oil production of 62,000 bbl a year; Mustang Island field, 90,121 bbl; and Nueces Bay, 33,000 bbl.

Realizing that this high level of production poses a constant threat of pollution, the Bay Drilling Committee was formed in 1965 to establish rules by which the oil companies could recover their mineral resources with a minimum impairment to the environment. As a result, an ordinance was adopted to prohibit drilling within a mile of the shore, limit the number of production platforms in the bay to three, require a design that would create a minimum of visual effect, establish lighting and well safety standards and require that well heads be clustered.

Danger of a major spill from a well is remote. The greatest pollution threat is posed by barges and tankers. Despite this, it has been recommended that spill booms and hay and straw be purchased and stored near the wells.

Minor spills do occur in the ship channel fairly regularly, but the biggest problem is in location of the source of the spill.

- In the Department of Oceanography at Texas A&M University, researchers are conducting studies of the high level of pesticides recently discovered in a fish captured more than 100 miles out in the Gulf of Mexico.

  Detailed analysis of the fish's brain indicated 15 parts per million of DDT residues.

- On the Texas Clipper, vessel of the Texas Maritime Academy in Galveston, an extensive sewage treatment system is in operation. It is the first such system installed on any academy ship in the United States.

- At the University of Texas at Austin an environmental geologic atlas of the Texas coastal zone has been prepared which provides information for planning and land use in the populous and industrial coastal zone of the state.

- Researchers at Florida State University report that they have developed strains of a bacteria that consume oil and quietly die off. They report that the bacteria could be mass-produced by methods similar to those used to make penicillin, then freeze-dried and stored. When needed, they could then be distributed by helicopter over the oil slick area.

- An extensive program on the effects of pesticides on a wide variety of marine organisms is conducted at the National Marine Fisheries Service (formerly the Bureau of Commercial Fisheries) Biological Laboratory in Gulf Breeze, Florida. In addition, a pesticide monitoring program has been established with approximately fourteen coastal states cooperating in the work.

- The U.S. Public Health Service (PHS) Gulf Coast Shellfish Sanitation Research Center (Dauphin Island, Alabama) is conducting a study to obtain data on pesticide concentrations in oysters and growing waters.

D COASTAL RESOURCES MANAGEMENT PROGRAM (For background information see Section, GOVERNMENTAL, EDUCATIONAL AND RESEARCH ORGANIZATIONS)

The Coastal Resources Management Program, Office of the Governor, is preparing a report on *The Management of Bay and Estuarine Systems*, to be submitted to the Texas Legislature as one of several studies pertaining to the Texas Coastal Zone Management Program. The Management study, a conceptual report identifying general guidelines for a model to be developed at a later stage, lists various activities that affect the bays and estuaries.

At the request of the Office of the Governor, the Texas Law Institute of Coastal and Marine Resources, College of Law, University of Houston, undertook a preliminary investigation of federal, state and local regulation of activities affecting bays and estuaries. The preliminary legal data will be developed in detail to coincide with further studies relating to bays and estuaries, as well as to the Coastal Zone Management Program. The legal study is summarized in tables to illustrate overlapping authority and existing gaps.

The following tables provide an indication of those administrative agencies and governmental entities which have some statutory authority to regulate selected coastal zone activities. The designation that a particular unit regulates an activity simply indicates a statutory provision to that effect exists, not that the agency currently regulates that particular activity. Since this preliminary study was designed to highlight the problem that some activities appear to be heavily monitored and others virtually ignored, the diagrams do not purport to be exclusive. They should function as a starting point for determining where regulatory powers exist.

Because the activities were identified in another project, the labels do not always conform exactly with the wording of the statutes; therefore, some activities must be regarded as covering a broad spectrum. Liquid waste disposal, for example, includes disposal of industrial wastes into navigable waters, acid and mine water pollution, disposal from vessels, oil spills, chemical spills, industrial and numicipal wastes, oil field brines and agricultural wastes.

OVERVIEW OF REGULATING AGENCIES:
FEDERAL, STATE, LOCAL

ACTIVITIES	AGENCIES			
	FEDERAL	STATE	LOCAL	TOTAL
Liquid Waste Disposal	4	2	6	12
Gaseous Waste Disposal	1	1	2	4
Solid Waste Disposal	3	2	2	7
Offshore Construction	2	1	0	3
Coastal Construction	0	1	2	3
Inland Construction	4	0	1	5
Land Canals	2	2	3	7
Offshore Channels	3	0	1	4
Dredging & Spoil Disposal	3	4	2	9
Excavation	1	2	2	5
Drainage	5	2	8	15
Filling	1	0	0	1
Flood Control	5	5	2	12
Water Wells	0	3	2	5
Oil & Gas Wells	1	2	1	4
Disposal Wells	1	5	2	8
Fertilizers & Biocides	8	5	2	15
Vehicular Travel	0	0	2	2

Source: Regulation of Activities Affecting Bays and Estuaries: A Preliminary Legal Study. A report prepared for the Coastal Resources Management Program, Office of the Governor by The Texas Law Institute of Coastal and Marine Resources College of Law, University of Houston. March 1972.

(9/72)

FEDERAL AGENCY / ACTIVITY	LIQUID WASTE	GASEOUS WASTE	SOLID WASTE	OFFSHORE CONSTRUCTION	COASTAL CONSTRUCTION	INLAND CONSTRUCTION	LAND CANALS	OFFSHORE CHANNELS	DREDGING & SPOIL	EXCAVATION	DRAINAGE & DRAINING	FILLING	FLOOD CONTROL	WATER WELLS	OIL & GAS WELLS	DISPOSAL WELLS	FERTILIZERS & BIOCIDES	VEHICULAR TRAVEL
PRESIDENT (Richard M. Nixon, 1600 Pennsylvania Ave., N.W., Washington, D.C. 20500)	X																	
DEPT. OF ARMY (Secretary, Robert F. Froehlke, Pentagon, Washington, D.C., 20310)				X		X		X	X									
CORPS OF ENGINEERS (A.B. Davis, Asst. Chief Eng. Div., Galveston Dist. P.O. Box 1221, Galveston, Texas 77550)	X		X			X	X	X			X	X	X		X	X		
BOARD OF ENGINEERS (U.S. Army Engineer Dist., P.O. Box 17300, Ft. Worth, Tex. 76102) Rivers and Harbors						X												
DISTRICT ENGINEERS (U.S. Army Engineer Dist., P.O. Box 17300, Ft. Worth, Tex. 76102)			X	X					X									
DEPT. OF INTERIOR (Field Representative, Federal Bldg., Albuquerque, N.M., 87101)										X	X		X			X		
BUREAU OF RECLAMATION (Field Representative, Reg. 5, Herring Plaza, 317 E. Third, P.O. Box 1609, Amarillo, Texas 79105)							X				X		X					
DEPT. OF AGRICULTURE (Secretary, Clifford M. Hardin, 14th & Independence Ave SW, Washington, D. C. 20250)											X		X				X	
AGRICULTURAL RESEARCH SERVICE (Dr. H. R. Johnston, Area Resident Director, Veterinary Toxicology and Livestock Entomology Research Laboratory, ARS, Texas A&M University, College Station, Tex. 77843)																	X	
DEPT. OF TREASURY (Under Secretary, 15th & Pennsylvania Ave., N.W., Washington, D.C. 20220)																	X	
DEPT. OF HEALTH, EDUCATION AND WELFARE																		
CONSUMER PROTECTION & ENVIRONMENTAL HEALTH SERVICE (Region VI Director, Howard D. McMahan, 1114 Commerce St., Dallas, Texas 75202)																	X	
FOOD AND DRUG ADMINISTRATION, (Howard D. McMahan, 1114 Commerce Street, Dallas, Texas 75202)																	X	
DEPT. OF HOUSING & URBAN DEVELOPMENT (Regional Representative, Region VI, Manuel A. Sanchez, III, 1000 Commerce St., Dallas, Tex. 75202)													X					
DEPT. OF TRANSPORTATION (Regional Represenative, Region VI, Ed Foreman, 1100 Commerce St., Dallas, Texas 75202)																		X
U.S. Coast Guard (Rear Admiral J. D. McCubbin, 8th Coast Guard District, Customhouse, New Orleans, Louisiana 70130)																		
WATER RESOURCES COUNCIL (Director, W. Don Maughan, 2120 L Street, NW, Washington, D.C. 20037)											X							
ENVIRONMENTAL PROTECTION AGENCY (Field Representative, Reg. VI, Arthur W. Bush, 1600 Patterson, Suite 1100, Dallas, Texas 75202)	X	X	X					X	X									X

STATE AGENCY \ ACTIVITY	Liquid Waste	Gaseous Waste	Solid Waste	Offshore Construction	Coastal Construction	Inland Construction	Land Canals	Offshore Channels	Dredging & Spoil	Excavation	Drainage	Filling	Flood Control	Water Wells	Oil & Gas Wells	Disposal Wells	Fertilizers & Biocides	Vehicular Travel
Air Control Board		X																
Board of Park Commissioners					X													
Department of Agriculture																	X	
Department of Health			X						X				X			X	X	
Department of Health/Division of Sanitary Engineers													X					
Department of Parks & Wildlife									X								X	
Director of Fertilizer Control																	X	
General Land Office				X			X			X					X			
Railroad Commission	X														X	X		
Water Development Board											X		X	X		X	X	
Water Quality Board	X		X						X							X		
Water Rights Commission							X		X	X			X	X				
Water Well Drillers Board														X		X		
Soil Conservation Board											X		X					

Source: Regulation of Activities Affecting Bays and Estuaries: A Preliminary Legal Study. A report prepared for the Coastal Resources Management Program, Office of the Governor by The Texas Law Institute of Coastal and Marine Resources College of Law, University of Houston. March 1972.

LOCAL AUTHORITY \ ACTIVITY	Liquid Waste	Gaseous Waste	Solid Waste	Offshore Construction	Coastal Construction	Inland Construction	Land Canals	Offshore Channels	Dredging & Spoil	Excavation	Drainage	Filling	Flood Control	Water Wells	Oil & Gas Wells	Disposal Wells	Fertilizers & Biocides	Vehicular Travel
City Public Works Director	X																	
County Commissioners	X	X			X		X				X							X
County Engineer	X		X															
County Health Authority																X		
County Herbicide Inspector																	X	
Drainage District Board											X							
Fresh Water Supply District Board											X							
Gulf Coast Waste Disposal Authority	X								X									
Houston-Galveston Council of Government	X																	
Levee Improvement District Board											X							
Local Ordinances	X	X	X		X	X	X		X	X	X		X	X	X	X	X	X
Navigation District Board								X			X		X					
Underground Water Conservation Board											X			X				
Water Control & Improvement District							X			X	X							

Source: Regulation of Activities Affecting Bays and Estuaries: A Preliminary Legal Study. A report prepared for the Coastal Resources Management Program, Office of the Governor by The Texas Law Institute of Coastal and Marine Resources College of Law, University of Houston. March 1972.

E ECONOMIC IMPACT OF TEXAS MARINE RESOURCES

Industries along the Houston Ship Channel employ more than 100,000 persons and generate more than one half billion dollars in income. Fifty-five thousand Houstonians are employed in activities directly connected with the port.

The deep water ports of Texas generated $1.4 billion in revenue in 1970. An additional $145 million was generated in the same year by the shallow water coastal ports.

The Texas Gulf Coast is the most important source of natural gas in the United States. The offshore oil and gas industry employs more than 23,600 Texans.

Over seven thousand fishermen in Texas (commercial) produced 167 million pounds of fish and shellfish in 1971. This catch is processed by 144 Texas firms with a valuation of $69 million and an annual employment of more than 5,000 persons.

The Texas coastal zone is one of the great wildlife refuge areas of the world. Sixty-one percent of the ducks and 80 percent of the geese in the U.S. winter in the coastal marshes of the State.

The State itself is one of the largest land holders in the coastal area. More than 1.5 million areas of coastal lands, islands, tidelands, and beaches are owned by the people of Texas.

Out-of-state visitors spent about $185 million in Texas coastal areas in 1970.

The United States Government spent almost $100 million in the coastal zone of Texas in 1969 for research, for harbor development, and for hurricane protection. Of this total about one-third was spent by the U.S. Army Corps of Engineers in marine activities.

In Texas the economic impact of coastal and marine resources has been estimated at $1.9 billion in sales annually.

TEXAS COASTAL ZONE

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PORTS AND WATERWAYS OF THE GULF OF MEXICO

CONTENTS

PORTS AND WATERWAYS OF THE GULF OF MEXICO

A <u>GULF COASTAL PORTS OF MAJOR IMPORTANCE</u>

- Port of Houston - largest inland port in the nation and third largest port in the United States
- Port of New Orleans - second largest port in the nation
  Port of Corpus Christi - ninth largest in the nation

- Gulf Coast ports are the major exporting outlets for tanker cargoes, contributing 64% of all tanker exports.

- Port of Galveston is the most important outlet for tanker cargoes in the U.S., handling 13% of all tanker exports from this nation.

- Because tanker shipments are less susceptible to longshore strikes, this works as an advantage to the Port of Galveston over such ports as Houston.

Editor's Note: *Italicized* words are defined in the Glossary.
Credit lines for figures refer to selected references.

B TEXAS PORTS

- There are 12 major deep water ports located along the Texas coastline:

Beaumont	Galveston	Port Isabel
Brownsville	Houston	Port Lavaca - Point Comfort
Corpus Christi	Orange	Texas City
Freeport	Port Arthur	

- Over 180 million tons of cargo passed through the deep-water ports in 1970 and over 65 million tons were transported on the Gulf Intracoastal Waterway.

  Every major Texas Port is the location point for petroleum refineries, bulk terminals and petrochemical plants.

  Most major Texas ports are characterized by substantial private investments in port facilities located near those owned and operated by port authorities or navigation districts of the local communities. This relatively independent structure sets Texas apart from other Gulf coast areas where state governments own and operate port facilities.

- The largest port authority by size is the Port of Houston, which covers 1,747 square miles.

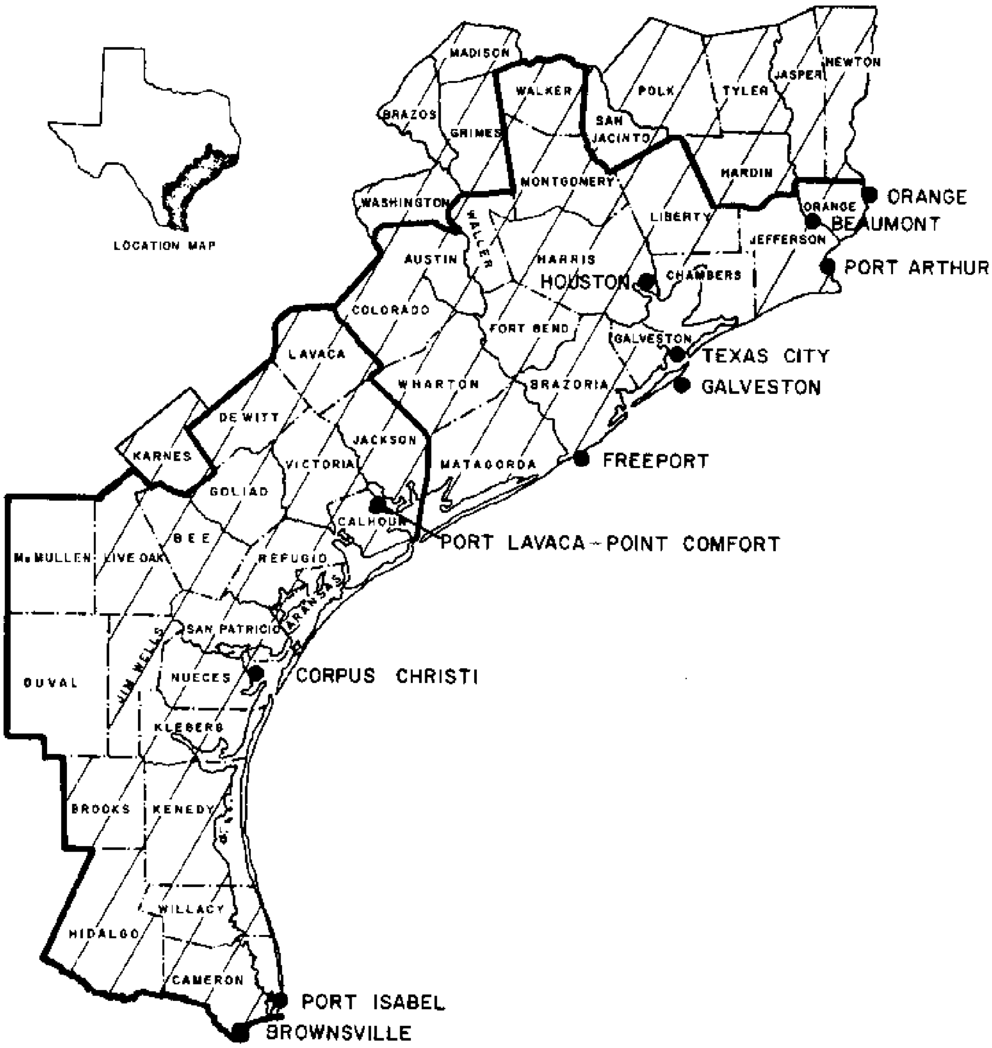
  The Port of Freeport encompasses 1,124 square miles.

  The smallest port authority by geographical measurement is Port Arthur, which covers only 58 square miles.

  Shipbuilding and repair activities in Texas include the construction of tugs, towboats, barges, tankers, regular cargo ships, oceanographic research vessels, mobile oil drilling units, shrimp trawlers, and various types of pleasure crafts.

  The marine transportation industry in Texas employs more than 55,000 people and annually contributes over one billion dollars to the economy of Texas.

  Of all the cargo shipped through the 12 major ports of Texas, 75% is comprised of liquids, mainly oil and chemicals.



Major deep water ports in Texas.

Port of Beaumont

Channel depth: 34 feet, well marked and lighted
Rail facilities: Kansas City Southern; Atchison, Topeka and Santa Fe; Missouri Pacific; and Southern Pacific Railroads

Port of Brownsville

Channel depth: 38 feet
Channel width: 300 feet at bottom
Turning basin: 1,000 feet wide, 350 feet long, 36 feet deep
Rail facilities: Missouri Pacific; Southern Pacific and National Railways of Mexico

Port of Corpus Christi

Channel depth: 40 feet
Channel width: 400 feet
Turning basin: 5,500 feet by 1,000 feet
Industrial Canal: 1.5 miles long; 200 feet wide, 40 feet deep
Rail facilities: Missouri Pacific Railroad; Southern Pacific Railroad and Texas-Mexican Railway

Port of Freeport

Channel depth: 36-38 feet
Channel width: 200-300 feet
Turning basin: Three basins ranging from 200-700 feet wide, 350-600 feet wide, and 500-600 feet wide.
Rail facilities: Missouri Pacific Railroad

Port of Galveston

Channel depth: 38 feet
Channel width: 1,200 feet at narrowest point
Rail facilities: Santa Fe Railroad, Chicago, Rock Island; M-K-T Railroad; Missouri Pacific Railroad; Southern Pacific Railroad and Burlington Northern Railroad

- In keeping with the new concept of containerization and unitization of cargo for shipping, the Port of Galveston recently opened four containership terminals for handling *containers*.

The Port of Galveston recently began handling barges in much the same way as containers are handled. The barge concept is merely an extension of the containerization and unitization concept.

Barges are usually 62 feet in length, 33' in width and will hold up to 450 tons of cargo. These require the use of 550 ton cranes for loading.

Molten sulphur is transported by unit transportation to dockside by this Port.

- The Port of Galveston handles 13% of all tanker exports from the U.S.

Sixty-one percent of the total wage and salary income of the city was estimated to be generated by the Port.

- Plans are underway for what is considered to be the world's largest floating dry dock.

One of the largest dry cargo ports in the United States.

Port of Houston

Channel depth: 36-40 feet
Channel width: 400 feet
Turning basin: 1,100 feet in diameter
Rail facilities: M-K-T Railroad; Missouri Pacific Railroad; Atchison, Topeka and Santa Fe Railroad; Southern Pacific Railroad; Ft. Worth-Denver Railroad; Chicago, Rock Island and Pacific Railroad.

- Industries located along the Houston Ship Channel were estimated to employ 100,000 persons, generating more than $500 million in income.

More than 55,000 persons or approximately more than double the number employed by waterborne transport industries were estimated as directly employed by the Houston Port's activity. This is about 11% of the total employment in the Houston area. Total impact of payrolls ranges up to $280 million annually.

Located in an area known as the "Spaghetti Bowl" which refers to the vast pipeline system interconnecting oil, gas and petrochemical plants.

The Port of Houston also provides *container* service.

A 16-acre marshalling yard at Houston has a capacity for more than 800 containers.

The Port of Houston has estimated that by 1975, one-half of the foreign trade general cargo, or two and one-half million tons, will be moving in containers over its wharves.

- The Barbours Cut Terminal located at Morgan's Point is being designed as a containership and LASH (Lighter Aboard Ship) terminal. It began operations during June 1972. Plans are underway for this to become a $100 million development.

Since 1910 the Federal government has spent more than $70 million to dredge and maintain the Channel.

More than 100 steamship lines offer regular services between the Port of Houston and some 250 ports of the world.

- Every year more than 4,000 ships call at Houston, which has more than 100 wharves in operation, including private terminals of the large industrial complex that lines both sides of the Channel for some 20 miles.

Leads the nation in the importation of steel and exportation of wheat.

Port of Orange

Channel depth: 30 feet
Channel width: 200 feet
Turning basin: 1,000 feet by 3,000 feet
Rail facilities: Missouri Pacific; Southern Pacific Railroads

Port of Port Arthur

Channel depth: Entrance, 42 feet; Pass, 35 feet; Canal, 36 feet; Dock, 25 feet.
Channel width: 300 feet
Rail facilities: Southern Pacific Railroad

Port of Port Isabel

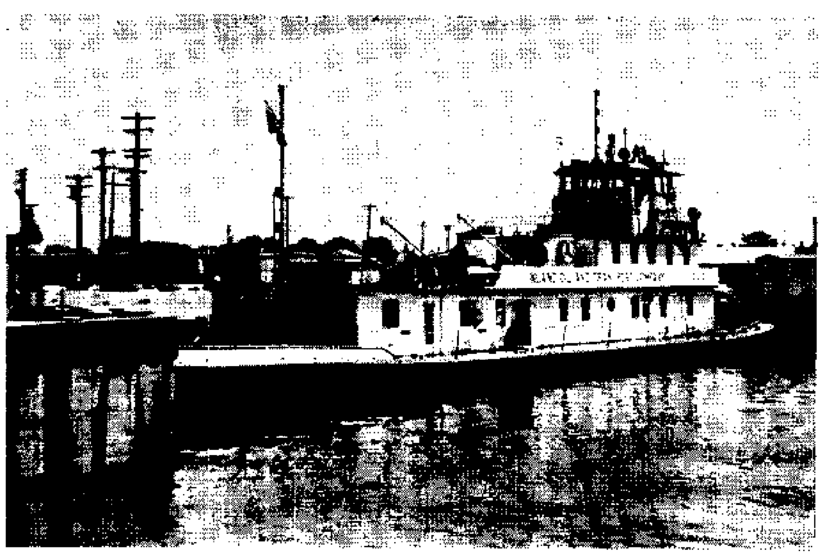
Channel depth: 38 feet
Channel width: 200 feet
Turning basin: 1,000 by 1,300 feet, marked and lighted
Rail facilities: No railroad service at the present time

Port of Port Lavaca-Point Comfort

Channel depth: 36 feet
Channel width: 200 feet
Turning basin: 1,000 feet by 1,000 feet
Rail facilities: Point Comfort and Northern Railroad

Port of Texas City

Channel depth: 40 feet
Channel width: 400 feet
Turning basin: 4,000 by 1,000 feet
Rail facilities: Texas City Terminal Railway Company



Galveston is the cross-roads of barge traffic on the Gulf coast inland waterways. This Mississippi River towboat belonging to Inland Oil Transport is assembling barges in Galveston harbor for the long haul to St. Louis.

C PORT OF NEW ORLEANS

The Port of New Orleans is the nation's second largest port and a major nucleus of industry, petroleum production, finance and trade.

The largest sugar refinery in the world is located there.

Other important industries are aerospace, shipbuilding and tourism.

The Port of New Orleans is being improved and expanded under a ten year $133 million program.

The water frontage of the Port covers 133 miles, of which 50 miles are on the Mississippi River and 11 miles are on the Industrial Canal which connects the river with Lake Pontchartrain.

Ships of more than eighty lines call regularly at New Orleans.

River barge lines reach as far inland as Chicago, Kansas City, Minneapolis and Pittsburgh.

In a normal year, the value of the cargoes handled through New Orleans is over $1 billion.

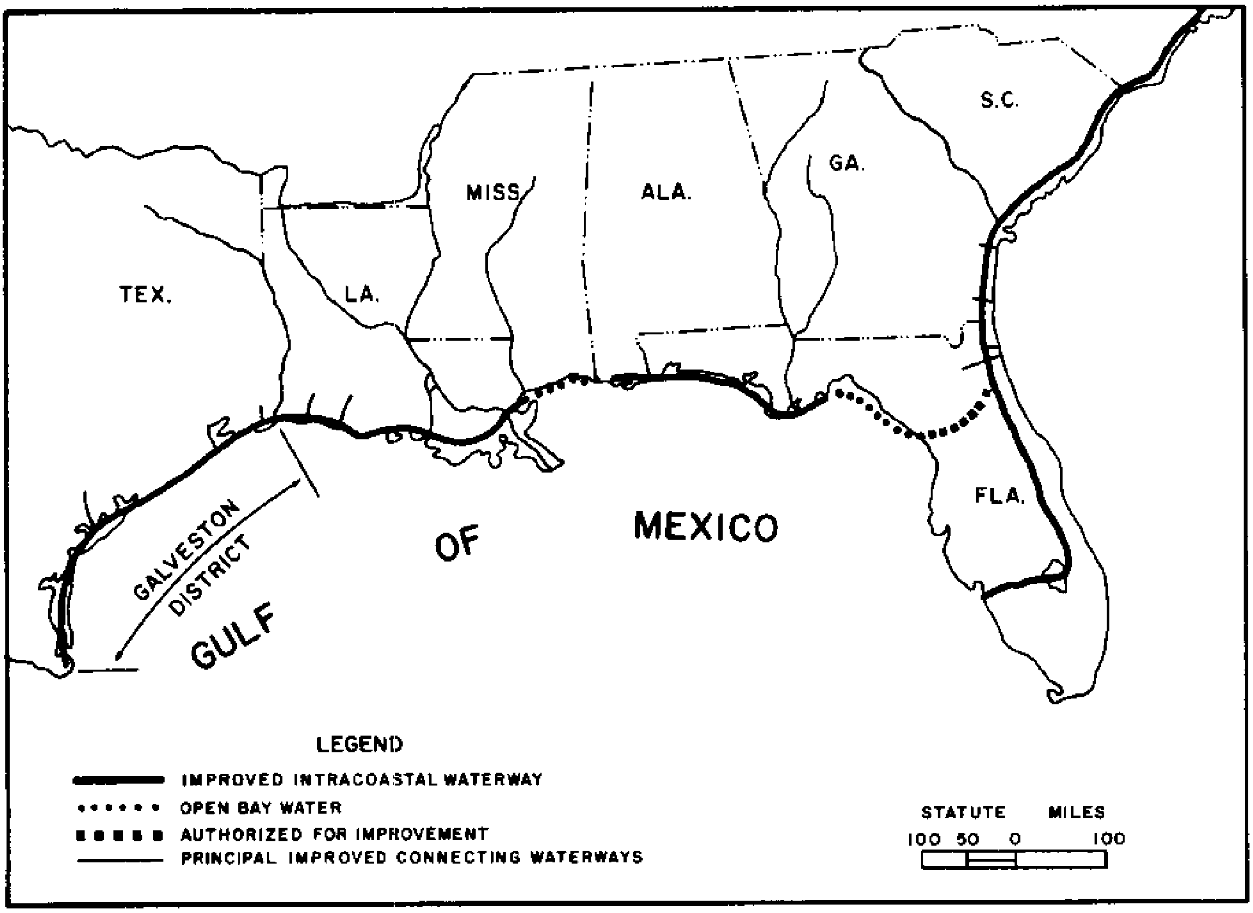
This Port handles more cotton, bananas and coffee than all other American seaports combined.

It is the country's second greatest port in value of foreign commerce.

It boasts some of the world's largest grain elevators which can load grain into ships at the rate of 100,000 bushels per hour.

D THE GULF COAST INTRACOASTAL WATERWAY

1,777-mile land-protected course which stretches from northern Florida across coastal Florida, Alabama, Mississippi, Louisiana and to the southern tip of Texas. It originates at Carrabelle, Florida.



(Source: Maps of Gulf Intracoastal Waterway, Texas Sabine River to the Rio Grande and Connecting Waterways including Ship Channels. U.S. Corps of Engineers, Galveston, Texas. 1966)

The first survey for a suitable route for the Waterway was made in 1873.

In 1892 a Federal project channel three and one-half feet deep by 200 feet wide was dredged in Galveston Bay to connect with the Brazos Canal.

In 1850 the segment between Oyster Bay and the Brazos River was dredged.

In 1949 the entire Waterway was completed.

In 1962 traffic moved a distance of more than 8.75 billion ton miles as compared to approximately 581 million ton miles in 1937.

- The greatest volume of tonnage on the Waterway consists of petroleum products, including gasoline, fuel oil, jet fuel and others. Other commodities also shipped are chemicals, iron, steel, sugar, limestone and other dry cargo products.

Commerce on the Texas section of the Gulf Intracoastal Canal, outbound and inbound, totaled 65,404,280 short tons during the calendar year 1970, according to the U.S. Army Corps of Engineers.

AUTHORIZED CHANNEL DIMENSIONS AND DISTANCE MEASUREMENT OF THE GULF COAST INTRACOASTAL WATERWAY WEST OF THE SABINE RIVER

LOCATION	CHANNEL DEPTH (feet)	CHANNEL WIDTH (feet)	LOCATION	DISTANCE IN MILES FROM NEW ORLEANS
Sabine River to Houston Ship Channel	16	150	Port Arthur	185
Houston Ship Channel to Corpus Christi	12	125	Beaumont	296
Corpus Christi to Brownsville	12	125	Galveston	355
			Freeport	399
			Houston	400
			Corpus Christi	552
			Brownsville	684

(Source: Gulf Intracoastal Waterway, U.S. Army, Corps of Engineers, December, 1964.)

PASSENGERS EMBARKING FROM SELECTED TEXAS PORTS

YEAR	CORPUS CHRISTI	HOUSTON	BEAUMONT	PORT ARTHUR	GALVESTON
1962	265	2,216	159	119	258
1963	317	2,021	77	80	523
1964	328	1,574	155	122	287
1965	331	1,617	166	103	268
1966	322	1,732	117	191	167
1967	281	1,571	139	97	377
1968	201	1,003	119	74	1,286
1969	202	695	70	21	526
1970	238	811	92	44	355

(Source: Waterborne Commerce of the United States, 1970, Part 2, Waterways and Harbors, Gulf Coast, U.S. Department of the Army, Corps of Engineers.)

TEXAS DEEP WATER PORTS

CALENDAR YEAR 1970

PORT	DRY CARGOES	LIQUID CARGOES (Petroleum and Chemical Products)	TOTAL
Brownsville	1,141,603	4,132,777	5,274,380
Port Isabel	15,818	374,671	390,489
Corpus Christi	7,770,900	22,773,812	30,544,712
Freeport	1,037,631	4,245,342	5,282,973
Galveston	2,901,485	561,667	3,463,152
Houston	23,131,645	41,522,618	64,654,263
Texas City	243,089	16,854,322	17,097,411
Sabine Pass Harbor	12,639	265,679	278,318
Port Arthur	1,709,732	20,961,674	22,671,406
Beaumont	2,698,738	27,781,968	30,480,706
Orange	1,122,691	500,740	1,623,431
Port Lavaca-Point Comfort	3,640,956	838,301	4,479,257

(Source: Waterborne Commerce of the United States, 1970, Part 2, Waterways and Harbors, Gulf Coast, U.S. Department of the Army, Corps of Engineers, and personal communication with the respective Port Authorities.)

Statistics show that tonnage handled at deep-draft Texas ports experienced a stable growth from 1959 to 1968, while shallow draft port tonnage tripled. More than 25 points along the Texas coast handled cargo during this period. Much of the increase can be attributed to the development of new inland waterways and the expansion of shallow draft ports during the period. Most of the tonnage consisted of bulk commodities and, in particular, crude petroleum.

(9/72)

TONNAGE HANDLED AT TEXAS PORTS AND OVER GULF INTRACOASTAL WATERWAY
(Short Tons)

PORTS AND WATERWAYS	1959	1960	1969	1970
DEEP-DRAFT PORTS				
Brownsville	842,717	970,361	4,911,267	4,986,243
Port Isabel	623,053	444,627	359,835	390,489
Port Aransas - Corpus Christi Waterway	24,112,415	24,840,443	29,854,615	30,544,712
Freeport	3,948,268	3,648,739	5,856,967	5,282,973
Galveston	6,707,618	6,072,922	2,752,335	3,463,152
Houston	60,265,293	57,132,659	55,961,778	64,654,263
Texas City	13,649,143	15,401,847	16,560,040	17,097,411
Sabine Pass Harbor	216,509	365,282	219,227	278,318
Port Arthur	23,095,561	28,207,396	23,538,604	22,671,406
Beaumont	26,125,522	27,113,480	27,086,799	30,480,706
Orange	944,281	1,022,784	1,591,262	1,623,431
Subtotal	160,530,380	165,220,540	168,692,729	181,473,104
SHALLOW-DRAFT PORTS				
Port Lavaca	1,157,281	2,037,369	5,206,296	4,479,257
Anahuac	128,738	109,015	397,317	480,805
Trinity River, Channel to Liberty	1,225,372	965,416	295,256	355,359
Double Bayou	149,923	58,261	7,047	6,412
Cedar Bayou	338,822	227,893	273,634	487,220
Sweeny (San Bernard River, Texas)	964,366	840,223	719,256	530,994
Chocolate Bayou, Texas	---	---	2,377,551	2,527,999
Palacios	102,273	140,844	91,756	98,284
Rockport	4,423	5,701	4,485	698
Aransas Pass	68,683	97,001	16,709	6,528
Port Mansfield	18,963	114,799	13,589	18,004
Rio Hondo - Harlingen	206,575	215,100	395,255	N.A.
Long Mott (Guadalupe River to Victoria)	349,944	252,504	1,893,065	N.A.
Subtotal	4,715,363	5,064,126	11,674,507	8,991,560
TOTAL PORTS	165,245,743	170,284,666	180,367,236	190,464,664

(CONTINUED ON NEXT PAGE)

TONNAGE HANDLED AT TEXAS PORTS AND OVER GULF INTRACOASTAL WATERWAY(continued)
(Short Tons)

PORTS AND WATERWAYS	1959	1960	1969	1970
GULF INTRACOASTAL WATERWAY				
Sabine River to Galveston	23,021,805	24,728,605	43,995,515	42,843,601
Galveston to Corpus Christi	8,057,685	8,558,825	21,556,270	20,212,427
Corpus Christi to Mexican Border	1,063,075	1,180,138	2,040,450	2,348,252
Subtotal	32,142,565	34,467,568	67,592,235	65,404,280
Less Duplications	-3,370,524	N.A.	N.A.	N.A.
TOTAL GULF INTRA-COASTAL WATERWAY	28,772,041	34,467,568	67,592,235	65,404,280

N.A. = Not Available

(Source: Waterborne Commerce of the United States, Part 2, 1970, Corps of Engineers, Department of the Army, Washington, D.C.)

GULF INTRACOASTAL WATERWAY FREIGHT TRAFFIC OF CRUDE PETROLEUM, AND TEXAS REFINERY RECEIPTS OF CRUDE PETROLEUM FROM LOUISIANA 1954-1966 AND 1980

YEAR	GULF INTRACOASTAL WATERWAY INTERNAL TRAFFIC, CRUDE PETROLEUM, (Million Short Tons)	TEXAS REFINERY RECEIPTS OF CRUDE PETROLEUM FROM LOUISIANA (Million Barrels)
1954	11.3	61.1
1955	9.5	56.8
1956	14.7	63.2
1957	16.6	71.2
1958	15.3	85.0
1959	18.0	98.9
1960	21.5	124.5
1961	23.0	140.0
1962	24.0	151.7
1963	27.3	168.5
1964	26.3	171.4
1965	30.0	186.1
1966	N.A.	209.0
1980:		
Low	30.0	200.0
Medium	45.0	300.0
High	60.0	420.0

N.A. = Not Available

(Source: Transportation of Mineral Commodities on the Inland Waterways of the South-Central States, 1969, Bureau of Mines, U.S. Department of the Interior, Washington, D.C.)

DIRECT EMPLOYMENT AND SALES
OF MARINE TRANSPORT AND SHIPBUILDING
IN THE TEXAS MARINE REGION AND THE REST OF TEXAS
1969

AREA	ACTIVITY	DIRECT EMPLOYMENT	DIRECT SALES
Coastal Zone	Ship-Building and Repairing	6,451	$126,096,048
	Boat-Building and Repairing	565	6,048,300
	Deep Sea, Domestic, Canal & Local Water Transportation	3,621	214,990,026
	Marine Cargo Handling & Other Transport Services	4,752	41,720,759
	Freight Forwarding and Related Services	2,068	36,322,000
	Subtotal	17,457	$425,177,133
Rest of Texas	Marine Transport Related Activity	892	14,293,000
	TOTAL	18,349	$439,470,133

(Source: Industrial Economics Research Division, Texas A&M University. College Station, Texas.)

A SUPERPORT FOR TEXAS ....

In 1971 the leading sectors of the Texas economy were:

petroleum refining	$6.3 billion
petroleum production	$4.4 billion
agriculture	$3.3 billion
construction	$2.2 billion
banking and credit	$1.9 billion

It is estimated that by 1980 Texas will be importing 3,500,000 barrels of crude oil per day, and these imports will increase to more than 5,500,000 barrels by 1985.

As recent as 1960, the largest tanker in the world was 69,000 deadweight tons (dwt) requiring between 40 and 45 feet of water depth.

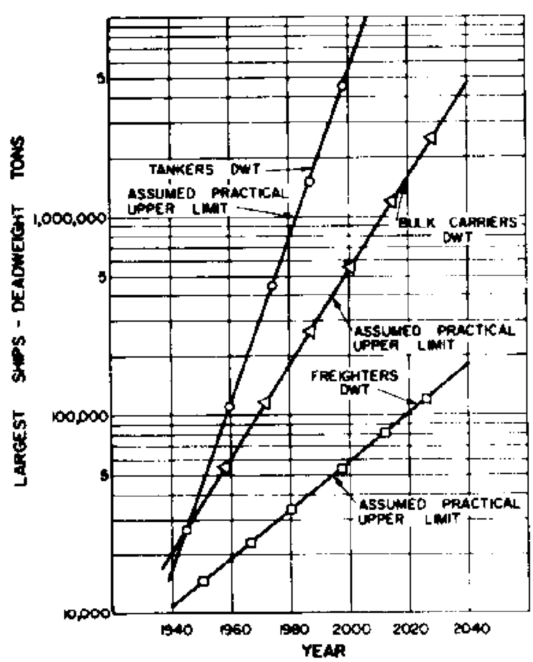
> Deadweight tonnage - customary unit for measuring tankers, refers to combined carrying capacity of a vessel's cargo, stores, water bunkers and fuel, in 2,240-pound tons.

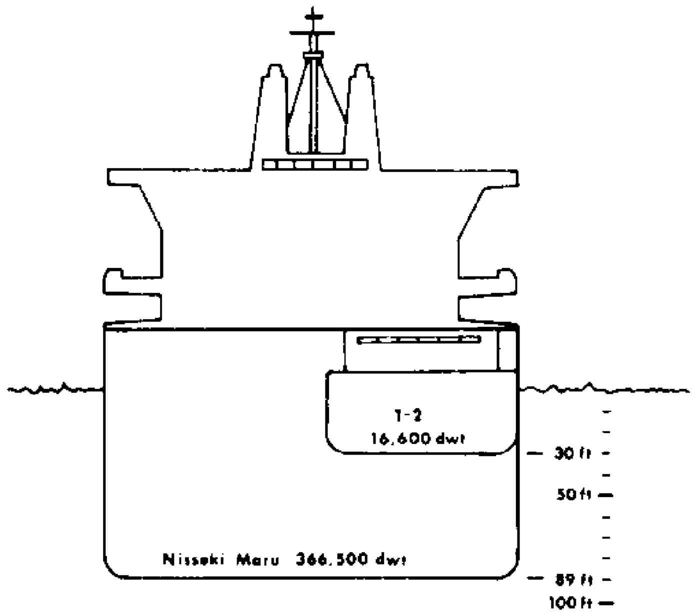
At the present time, now ship larger than 80,000 - 90,000 dwt can enter Texas ports since the water depths are no deeper than 40 feet. Because of this more than 700 ships cannot dock in Texas.

It is predicted that by 1983, more than 1,400 of the projected world tanker fleet of 4,300 ships will be unable to enter Texas ports due to their restricting depths and the increased tonnage capacity of this fleet.

Projected deadweight tonnage of large ships to the year 2040 is shown in this chart as based on trends from 1937-67.

(Source: Bragg 1972)





The standard oil tanker of the 1940's had a draft of 30 feet in comparison to the supertanker NISSEKI MARU which requires a water depth greater than 89 feet.

(Source: Bragg 1972)

Today, more than 150 ships over 200,000 dwt called "supertankers" sail the world's oceans.

"Supertankers" - average over 1,100 feet or about three football fields in length and as much as 180 feet in width.

Ships of up to 470,000 dwt are presently under construction, and supertankers up to one million deadweight tons are on the drawing board.

Favorable aspects of the "supertankers":

1. per-barrel cost of transportation lessened
2. more seaworthy
3. reduction in manpower due to increased automation on board ships

Solution: Build one or more terminals at offshore locations where the Gulf waters are naturally deep enough to accommodate the supersize ships or dredge existing channels and harbors to the necessary depths.

- At Texas A&M University, the Industrial Economics Research Division has recently completed one of the first studies of the Texas superport.

PORTS AND WATERWAYS OF THE GULF OF MEXICO

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Bragg, Dan, "A Superport for Texas", *The University and the Sea*, Vol. 5, No. 3, May-June 1972.

Miloy, John and E. Anthony Copp, *Economic Impact Analysis of Texas Marine Resources and Industries*, Texas A&M University and Sea Grant Program, TAMU-SG-70-217, 187 pp., June 1970.

Nesbitt, R. A. (Editor and Publisher) *Port of Galveston*, Vol. 24(3), October 1970.

Texas A&M University, *Marine Resources Activities in Texas*, Prepared for the National Science Foundation's Sea Grant Program of Texas A&M University by the Industrial Economics Research Division, Texas Engineering Experiment Station, 202 pp., August 1969.

GOVERNMENTAL, EDUCATIONAL AND RESEARCH ORGANIZATIONS

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GOVERNMENTAL, EDUCATIONAL AND RESEARCH ORGANIZATIONS

- There are at least eight organizations of the Federal government at work along or in the Gulf of Mexico.
- Seven laboratory locations for the National Marine Fisheries Service (formerly the Bureau of Commercial Fisheries) are located along the Gulf coast.
- The U.S. Navy also has two laboratories located along the Gulf coast.
- At least a dozen state agencies in Texas involved in marine-related activities as well as active agencies in Louisiana, Mississippi and Florida, operate from the coastal zone.
- There are seventeen institutions along the Gulf of Mexico offering degrees either in oceanography or marine sciences, or offering courses toward obtaining such degrees.

Editor's Note: *Italicized* words are defined in the Glossary.
Credit lines for figures refer to selected references.

(9/72)

A ROLE OF THE FEDERAL GOVERNMENT IN MARINE-RELATED ACTIVITIES ALONG THE GULF COAST

Six Federal Departments have been identified as sponsors of marine-related research in Texas: Interior, Commerce, Defense, State, Transportation and Army. Three Federal agencies also play an active role in similar research: Environmental Protection Agency, National Science Foundation and the Smithsonian Institution. Within the above-mentioned Departments are many agencies actively involved but without specific laboratory facilities located along the Gulf coast, such as the United States Coast Guard.

FEDERAL AGENCIES ENGAGED IN MARINE-RELATED ACTIVITIES ALONG THE GULF COAST

AGENCY	LABORATORY LOCATION	VESSELS OR OTHER FACILITIES
National Marine Fisheries Service (formerly Bureau of Commercial Fisheries)	Panama City, Florida St. Petersburg Beach, Florida Southeast Fisheries Center, Miami, Florida Miami Laboratory, Miami, Florida Galveston Laboratory, Galveston, Texas Pascagoula Laboratory, Pascagoula, Florida Bay St. Louis Fisheries Engineering Laboratory, Bay St. Louis, Mississippi	R/V RACHEL CARSON R/V KINGFISH II R/V TOMMY BOX R/V REDFISH Some outboard motorboats
Corps of Engineers	4 District Offices in Gulf States Waterways Experiment Station Vicksburg, Mississippi	
United States Navy	Navy Coastal Systems Laboratory, Panama City, Florida Atlantic Undersea Test & Evaluation Center, West Palm Beach, Florida	2 Offshore Towers

continued on following page

FEDERAL AGENCIES ENGAGED IN MARINE-RELATED ACTIVITIES ALONG THE GULF COAST
(continued)

AGENCY	LABORATORY LOCATION	VESSELS OR OTHER FACILITIES
Environmental Research Laboratories	Atlantic Oceanographic & Meteorological Laboratory, Miami, Florida National Hurricane Research Laboratory, Miami, Florida Experimental Meteorological Laboratory, Miami, Florida	R/V DISCOVERER R/V RESEARCHER Inboard motorboats
United States Bureau of Sports Fisheries and Wildlife	Port Aransas Laboratory, Aransas, Texas (under construction)	
United States Geological Survey, Office of Marine Geology	Corpus Christi, Texas	
Environmental Protection Agency, (Region VI) Surveillance & Analysis Division	Lower Mississippi River Facility, Slidell, Louisiana (near Bay St. Louis) National Pesticides Monitoring Laboratory, Slidell Regional Pesticide Regulation Chemical Laboratory, Slidell	Emergency response activities to oil & hazardous material spills; water & sediment analysis; computer programming facilities
National Aeronautics & Space Administration	Manned Spacecraft Center, Houston, Texas Mississippi Test Facility, Slidell, Louisiana	Aircraft & smaller boats

Source: Personal communication with the individual agencies.

National Oceanic and Atmospheric Administration

NOAA, the National Oceanic and Atmospheric Administration, was created within the U. S. Department of Commerce on October 3, 1970, by Presidential Reorganization Plan Number 4 of 1970.

Purpose - to explore, map, and chart the global oceans and translate new physical and biological knowledge into systems capable of assessing the sea's potential yield which the Nation and its industries can employ. To manage, use, and conserve these animal and mineral resources; monitor and predict the characteristics of the physical environment and the changes of the atmosphere, ocean, sun and solid earth, gravity and geomagnetism, and warn against impending environmental hazards, and ease the human burden of hurricanes, tornadoes, floods, tsunamis, and other destructive natural events.

Organization - consists of staff offices, the field organization and six major components:

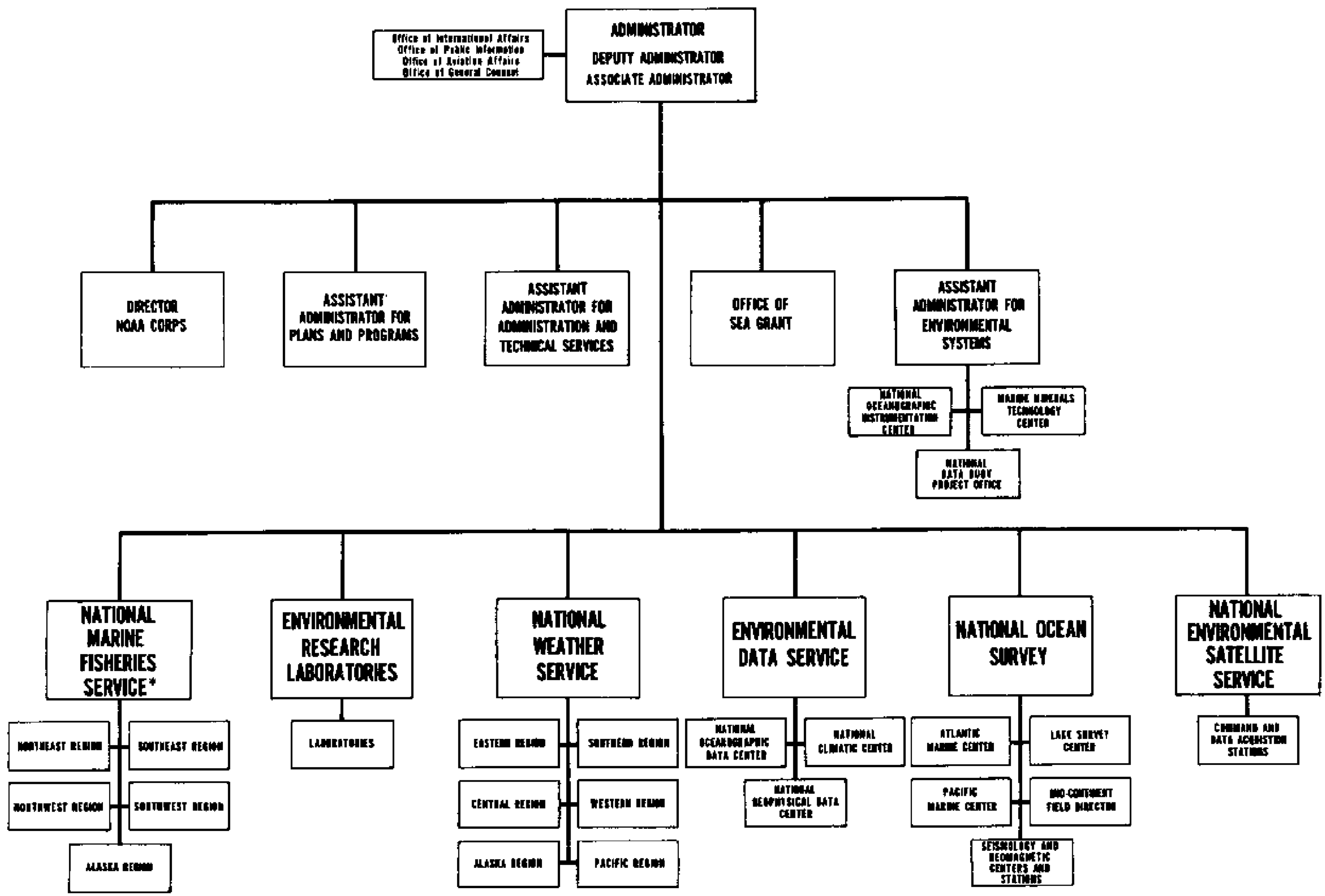
National Marine Fisheries Service
Environmental Data Service
National Weather Service
Environmental Research Laboratories
National Ocean Survey
National Environmental Satellite Service

Functions and Activities - Among its principal functions and activities, NOAA:

reports the weather and provides forecasts
prepares and issues nautical and aeronautical charts
conducts geodetic, oceanographic and marine geophysical surveys
predicts tides, currents and ocean states
conducts biological research
analyzes economic aspects of fisheries operations
operates a national environmental satellite system
conducts an integrated program of research and services relating to the oceans and inland waters, the atmospheres and the earth
stores and disseminates worldwide environmental data
administers and directs the National Sea Grant Program.

U.S. DEPARTMENT OF COMMERCE

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION



*MARINE SPORT FISHERIES LABORATORIES TEMPORARILY REPORT TO THE OFFICE OF THE DIRECTOR

OCTOBER 3, 1970

National Sea Grant Program - created by Congress in 1966 (Public Law 89-688), the National Sea Grant College and Program Act is intended to accelerate national development of marine resources including their conservation, proper management, and maximum social and economic utilization.

Through NOAA's Office of Sea Grant Programs, grants and contracts are made to universities, institutes, laboratories, and public and private industry to carry out the missions of the program. Two-thirds of the funds may be derived from federal appropriations; the remaining one-third must come from non-federal sources.

Five levels of funding exist, that of Sea Grant Colleges, Institutional Awards, Coherent Area Support and Project Support. The Sea Grant College support is the highest level and is defined by law as an "institution of higher education supported pursuant to the purposes of this title which has major programs devoted to increasing our Nation's utilization of the world's marine resources."

- There are six Sea Grant Colleges in the United States:

  Oregon State University
  Texas A&M University
  University of Hawaii
  University of Rhode Island
  University of Washington
  University of Wisconsin

Federal Legislation

More than 500 bills relating to the environment are awaiting congressional action in Washington.

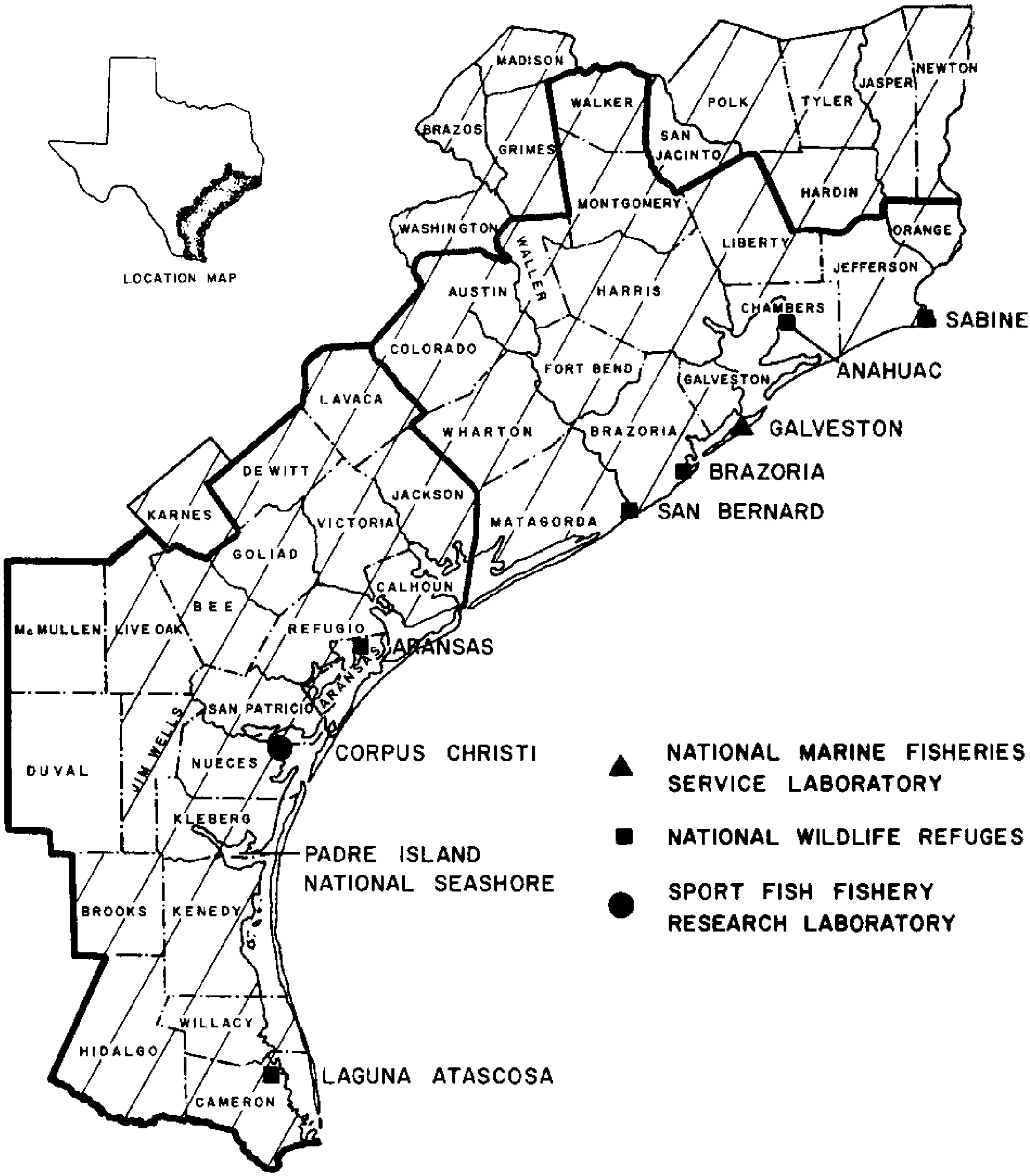
Of particular interest are the following:

- The COASTAL MANAGEMENT BILL (H.R. 14146) recently passed the House - calling for a national program for the management, beneficial use, protection and development of the land and water resources of the Nation's coastal zone. Funds for the three-year program, as approved by the Office of Management & Budget, would amount to more than $69 million and be administered by the Secretary of Interior.

- A similar bill (S. 3507) also referred to as a COASTAL MANAGEMENT BILL recently passed the Senate. The two bills are almost identical with a few exceptions such as: the Senate bill calls for approximately $61 million and would be administered by the Secretary of Commerce and the amount of the Federal funds appropriated for grants to the states is less in the Senate bill than in H.R. 14146.

Both bills are now ready to be reviewed by a Joint Committee of the Legislature.

Still pending is the NATIONAL LAND USE POLICY ACT (S. 3354) "to encourage the conservation, development and utilization of the land and water resources of the United States on a comprehensive and coordinated basis by the Federal Government, States, localities and private enterprise with the cooperation of all Federal agencies, States, local governments, individuals, corporations, business enterprises, and others concerned."



Federal marine research laboratories and coastal
wildlife refuges in Texas

(Source: Miloy and Copp 1970)

B STATE AGENCIES WHICH PLAY AN ACTIVE ROLE IN MARINE-RELATED ACTIVITIES AND OTHER ACTIVITIES AFFECTING THE COASTAL ZONE

State agencies along the Gulf coast engaged in marine-related activities include the following:

Alabama Department of Conservation
Florida Board of Conservation
Florida Coastal Coordinating Council
Florida Inter-Agency Advisory Committee on
   Submerged Land Management
Louisiana Wildlife and Fisheries Commission
Mississippi Game and Fish Commission

In Texas such organizations as those listed play an active role in marine-related activities:

Interagency Natural Resources Council
General Land Office
Texas Air Control Board
Texas Industrial Commission
Texas Railroad Commission
Texas Parks and Wildlife Department
Texas State Soil and Water Conservation Board
Texas Water Development Board
Texas Water Quality Board
Texas Water Rights Commission
Texas Employment Commission
Texas State Department of Health
Texas Education Agency
Texas Game and Fish Commission
Texas Highway Department
Tourist Development Agency

Interagency Natural Resources Council

- Formed by the Governor of Texas to give attention to the interagency coordination necessary for the unified development of water, parks, and environmental quality programs in Texas

Members:
General Land Office
Texas Air Control Board
Texas Industrial Commission
Texas Railroad Commission
Texas Highway Department
Texas Parks and Wildlife Department
Texas Soil and Water Conservation Board
Texas Water Development Board
Texas Water Quality Board
Texas Water Rights Commission

- Both the Bureau of Economic Geology of the University of Texas and Texas A&M University have a representative on the Council as a non-voting member.

The Council created a Coastal Study Committee to formulate guidelines for a multidisciplinary consultant survey of the Texas coast with the ultimate goal of improved State management and development of the rich resources of its bays and estuaries.

In March 1969, by means of an interagency contract between the Natural Resources Council and the Sea Grant Program of Texas A&M University, the initial planning effort began, which included compilation of an annotated bibliography of studies, studies currently funded, and proposed research reports, action programs by Federal, State and local governments and by institutions, entities, and industries within the coastal region.

- The Coastal Resources Management Program of Texas, a subsidiary of the Council, authorized by S.C.R. 38, was established by the 61st Legislature and funded in the Division of Planning Coordination, within the Governor's office.
- Purpose of this Program is a better understanding of the environmental complexities of the coastal zone.
- Twenty-four task areas within the coastal zone were determined, fifteen of which were considered major problems relating to natural resources in the coastal zone:

fish and wildlife resources	hurricanes
coastal zone management	mineral resources
wildlife habitats	water pollution

beaches	aquatic ecosystem
governmental regulations	air pollution
commercial fishing	mining
historical sites	transportation
oil and chemical spills	

(For further information regarding the Coastal Resources Management Program see COASTAL ZONE section.)

Council on Marine-Related Affairs

- This council is chiefly an advisory group for the Governor, the Legislature and the people. Its purpose is to provide expertise in the fields of marine affairs and science.

- It was established during the summer of 1972.

C EDUCATIONAL INSTITUTIONS ALONG THE GULF OF MEXICO OFFERING MARINE-RELATED DEGREES

INSTITUTIONS OFFERING OCEANOGRAPHY OR
MARINE SCIENCE DEGREES

NAME	DEGREES	REMARKS
Alabama, University of, Marine Science Institute, Bayou La Batre, Alabama 35486	BS, MS, and PhD in many of the Marine Sciences	Operates a small marine lab at Bayou La Batre, 250-acre waterfront site at Point aux Pins, Alabama
Brazosport College, Brazosport, Texas 77541	Prep. course for obtaining U. S. Coast Guard licensing and Associate of Applied Science degree	A two-year college offering courses in oceanography, seamanship, navigation, diesel engines, boat handling, nautical rules of the road, fire fighting, SCUBA diving, marine electronics
Eckerd College (formerly Florida Presbyterian College) St. Petersburg, Florida 33733		Offers various courses in marine sciences
Florida, University of Gainesville, Gainesville, Florida 32601	BS, MS, & PhD in sciences with major emphasis on Marine Science studies	Operates Marine Biology Laboratory near Cedar Key and the Sea Horse Key Marine Laboratory west of Gainesville
Florida State University Tallahassee, Florida 32306	MS & PhD in Marine Biology & Oceanography; PhD in Geophysical Fluid Dynamics	Operates Turkey Point Harbor and Laboratory center
Houston, University of Houston, Texas 77004	BS, MS in Geology, BS, MS & PhD in Biology	A J.D. with emphasis in the marine field is offered by the Bates College of Law
Institute of Engineering Technology (formerly Gulf Coast Technical Institute) Mississippi State University, State College, Mississippi 39762	Two-year senior college level program in Marine Engineering Tech. in cooperation with Miss. State Univ., BE in Marine Tech.	Various undergraduate courses in oceanography and underwater acoustics
Lamar State College of Technology, Beaumont, Texas 77705	BS in Oceanographic Technology	
Louisiana State University Baton Rouge, Louisiana 70803	BS, MS & PhD in Marine Sciences	Department of Marine Sciences is affiliated with LSU's Coastal Studies Institute and Office of Sea Grant Development. University-leased facilities at Grand Isle.
Marine Science Institute of The University of Texas, Port Aransas, Texas 78373	PhD in Botony, Chemistry, Geology, Microbiology, Physics, Zoology, or Engineering with work concentrated in marine science	

INSTITUTIONS OFFERING OCEANOGRAPHY OR
MARINE SCIENCE DEGREES
(continued)

NAME	DEGREES	REMARKS
Nova University Oceanographic Laboratory, Fort Lauderdale, Florida 33316	PhD in Physical Oceanography, Chemical Oceanography, Marine Biology or Physics with a dissertation in Oceanography	
Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida 33149	MS & PhD in Marine Biological Science, Marine Geology and Geophysics, Physical Oceanography & Atmospheric Sciences.	Other facilities at Fisher Island and a 45-mile underwater acoustic range from Miami to Bimini. Pigeon Key facilities for biological studies.
Southern Mississippi, University of Hattiesburg, Mississippi 39401	MA & MS in Biology & Geology and PhD in Marine Biology	Closely affiliated with Gulf Coast Research Laboratory at Ocean Springs
South Florida, University of Marine Science Institute, St. Petersburg, Florida 33701	MS in Marine Science	
Texas A&M University College Station, Texas 77843	MS & PhD in Oceanography, also in Zoology, Microbiology, Botany or Biology (Marine emphasis) & MS Marine Resources Management	Directs Galveston Marine Laboratory operations; cooperative research & instruction through many departments on the campus such as: Wildlife & Fisheries Science, Oceanography, and Environmental Engineering
Texas Christian University Ft. Worth, Texas 76129	MS in Biology, Environmental Science and Geology with emphasis on marine problems	
Texas Maritime Academy, Texas A&M University, Galveston, Texas 77550	BS in Marine Engineering & Transportation	One hundred high school graduates may participate in "Summer School at Sea" during cruise to foreign ports.
West Florida, University of Pensacola, Florida 32504	BS & MS in Biology with emphasis on Marine Sciences & Estuarine Studies	Shares facilities on Sabine Island with National Marine Fisheries Service for estuarine studies

Source: Oceanographer of the Navy, University Curricula in the Marine Sciences and Related Fields, Academic Years 1971-72 and 1972-73, Pamphlet #43, U.S. Navy, 214 pp., August 1971.

PARTIAL LISTING OF CURRENTLY AVAILABLE FACILITIES ON THE GULF OF MEXICO

UNIVERSITY	LABORATORY LOCATION	VESSEL	OTHER
Alabama, University of	Marine Science Laboratory at Bayou La Batre Point aux Pins Laboratory	65' R/V AQUARIUS 36' FIN 23' SEABIRD	
Brazosport College	Campus Labs	65' TEXSUN 65' LADY ANNA	
Del Mar College	Shore Laboratory		Wave Tank
Eckerd College	Campus		
Florida Institute of Technology	Campus	65' vessel	
Florida State University	Marine Lab; Turkey Point Biology Field Station	65' TURSIOPS 30' and 22' Craft Smaller Craft	4 Portable Lab 2 Shelf Depth Submersible 1 Deep Ocean Buoy
Florida, University of	Coastal & Oceanographic Engineering Laboratory, Gainesville Seahorse Key Marine Laboratory Communication Service Laboratory, Gainesville Marineland, Inc., Flagler County	32' vessel	Wave Tanks
Gulf Coast Research Laboratory	Ocean Springs, Mississippi	Ten craft ranging in size from 18' - 65'	
Gulf South Research Institute	New Iberia, Louisiana		
Houston, University of	Coastal Environment Field Station, Galveston		Wave and towing tanks
Lamar University	Campus (Supporting Staff)	21' Inboard/Outboard motorboat 20' Outboard motorboat 64' Converted fire patrol boat 21' Outboard boat 35' Catamaran Smaller boats	Lighthouse

PARTIAL LISTING OF CURRENTLY AVAILABLE FACILITIES ON THE GULF OF MEXICO
(continued)

UNIVERSITY	LABORATORY LOCATION	VESSEL	OTHER
Louisiana State University	Coastal Studies Institute, Baton Rouge Barataria Bay Facility Nuclear Science Center, Baton Rouge Field Facilities, Grand Isle	16' Craft 24' Craft	Portable lab Float-mounted lab
Mexico, University of	Three Fisheries Stations, Isla Mujeres, Tampico, Campeche Marine Station, Veracruz Institute of Biology, Ciudad del Carmen		
Miami Seaquarium	Miami, Florida		
Miami, University of	Rosenstiel School of Marine and Atmospheric Science Fisher Island facilities 45-mile underwater acoustic range from Miami to Bimini Pigeon Key facilities	176' R/V PILLSBURY 78' R/V GERDA R/V GILLISS Several smaller craft	
Mississippi, University of	Campus (Supporting Staff)		
Mote Marine Laboratories	Sarasota, Florida Placida, Florida		
Nova University	Nova University Oceanographic Laboratory		
Ocean World	Miami, Florida		
Rice University	Campus Labs (Supporting Staff) Field Labs	Outboard mototboats 20' Cabin cruiser	Marsh Buggies
South Florida, University of	Marine Science Institute, St. Petersburg	38' Catamaran	
Southwest Center for Advanced Studies	Dallas, Texas		

PARTIAL LISTING OF CURRENTLY AVAILABLE FACILITIES ON THE GULF OF MEXICO

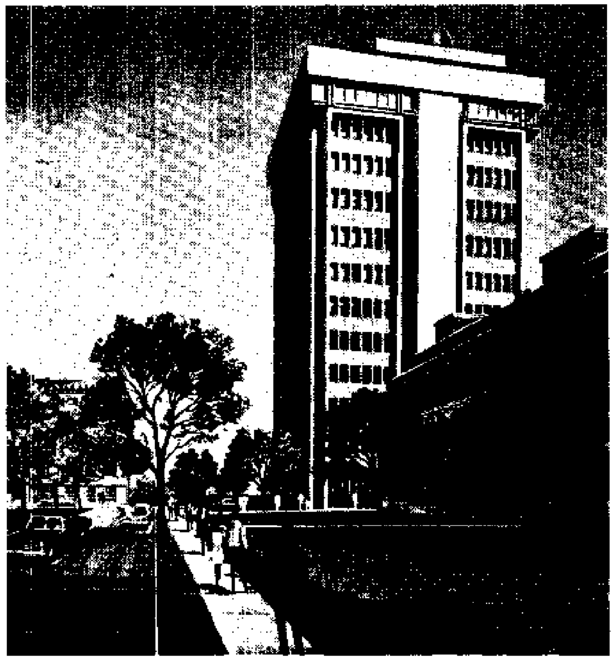
(continued)

UNIVERSITY	LABORATORY LOCATION	VESSEL	OTHER
Southwest Research Institute	Ocean Science and Engineering Lab, Corpus Christi	46' WRANGLER 16' Craft	
Texas A&I University	Biological station on Baffin Bay	Two outboard motors & work barge	
Texas A&M University	Oceanography, Meteorology, Geology, Geophysics, Geography labs Marine Lab, Galveston Civil Engineering (Ocean Engineering) Labs, Campus and Morgan's Point Mariculture ponds at Angleton	180' R/V ALAMINOS 56' R/V EXCELLENCE 62' R/V DUET 50' R/V MARINER 110' R/V KASIDAH II 39' R/V LA MER II	Fish Protein Concentrate Pilot Plant Wave tanks Nuclear Activation Lab Cyclotron and reactor Mobile lab
Texas Lutheran College	Campus laboratories at Seguin	20' powered nonomoy surfboat 13' powered shallow draft boat	
Texas Maritime Academy	Labs on Pelican Island	473' TEXAS CLIPPER	
Texas, University of	Marine Science Institute, Port Aransas Marine Biomedical Institute, Galveston Applied Research Laboratories, Balcones Research Center Center for Research in Water Resources, Balcones Research Center	40' LORENE 40' Barge 135' M/V MISS FREEPORT 80' LONGHORN 62' Houseboat, LAZY DAYS Two-man research submarine Several smaller boats Two flying laboratories (C-54 & C-45)	Concrete and fiberglass Experience ponds
Texas Wesleyan College	Campus laboratories at Fort Worth	27' Inboard motor 18' Outboard motors (2)	
West Florida, University of	Shares facilities on Sabine Island with NMFS		

Source: Oceanographer of the Navy, University Curricula in the Marine Sciences and Related Fields, Academic Years 1971-72 and 1972-73, Pamphlet #43, 214 pp., August 1971 and Norman C. Whitehorn, Marine Resources Capabilities in Texas: Directory of Facilities, TAMU-SG-72-603, Industrial Economics Research Division, Texas A&M University and the Sea Grant Program, 59 pp., May 1972.

(9/72)

Texas A&M University's Program in Marine Resources



Artist's Concept of Oceanography & Meteorology
Building at Texas A&M University

Texas A&M University's programs in marine resources function primarily within:

- Department of Oceanography
- Moody College of Marine Sciences and Maritime Resources
  - Texas Maritime Academy
  - Institute of Marine Sciences
    - Galveston Marine Laboratory
  - Coastal Zone Laboratory
- Center for Marine Resources
  - Sea Grant Program

Related programs may also be found in:

- College of Agriculture
- College of Business Administration
- College of Engineering
- College of Geosciences
- College of Liberal Arts
- College of Veterinary Medicine
- Texas Agricultural Extension Service
- Texas Engineering Experiment Station
- Texas Agricultural Experiment Station

- The total annual operations for marine-related programs at Texas A&M University are estimated at $6.3 million during 1971-72.

These expenditures were estimated by organizational units to be:

Department of Oceanography	2.39 million
Sea Grant Program Office	2.16 million
Texas Maritime Academy	1.04 million
Others	.74 million

- Virtually all of the University's extension activity in this field is to be found in the Sea Grant Program.

- Of the University's total marine program expenditures, approximately 30% are directed toward work in Galveston.

Facilities on Campus

1. Department of Oceanography

   Originated on the campus in 1949.

   Fourth oldest academic department of its type in the country.

   Offers both the MS and PhD degrees in Oceanography.

   The only university in the state with ocean-going research capabilities operating three vessels ranging in size from 39 - 186 feet. A new vessel will be ready for operation in the spring 1973.

   Since its establishment, the department has granted approximately 192 graduate level degrees.

   Construction of an $8 million, 14-story oceanography and meteorology building on the College Station campus is expected to be completed by spring 1973.

2. Center for Marine Resources

Based in College Station, the Center was established in the spring of 1971 to administer broad programs of marine resource development, including the Sea Grant Program.

Its purpose is to provide a coordinating mechanism for marine programs which are interdisciplinary in nature, to identify potential program areas, to assist in proposal preparation and to advise on possible sources of funding.

It serves as a center for information on marine activities and includes:

Department of Marine Resources Information
Department of Marine Advisory Services

Department of Marine Resources Information

Responsible for providing timely and useful information to marine resources developers and users.

Concerned entirely with the preparation, printing, and distribution of the university's marine resource publications series, and for the coordination of information aspects of workshops, conferences, exhibits and similar functions.

Operates as an originating source of publications and articles, and provides an editing service in connection with the documentation needs of all Sea Grant participants.

The distribution of the various publications issued by this Department is wide-spread and may reach as many as 5000 in one mailing..

Department of Marine Advisory Services

Deals in public service activities such as short courses, summer institutes, conferences, workshops and seminars, resource data surveys and field service activities involving direct consultation, demonstration activities and special projects.

This Department serves as a coordinating mechanism for marine advisory projects which, in its fourth year (1971-72) are being conducted in seven departments of the University, two other institutions and two non-university groups.

3. Sea Grant Program

Began on the campus in 1968, when it was designated as the second highest of the major institutional awards at $475,000 from the National Science Foundation

Since 1968, more than $5.8 million have been directed to the program through institutional contributions and federal funding, currently awarded by the National Oceanic and Atmospheric Administration (NOAA), U. S. Department of Commerce.

On September 7, 1971, Texas A&M University was designated as a Sea Grant College by Secretary of Commerce Maurice H. Stans. Three others were also named:

Oregon State University
University of Rhode Island
University of Washington

Recently, Texas A&M University was awarded a $1.5 million grant from the U.S. Department of Commerce for continuation of its Sea Grant College activities. This must be matched by $750,000 in non-federal funds by the University. Part of this funding will come from the state and part from private sources bringing the total Sea Grant effort to $2.25 million for the 1972-73 academic year.

During the 1970-71 funding year more than 250 university staff and faculty members were involved in Sea Grant sponsored activities. Seventy students were actively supported by this program in their research.

This program reaches into 18 departments or divisions in seven of the University's 10 academic Colleges.

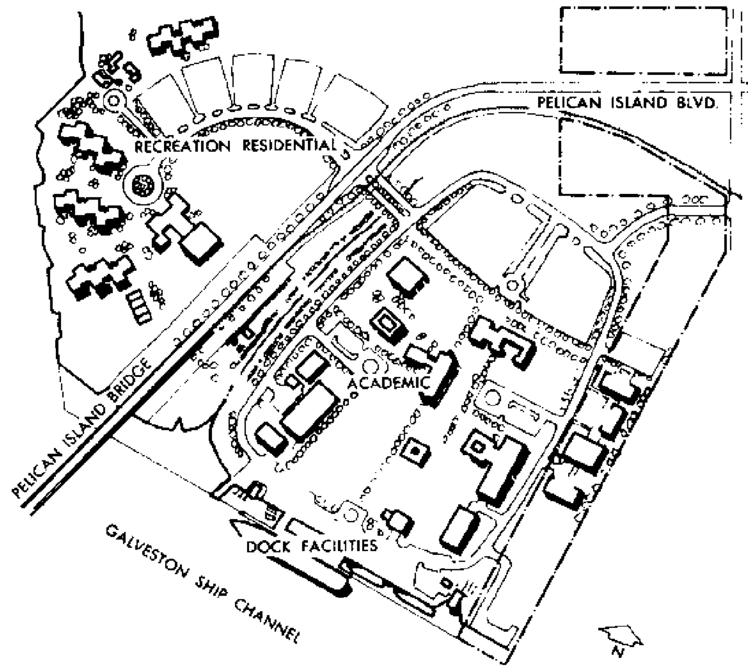
These funds will also support work conducted at:

University of Houston
Lamar University
Brazosport College
Baylor College of Medicine
Education Service Center (Region II) in Corpus Christi
Southwest Research Institute

Sea Grant activities are divided into the following program areas:

Education & Training
General Advisory Services
Advisory Field Services
Marine Resources Information
Fisheries & Seafood Technology
Shrimp Mariculture
Commerce & Resource Management
Offshore Technology
Environmental Quality
Medicine & Public Health
Coastal Laboratories

Facilities Off Campus



PELICAN ISLAND PROJECTED DEVELOPMENT

Moody College of Marine Sciences and Maritime Resources

Established September 1971 in Galveston, Texas, to include these existing operations:

TEXAS MARITIME ACADEMY
INSTITUTE OF MARINE SCIENCES
Galveston Marine Laboratory
COASTAL ZONE LABORATORY

Located on a 100-acre site on Pelican Island and known as the Mitchell Campus after Mr. and Mrs. Mike Mitchell, parents of the donor, a Houston business executive.

The College is named after the late W. L. Moody, Jr., who contributed $1 million for the construction of the first facilities.

1. Texas Maritime Academy

   Newest of the nation's six major accredited maritime academies.

   - The only maritime academy located on the Gulf coast.

   Offers four year academic program leading to the Bachelor of Science degree in marine transportation or marine engineering.

   Founded in 1963, it now has an enrollment of approximately 150 students.

   Training vessel for the Academy is the Texas Clipper.

      15,000-ton converted ocean liner

      During the school year, it acts as a dormitory for approximately 150 students of the Academy.

      During the summer, it becomes a floating classroom for cruises to foreign ports, when some 100 high school graduates enroll in "Summer School At Sea." Sponsored jointly by the College of Liberal Arts and Maritime Academy, students may enroll in English, History and Mathematics on board ship.

2. Galveston Marine Laboratory

   Engaged in a variety of marine and biological research projects, particularly studies involving parasites fatal or injurious to fish and oysters.

   - Offers courses and research leading toward a Master of Science degree in marine biology. Also offers a technical training program in fisheries biology.

   Offers a survey course for advanced high school students and college freshmen.

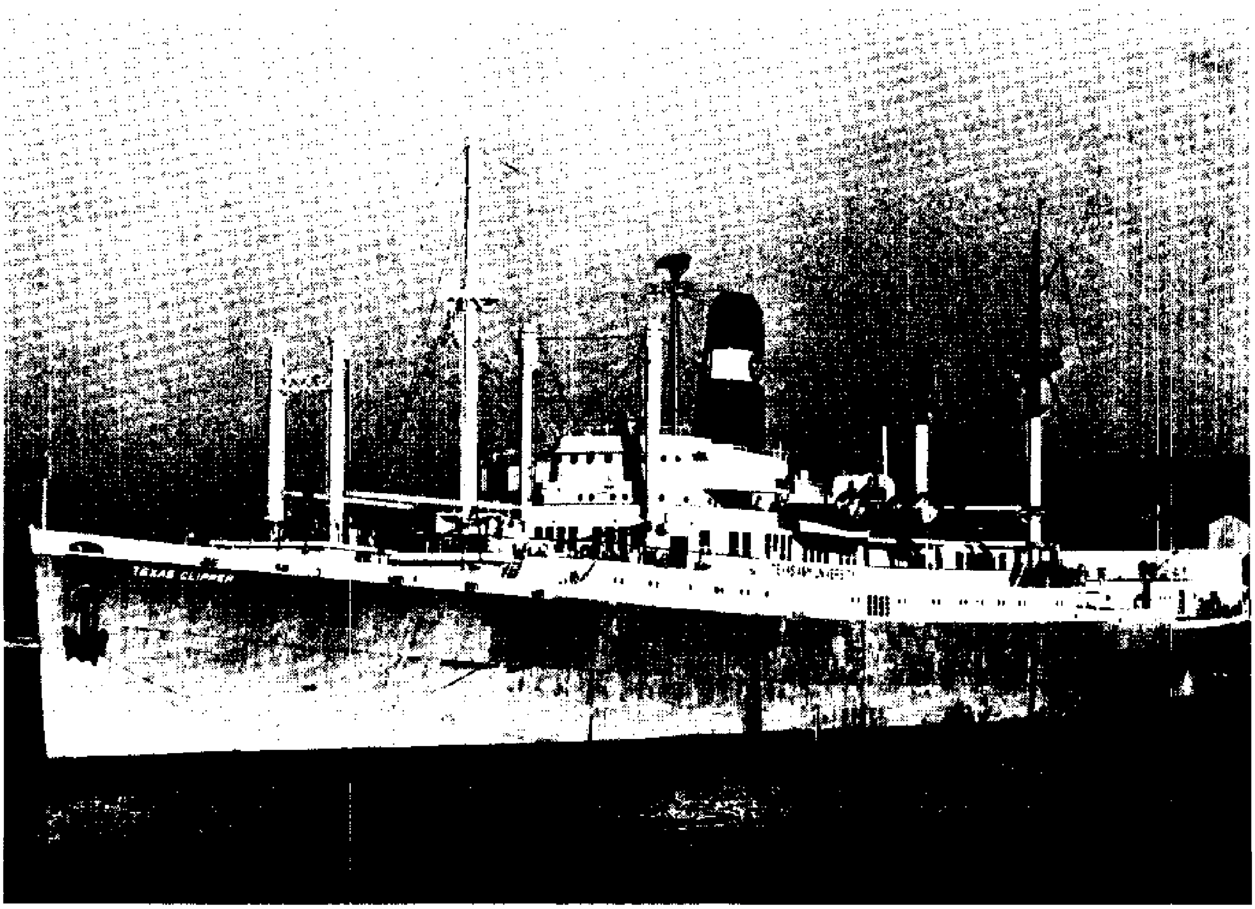
3. Coastal Zone Laboratory

   First in a proposed chain along the Texas coast, serving as a center for applied interdisciplinary research in bays and estuaries; focuses on problems unique to the Galveston area by using the talents and capabilities of the entire University staff in a problem-solving manner.

Texas A&M University sea-going facilities include:

TEXAS CLIPPER, 15,000-ton converted ocean liner
R/V ALAMINOS, 179' converted Army freighter
R/V LA MER II, 38' twin diesel craft
R/V MARINER, 50' twin diesel Chris Craft
R/V EXCELLENCE, 56' Chris Craft Constellation
R/V DUET, 62' shallow draft vessel
R/V ORCA, 98' twin diesel craft

- A new vessel will be ready for operation in the spring of 1973. Called an AGOR (Auxiliary General Oceanographic Research/Utility) vessel, its overall length will be 165 feet and will accomodate 28 persons, including scientific party and crew. It is unique in that it is constructed to house any one of ten mobile laboratories constructed as vans which may by placed on the vessel as needed.



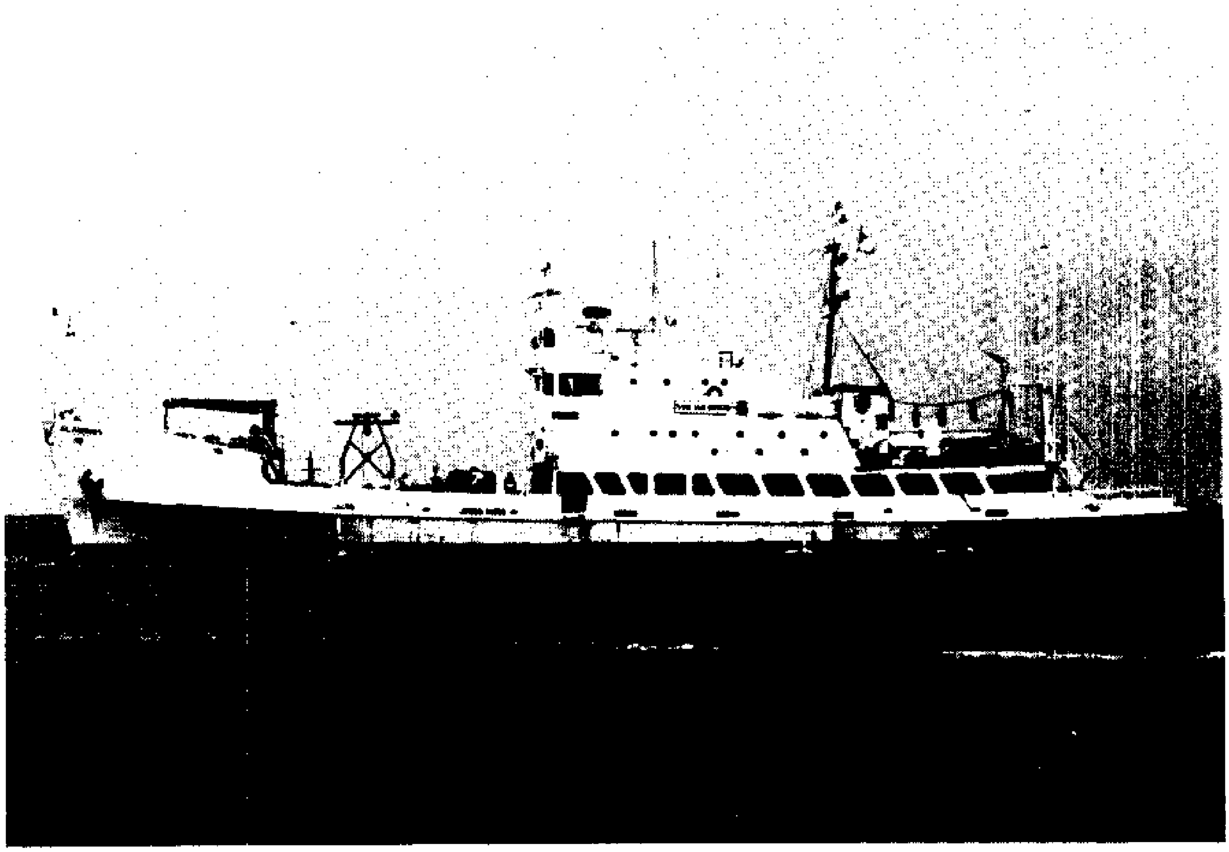
TEXAS CLIPPER
Texas Maritime Academy
Texas A&M University

Length Overall: 473'01"
Number of Propellers: One-pitch 20'
Type of Propulsion: Steam turbine
Age: 29 years
Displacement: 9644 gross tonnage
Steaming Radius: 12,000 miles
Size of Crew: 35 w/cadets, 65 wo/cadets
Electrical Generating Capacity: 3-300 KW generators (steam) 450 psi 750°F 230 V-115 V DC
Number and Capacity of Booms: 6-3 tons
Number and Capacity of Winches: 6-3 tons
Accommodations for Non-Crew Personnel: 210

Longest Voyage with Full Crew & Maximum Non-Crew Personnel: 13,600 miles (Actually there is no limit here as fuel and provisions can be obtained nearly anywhere by the Texas Clipper.)

Scientific Equipment (Major): Sewage treatment system - 7500 gal. capacity aeration-chlorination process for 250 persons.

Special Features, Capabilities or Equipment: Shaft horse power 8000, radio equipment-28 channel VHF, standard FCC merchant vessel radio telegraph equipment, sewage treatment plant capable of extensive research, deepest draft 27'06".



R/V ALAMINOS
Oceanography Department
Texas A&M University

Length Overall: 179' 10" *Size of Crew:* 18 crewmembers, 16 scientists

Displacement: 840 gross tonnage *Number of Propellers:* 2

Age: 26 years *Draft:* 9' 3" *Steaming Radius:* 4000 miles

Type of Propulsion: 2-GM 6-278A Diesels, 500 HP each @ 750 RPM

Electrical Generating Capacity: 2 DC gen. 100 KW ea., 1 AC gen. 115 KW, 1 AC gen. 60 KW.

Number and Capacity of Booms: 1 flexlift crane 8 ton, 1 flexlift crane 6 ton

Number and Capacity of Winches: 2 hydrographic winches - 30,000' 3/16" wire, 1 dredging winch - 30,000' 7/16" wire.

Accommodations for Scientific Personnel: 2-man rooms with adjoining bathroom

Longest Voyage with Full Crew & Maximum Scientific Personnel: 4000 miles

Special Features, Capabilities or Equipment: 10 separate laboratories, all traditional equipment, air-conditioned.

LA MER II
Oceanography Department
Texas A&M University

Length Overall: 38'6"

Age: 9 years

Size of Crew: 1 crewmember, 5 scientists

Type of Propulsion: Twin diesel engines

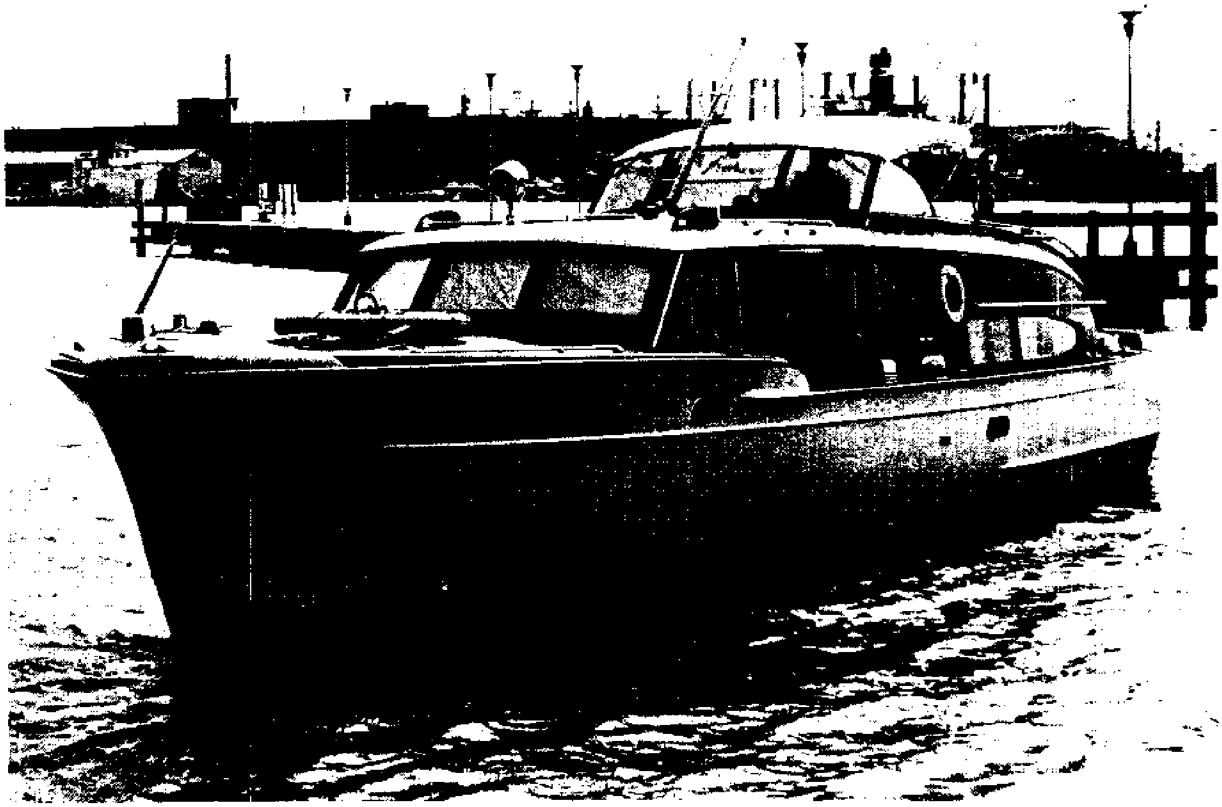
Number of Propellers: 2

Electrical Generating Capacity: one 5-KW AC

Steaming Radius: 400 miles

Accomodations for Scientific Personnel: 1 cabin

Longest Voyage with Full Crew & Maximum Non-Crew Personnel: 2 days



R/V MARINER
Civil Engineering Department
Texas A&M University

Length Overall: 50'

Draft: 36"

Type of Propulsion: Diesel

Steaming Radius: 100 miles

Size of Crew: 2

Number of Propellers: 2

Electrical Generating Capacity: 12.5 KW

Number and Capacity of Booms: 1 boom, 1000 lb. capacity

Number and Capacity of Winches: 1 winch, 1000 lb. capacity

Accommodations for Non-Crew Personnel: 15/5 (single day operation/overnight operation).

Longest Voyage with Full Crew & Maximum Non-Crew Personnel: 100 miles.

Scientific Equipment (Major): 2 overboard pumping systems, portable monitoring equipment (pH, D.O., salinity, temperature), samplers, velocity meters.

Special Features, Capabilities or Equipment: Heavy duty work vessel; biological related activities (i.e. trolling for aquatic organisms).

R/V EXCELLENCE
Civil Engineering Department
Texas A&M University

Length Overall: 56'

Draft: 42"

Age: 9 years

Steaming Radius: 100 miles

Type of Propulsion: Diesel

Number of Propellers: 2

Electrical Generating Capacity: 10 KW

Size of Crew: 2

Number and Capacity of Booms: 1 boom, 1000 lb. capacity
Number and Capacity of Winches: 1 winch, 1000 lb. capacity
Accommodations for Non-Crew Personnel: 20/5 (single day operation/overnight)

Longest Voyage with Full Crew & Maximum Non-Crew Personnel: 100 miles.

Scientific Equipment (Major): Two water quality monitoring systems, 2 overboard pumping systems, 2 fluorometers, total carbon analyzer, oxygraph, samplers, velocity meters, corers.

Special Features, Capabilities or Equipment: Extensive instrumentation for water quality research.

R/V DUET
Civil Engineering Department
Texas A&M University

Length Overall: 62'

Draft: 12"

Type of Propulsion: Diesel

Number of Propellers: 2

Size of crew: 2

Steaming Radius: 100 miles

Electrical Generating Capacity: 10 KW

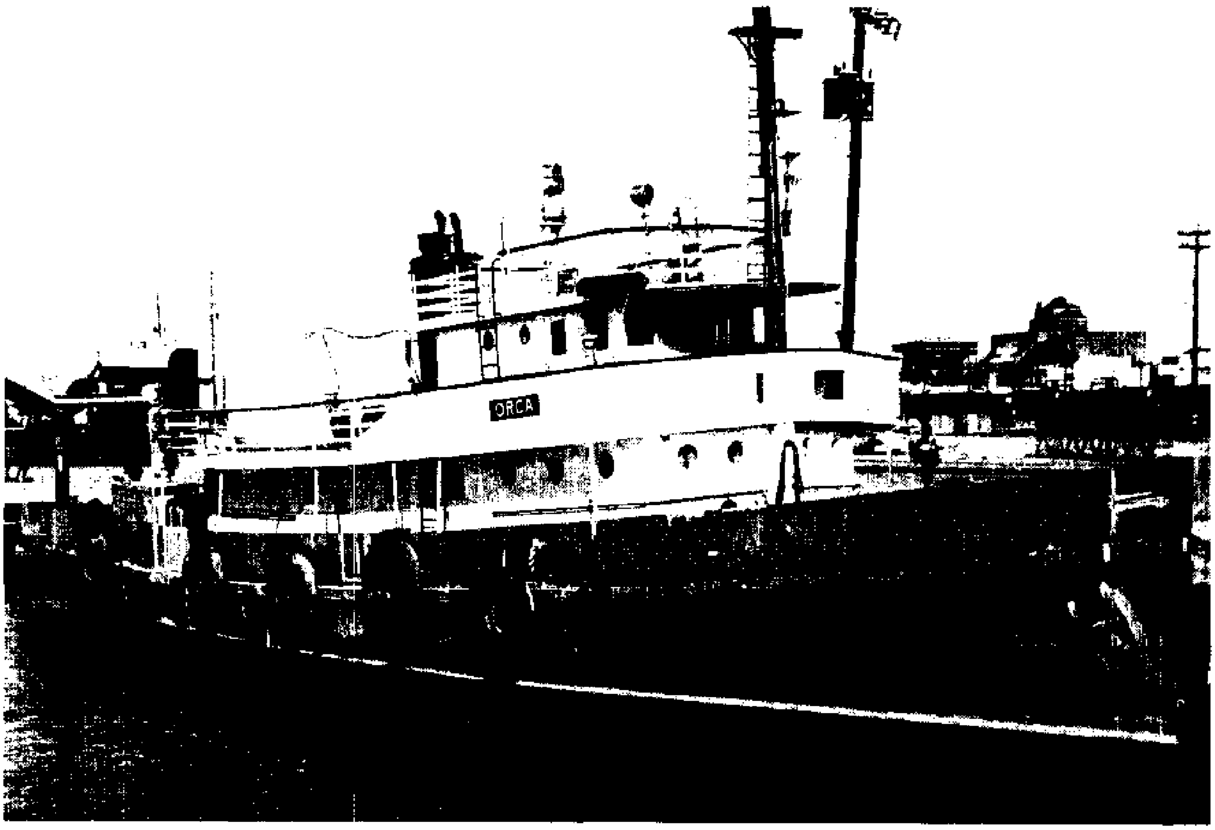
Age: 1 year

Accommodations for Non-Crew Personnel: 20/5 (single day operation/overnight operation).

Longest Voyage with Full Crew & Maximum Non-Crew Personnel: 100 miles.

Scientific Equipment (Major): One water quality monitoring system, 2 overboard pumping systems, portable monitoring equipment (pH, D.O., salinity, temperature), samplers, velocity meters, corers.

Special Features, Capabilities or Equipment: Shallow draft vessel, adjustable outdrives.



R/V ORCA
Oceanography Department
Texas A&M University

Length Overall: 98'
Size of Crew: 4-7 crewmembers, 9 scientists
Age: 46 years
Steaming Radius: 1450 miles
Displacement: 8' draft - 250 tons

Type of Propulsion: 2-GMC 6V-71 diesels, full reversible, wheel house control, twin fixed-blade screws, single rudder.

Electrical Generating Capacity: 2-45 KW AC generators, diesel drivers, rectifier unit for 25 KW DC power.

Number and Capacity of Winches: Hydraulically-controlled hydrographic winch with slip rings, 5000' of single conductor cable, bathythermograph winch, hydraulically-controlled stern winch with 4500' of 3/8" swaged wire rope.

Longest Voyage with Full Crew & Maximum Scientific Personnel: 7-10 days

Scientific Equipment (Major): Portable AC electronics van, 3.5 KHz subbottom profiling system (towed transducer), salinity-temperature-depth profiling system, radar, loran, magnetic compass, Sperry Mk 14 gyrocompass with repeaters, 3.75 KHz depth recorder.

Special Features, Capabilities or Equipment: Rigid A-frame mounted at transom on squared stern deck, air-conditioned.

D RESEARCH ORGANIZATIONS

Of the many non-profit research organizations operating along the Gulf coast the four listed below are noted for their marine-related research and development activities:

Gulf States Marine Fisheries Commission
Gulf Universities Research Consortium
Southwest Research Institute
The Marine Biomedical Institute

Gulf States Marine Fisheries Commission (New Orleans, Louisiana)

A coordinating agency among groups representing the five coastal states, Alabama, Florida, Mississippi, Louisiana and Texas. The Commission has 15 members, three from each of the member states.

It coordinates the actions in each of these five states with regard to water pollution, utilization of fisheries, estuaries, and other problems in order to recommend the most effective method dealing with such problems.

Gulf Universities Research Consortium (Galveston, Texas) 1965

A non-profit organization composed of 25 universities and research institutes from Florida to Mexico. Texas institutions comprise the majority of its members.

The consortium is devoted to the development of the Gulf of Mexico as an important natural resource and concentrates on research and development along the Gulf coastal margin.

Southwest Research Institute (San Antonio, Texas) 1947

A non-profit corporation devoted to industrial research sponsored by business, industries, governmental agencies and individuals. Laboratories are located in San Antonio, Houston and Corpus Christi, engaged in applied and basic research, air pollution, and marine science and engineering, respectively.

Marine Biomedical Institute (Galveston, Texas) 1969

Established as a result of cooperative effort by the University of Texas Medical Branch and Texas A&M University. Subsequently, these arrangements have been altered with the Institute being sponsored by several Texas institutions. Although Texas A&M is no longer aśsociated as a sponsor cooperative research between the two organizations still exists.

GOVERNMENTAL, EDUCATIONAL AND RESEARCH ORGANIZATIONS

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WORLD OCEAN FACTS

Contents

WORLD OCEAN FACTS

A THE WATER PLANET

- Volume of the world's oceans is estimated at about 328 million cubic miles.

  The volume of all land above sea level is only 1/18th of the volume of the oceans.

- If the solid earth were perfectly smooth (level) and round, the ocean would cover it to a depth of 12,000 feet.

- Ninety-seven percent of the Earth's water supply is ocean water -- approximately 317 million cubic miles.

  A little more than 2% is frozen in icecaps and glaciers, mostly in the Antarctic ice sheet.

  All fresh and salt lakes, inland seas, rivers and streams make up less than 1% of all the world's water.

  An average of 30 inches of precipitation falls on the continental U.S. annually -- about 1,430 cubic miles of water.

  Some 1,000 cubic miles of this is returned to the atmosphere.

  About 390 cubic miles a year runs back to the sea in streams and rivers.

  Most of the rest goes directly to the sea from groundwater sources.

- The greatest tides in the world occur in the Bay of Fundy, Nova Scotia, where tides rise 53 feet.

  The deep and bottom waters of all the earth's oceans are believed to be chiefly derived from the polar regions.

B GEOMORPHOLOGY

Area of the Earth: Globe: 197 million square miles

Land area: 58 million square miles (29%)
Ocean area: 139 million square miles (71%)

- Pacific: 64,186,300 square miles (46% of the world's water)
- Atlantic: 33,420,000 square miles (23.9% of the world's water)

- Indian: 28,350,500 square miles (20.3% of the world's water)
- Arctic: 3,662,200 square miles (2.6% of the world's water)
- Gulf of Mexico: 582,100 square miles

Volume of the Earth:

Globe: 260 billion cubic miles

- Land: 23 million cubic miles (above sea level)
- Oceans: 330 million cubic miles

Weight of the Oceans: 1.419×10^{18} metric tons

Average Depth of the Oceans: 3,790 meters (12,431 feet)

Average Height of Land: 840 meters (2,755 feet)

Greatest Ocean Depths:

- Pacific: Mariana Trench: 36,198 feet (approximately 7 miles)
  Atlantic: Puerto Rico Trench: 27,344 feet
  Indian: Java Trench: 24,344 feet
  Arctic: Unnamed location: 17,880 feet

Greatest Continental Heights:

- Asia: Mt. Everest: 29,028 feet
  Africa: Mt. Kibo: 19,340 feet
  North America: Mt. McKinley: 20,320 feet
  South America: Mt. Aconcagua: 22,834 feet
  Europe: Mt. El'brus: 18,481 feet
  Australia: Mt. Kosciusko: 7,310 feet
  Antarctica: Vinson Massif: 16,860 feet

The thickness of the earth's crust decreases as depth of water increases. The crustal thickness of the earth varies from 25 to 30 miles on the continental crust to about 13 miles in shallow continental shelf water, 5 miles in deep ocean water, and about one-half mile at the bottom of ocean trenches.

The bed of the ocean is underlain with basalt while granite underlies the continents.

- The continental shelves of the earth are the most productive areas on earth. The shelf is the relatively shallow seaward sloping of the continent. Its depth varies from a few kilometers to 650 kilometers off Russia in the Arctic region. The shelf off Florida extends 15 miles,while off the coast of Maine, it reaches 500 miles. All of the North Sea is a continental shelf. In the Pacific Ocean between Red China and Russia there are one million square miles of continental shelf.

    - The average width of the continental shelf is 42 miles.
    - The average depth of the shelf is 180 to 210 feet.
    - The average slope of the shelf is 10 feet in 1 mile.

  The circumference of the earth is approximately 25,000 miles, but there are 40,000 miles of undersea mountain ranges. This mountain ridge system is almost equivalent in size to Africa, Europe and North America combined.

- At 7 miles deep, pressure is about 10 tons per square inch. At sea level, pressure is about 14.5 pounds per square inch.

C OLD MAN RIVER

- The Amazon River -- world's largest -- discharges 1,300 cubic miles of water a year. It drains an area of 2.3 million square miles.

  The volume of water passing through the Drake Passage (between South America and Antartica) is more than 400 times the total volume of the Amazon.

  The Congo River in Africa -- second largest in the world -- discharges 340 cubic miles of water annually.

- Sixty-six principal rivers of the earth discharge 3,720 cubic miles of water a year.

  The Mississippi River discharges some 133 cubic miles of water a year into the Gulf of Mexico.

  The Mississippi River drains about 40% of the total area of the United States (an area of about 1,243,000 square miles).

  The Columbia River (second largest to the Mississippi in North America) discharges less than 75 cubic miles of water a year.

- All rivers -- large and small -- discharge about 9,200 cubic miles of water a year.

D LIFE IN THE SEA

- Eighty percent of many marine organisms is water.

  The female cod fish lays 4.4 million eggs per year; 99.9997% die in the larval stage.

  The herring produces 5 million eggs per year.

  The _Mola mola_ (ocean sunfish) produces 350 million eggs per year.

  The _Tilapia_ (small African cichlid) produces only 50 to 100 eggs per year. The male fish swallows the eggs to protect them.

- The weight of the zooplankton (tiny floating animals) in the upper 150 meters of the Pacific is more than 10^9 tons, or about 3 times the weight of all humans in the world.

- The 57 million tons of fish caught annually in the world constitute 1% of the total food for the world and yet account for 12% of the protein diet.

- The oceans cover 71% of the globe and yield more than 57 million tons of food each year. These foodstuffs contain as much protein as that of a herd of 200 million cattle. Some scientists maintain that the productive capacity of the sea is more than 1000 times that of arable land area.

  An annual seafood harvest of 200 million tons would provide enough protein for the 6 to 7 billion people expected to be on Earth by the year 2000.

  100 metric tons (1 metric ton = 2,250 lbs.) of phytoplankton will result in only 10 tons of copepods or 1 ton of herring or 100 kilograms of cod fish. (Calculations based on 90% loss rate)

  Many historians believe that the Golden Fleece sought by Jason and the Argonauts in Greek legend is a byssus cloth or sea silk manufactured by the marine bivalves known as pen shells (_Atrina rigida_). The legendary cloth-of-gold is made by byssus fibers secreted by the animal and used to anchor it to the sea bottom.

  The largest shark ever caught by rod and reel was a white shark caught off South Australia in 1959. It weighed 2,664 pounds and measured 16 feet 10 inches in length.

  There are approximately 500 kinds of fishes that generate appreciable amounts of electricity. The average discharge is more than 350 volts although discharges as high as 650 volts have been recorded.

A layer of living organisms spreads over much of the oceans at a depth of several hundred fathoms. This is called the deep scattering layer.

In 1938, a coelacanth, a fish thought to have become extinct 50 to 70 million years ago, was found to be living off South Africa.

E SEA MINERALS

● Common sand and gravel, sulphur, and oyster shells contribute $150 million of the $200 million of man's economy that is derived from sea minerals, excluding oil and gas.

Offshore oil wells account for 16 percent of the world's oil production, producing about 5 billion barrels daily.

Manganese nodules are scattered widely about the deep sea floor. Precipitated from seawater, they form crusts around objects such as shark's teeth. The crust includes cobalt, copper, nickel and manganese. Harvesting methods for these mineral-rich nodules are being devised.

● The saltiest ocean is the Atlantic with a salinity of 37.5°/₀₀. The Arctic and Antarctic waters are the least salty.

One of the greatest salinities recorded is from the Red Sea, where salinities of more than 270°/₀₀ below 2,000 meters have been recorded.

● The hottest ocean temperatures have been recorded in the Red Sea, where scientists have reported 132.8°F. at a depth of 2,000 meters. This reading compares with an expected temperature at that depth of about 68°F. The reason for the extreme temperature is not known.

This same area has salinities exceeding 270 °/₀₀ (close to saturation) at 2,000 meter depths.

F MARINE PARKS

The nation's first marine park , Ft. Jefferson National Monument at Dry Tortugas, was established in 1935. It consists of 8 small islands and surrounding seas.

Ten of the 47 national parks, monuments, seashores, and historical sites in the country's coastal zone are administered by the National Park Service.

● Five national seashores exist in the U.S. -- Assateague Island, Cape Cod, Fire Island, Padre Island and Point Reyes.

Christ of the Abyss is a well-known undersea landmark in the Florida Keys. The statue is located at John F. Pennekamp State Park in about 60 feet of water at Key Largo Dry Docks.

WORLD OCEAN FACTS

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GLOSSARY

PREFACE

Entries which have been italicized in the previous sections are defined here; additional terms which will be useful to the reader have also been included. Definitions have been derived from the Selected References and from *The Glossary of Oceanographic Terms* (2nd Edition) Special Publication SP-35, Edited by B. B. Baker, Jr., W. R. Deebel, R. D. Geisenderfer, U. S. Naval Oceanographic Office, Washington, D. C. 205 pgs., 1966.

As a further guide to the reader three commonly used conversion tables have been included:

- Centigrade-Fahrenheit Conversion Table
- Fathoms, Meters, Feet Equivalents
- Nautical Miles, Kilometers, Statute Miles Equivalents

Also included is a listing of advisors in marine-related fields who may be contacted for further information.

GLOSSARY

A

abyssal plain - refers to that submarine area generally below 2,000 fathoms (12,000 feet). Usually flat or gently sloping.

aerobic - pertaining to organisms which require oxygen in order to exist.

age of water - the time elapsed since a water mass was last at the surface and in contact with the atmosphere. The water's age gives an indication of the rate of overturn of ocean water, an important factor in the use of the oceans for dumping radioactive wastes and determining the rate of replenishment of nutrients.

Airy Wave Theory - deals with ideal wave motion. Ideal waves are long waves with small amplitudes and sinusoidal shapes.

alga(e) - a thallophyte possessing chlorophyll; includes almost all seaweeds.

algal reefs - reefs composed largely of remains of algae.

algin - the soluble sodium salt of alginic acid, obtained from large brown algae, especially Macrocystis.

ambient temperature - the temperature of the medium surrounding an object.

aquaculture - fish, shellfish, and algae farming; development of new seafoods, and methods of rearing larvae of clams and oysters. Today largely practiced in Japan and Southeast Asia.

artificial upwelling - the concept of having a nuclear reactor (or other unnatural source) sitting on the bottom of the ocean in cold, low productivity parts of the sea to create warmth needed to generate turbulence and subsequent fertility to the area.

athecate - see *thecate*

atmosphere - when used as a pressure term, it is defined as the pressure exerted per square centimeter by a column of mercury 760 millimeters high at a temperature of 0°C, where the acceleration of gravity is 980.665 centimeters per second per second. One atmosphere is approximately equivalent to 15 pounds per square inch.

atmospheric pressure - (also called barometric pressure). The pressure as a consequence of gravitational force exerted upon the "column" of air lying directly above the point in question.

azoic - without life; however, most ocean areas described as azoic are known to contain at least a bacterial flora.

B

backwater - 1. Water turned back by an obstruction, opposing current, etc.
2. Water held back from the main flow, as that which overflows the land and collects in low places or that forming an inlet approximately parallel to the main body and connected thereto by a narrow outlet.
3. An arm of the sea, usually lying parallel with the coast, behind a narrow strip of land.

barnacle - One of an order (Cirripedia) of crustaceans which are enclosed in a calcareous shell and sessile during their adult life. They are of two general types, the acorn barnacles and the stalked barnacles. Barnacles are one of the most notable groups of fouling organisms.

barometer - an instrument for measuring atmospheric pressure.

barrier chain - a series of barrier islands, barrier spits, and barrier beaches which extends along a considerable length of coast.

barrier lagoon - a bay roughly parallel to the coast and separated from the open ocean by barrier islands. Also the body of water encircled by coral islands and reefs, in which case it may be called an atoll lagoon.

basin - a depression of the sea floor more or less equidimensional in form and of variable extent.

bathymetric - pertaining to <u>bathymetry</u>, the science of measuring ocean depths in order to determine the sea floor configuration.

bathythermograph - (abbreviated BT). A device for obtaining a record of temperature against depth (strictly speaking, pressure) in the ocean; may be obtained from a ship underway at a speed of 12-14 knots.

bay - 1. A recess in the shore or an inlet of a sea between two capes or headlands; not as large as a gulf but larger than a cove.
2. An inward bend in the ice edge formed either by wind or current.

bay deltas - deltas formed at the mouths of streams which discharge into bays or estuaries. Their advance toward the bay mouths often extinguishes lagoons behind bay bars or completely fills open bays, thus simplifying the shoreline. When the delta forms at the head of the bay, it is a bay-head delta.

bayou - a small sluggish stream or estuarial creek, with a slow or imperceptible current, in coastal swamps or river deltas.

beach - (or seabeach). 1. The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form . . . or to the line of permanent vegetation (usually the effective limit of storm waves). A beach includes foreshore and backshore.

beach erosion - the carrying away of beach materials by wave action, tidal currents, or littoral currents, or by wind.

benthic - (also called benthonic). 1. That portion of the marine environment inhabited by marine organisms which live permanently in or on the bottom.
2. Pertaining to all submarine bottom terrain regardless of water depth.

biofouling - deterioration of structures such as wood pilings, hulls of ships and other underwater structures, by marine organisms which attach themselves to these surfaces.

biological oceanography - the study of the ocean's plant and animal life in relation to the marine environment, including the effects of habitat, sedimentation, physical and chemical changes in the environment, and other factors on the spatial and temporal distribution of marine organisms, as well as the action on organisms on the environment.

bioluminescence - (also called phosphorescence, luminescence). The production of light without sensible heat by living organisms as a result of a chemical reaction either within certain cells or organs or extracellularly in some form of secretion. Luminescence usually is induced by external stimuli, especially mechanical, such as wave action or shock waves. It is produced by a variety of marine organisms.

biomass - (also called standing crop, standing stock, live-weight). The amount of living matter per unit of water surface or volume expressed in weight units.

bird-foot delta - a delta formed by the outgrowth of pairs of natural levees making the digitate or bird-foot form.

bottom sample - a portion of the material forming the bottom, brought up for inspection.

brackish water - water in which salinity values range from approximately 0.50 to 17.00 parts per thousand. Average salinity value of Gulf water is 35.00 parts per thousand.

breakwater - a structure protecting a shore area, harbor, anchorage, or basin from waves.

buoy - a float; especially a floating object moored to the bottom, to mark a channel, anchor, shoal rock, etc. Some common types are:
A nun or nut buoy is conical in shape;
A can buoy is squat, and cylindrical or nearly cylindrical above above water and conical below water;
A spar buoy is a vertical, slender spar anchored at one end;
A bell buoy is one having a bell operated mechanically or by the action of waves, usually marking shoals or rocks;
A whistling buoy is similarly operated (by wave action), marking shoals or channel entrances;
A dan buoy carries a pole with a flag or light on it.

C

calcareous - consisting of or containing calcium or calcium carbonate; impregnated with calcium carbonate.

carbonate-clastic - a mixture of salts formed of carbonic acid and rock; composed principally of detritus transported mechanically into its place of final deposition. Sandstones and shales are the most common clastics.

carbon method - a method of radioactive dating which utilizes the ratio of radiocarbon (Carbon^{14}) to Carbon ^{12} to determine the age of samples containing formerly living matter.

cavitation - the turbulent formation, generally mechanically induced, including growth and collapse of bubbles in a fluid, and occurring when the static pressure at any point in fluid flow is less than fluid vapor pressure.

Cenozoic - refers to the latest of the eras of geologic time, following the *Mesozoic*, and extending to include the present.

Challenger Expedition - the expedition mounted by the British in H.M.S. Challenger, 1873 - 1876, which made the first extensive oceanographic research cruise.

chemical oceanography - the study of the chemical composition of the dissolved solids and gases, material in suspension, and acidity of ocean waters and their variability both geographically and temporally in relationship to the adjoining domains, namely, the atmosphere and the ocean bottom.

chert - a hard, smooth, compact, translucent rock composed primarily of crypto-crystalline quartz. Also called flint.

chlorinity - (symbol Cl). A measure of the chloride content, by mass, of sea water (grams per kilogram of sea water, or per mille). Originally chlorinity was defined as the weight of chlorine in grams per kilogram of sea water after the bromides and the iodides had been replaced by chlorides. To make the definition independent of atomic weight, chlorinity is now defined as 0.3285233 times the weight of silver equivalent to all the halides.

Because of the Law of Constancy of Relative Proportions the amount of chlorinity in a sea water sample is generally used to establish the sample's salinity.

coast - the general region of indefinite width that extends from the sea inland to the first major change in terrain features.

commensal - refers to a symbiotic relationship between two species in which only one species is benefited, while the other is simply not harmed.

containers - specially built boxes, usually 8' to 8-1/2' high, 8' wide, and in length of multiples of 10' (usually 10', 20' and 40'). These are filled with cargo and loaded onto specially-built cargo ships. They may be transferred to specially designed trucks or rail cars.

continental drift - the concept that the continents can drift on the surface of the earth because of the weakness of the suboceanic crust, such as ice can drift through water.

coral - 1. The hard calcareous skeleton of various anthrozoans and a few hydrozoans (the millepores), or the stony solidified mass of a number of such skeletons. In warm waters colonial coral forms extensive reefs of limestone. In cool or cold water coral usually appears in the form of isolated solitary individuals. Occasionally, large reefs formed in cold waters by calcareous algae (lithothamnion) have been referred to as a coral.

coral reef - a ridge or mass of limestone built up of detrital material deposited around a framework of the skeletal remains of mollusks, colonial coral, and massive calcareous algae. Coral may constitute less than half of the reef material.

core - 1. A vertical, cylindrical sample of the bottom sediments from which the nature and stratification of the bottom may be determined.
2. The central zone of the earth . Its upper boundary is defined by a seismic discontinuity at 2,900 kilometers (Gutenberg-Wiechert discontinuity).

corer - A hollow tube that is driven into the ocean floor for the purpose of collecting a bottom sediment sample.

core sample - a sample of rock, soil, snow, or ice obtained by driving a hollow tube into the medium and withdrawing it with its contained sample or core. In general, the aim of core sampling is to obtain a specimen in its undisturbed natural state for subsequent analysis.

crustacean - one of a class (Crustacea) of arthropods which breathe by means of gills or branchiae and with the body commonly covered by a hard shell or crust. The group includes the barnacles, crabs, shrimps, and lobsters.

cultch - material placed on the sea bed for encouraging oyster *setting*. These may be racks, trays or similar supports.

current - a horizontal movement of water.

D

decibar - a unit of pressure used principally in oceanography. One decibar (10^5 dynes per square centimeter) equals 0.1 bar.

In the ocean, hydrostatic pressure in decibars very nearly equals the corresponding depth in meters.

deep scattering layer - (also called DSL, false bottom, phantom bottom). The stratified population(s) of organisms in most oceanic waters which scatter sound. The scattered sound is recorded on echo-sounder records as a uniform, horizontal band or stripe, and such layers generally are found during the day at depths from 100 to 400 fathoms. A layer rarely is less than 25 fathoms thick. Several layers often are recorded at the same time and may be continuous horizontally for many miles. Most layers typically undergo diurnal vertical movements.

delta - an alluvial deposit, roughly triangular or digitate in shape, formed at the mouth of a stream or tidal inlet.

density - the ratio of the mass of any substance to the volume it occupies; the reciprocal of specific volume. In oceanography, density is equivalent to specific gravity and represents the ratio, at atmospheric pressure, of the weight of a given volume of sea water to that of an equal volume of distilled water at 4°C (39.2°F). It is thus dimensionless and is expressed in units of sigma-t.

desalination of sea water - the process by which enough dissolved salts are removed from sea water to render it potable. The most common method for desalting sea water is distillation, with the favored form being the "multi-flash" process whereby sea water is made to evaporate in low-pressure chambers.

detritus - (or debris). Any loose material produced directly from rock disintegration.

detrital - pertaining to detritus (or debris).

diapir - refers to submarine dams pushed upward by salt domes.

digenetic - pertaining to digenesis, dealing with successive generations by two different processes, as sexual and asexual.

diurnal - (or daily). 1. Daily, especially pertaining to actions which are completed within twenty-four hours and which recur every twenty-four hours; thus, most reference is made to diurnal cycles, variations, ranges, maximums, etc.
2. Having a period or cycle of approximately one lunar day (24.84 solar hours): Certain tides and tidal currents are said to be diurnal when one high water and one low water, and one flood and one ebb current, occur each lunar day.

diurnal tide - a tide in which there is only one high water and one low water each lunar day.

divergence - 1. A horizontal flow of water, in different directions, from a common center or zone; often associated with upwelling.
2. In refraction phenomena, the increasing of the distance between orthogonals in the direction of wave travel. Denotes an area of decreasing wave height and energy concentration.

domes - submarine elevations rising with steep angles from the sea floor to depths of more than 109 fathoms below the water surface.

drift bottle - (also called bottle post). A bottle, of one of various designs, which is released into the sea for use in studying currents. It contains a card (bottle paper), identifying the date and place of release, to be returned bv the finder with the date and place of recovery.

drogue - (or parachute drogue). A current measuring assembly consisting of a weighted parachute and an attached surface buoy. The parachute can be placed at any desired depth and current speed and direction determined by tracking and timing of the surface buoy.

E

echo - an acoustic signal which has been reflected or otherwise returned with sufficient magnitude and time delay to be detected as a signal distinct from that directly transmitted.

echogram - the graphic presentation of echo soundings recorded as a continuous profile of the ocean bottom.

echo sounding - (or acoustic sounding). Determination of the depth of water by measuring the time interval between emission of a sonic or ultrasonic signal and the return of its echo from the bottom.

ecology - *see marine ecology.*

eddy - a circular movement of water usually formed, where currents pass obstructions, between two adjacent currents flowing counter to each other, or along the edge of a permanent current.

effluence - a flowing out.

electric log - a graphic recording of the various electrical properties of a sediment or rock through which a hole has been drilled. Obtained by lowering electrodes into the hole.

electromagnetic energy - (often called simply radiation). Energy propagated through space or through material media in the form of an advancing disturbance in electric and magnetic fields existing in space or in the media.

El Niño - a warm current setting south along the coast of Ecuador. It generally develops just after Christmas concurrently with a southerly shift in the tropical rain belt. In exceptional years the current may extend along the coast of Peru to 12°S. When this occurs, plankton and fish are killed in the coastal waters and phenomenon somewhat like the red tide of Florida results. During this time discolored water and intense displays of bioluminescence are common. El Niño is much more widespread and destructive than the more local phenomenon of aguaje, which occurs every year.

environment - the sum total of all the external conditions which may affect an organism, community, material, or energy, if brought under the influence of these external conditions.

erosion - any or all processes by which soil or rock is broken up and transported from one place to another.

escarpment - an elongated and comparatively steep slope of the sea floor, separating flat or gently sloped areas.

estuaries - tidal bays formed by submergence or drowning of the lower portions of nonglaciated river valleys and containing measurable amounts of sea salt.

estuarine muds - Silts, often containing sufficient clay to impart some plasticity, and containing a considerable proportion of decomposed organic matter.

F

Fahrenheit temperature scale - (abbreviated F). A temperature scale with the freezing point at 32 degrees and the boiling point of water at 212 degrees at standard atmosphere pressure.

fault - a fracture or fracture zone in rock along which one side has been displaced relative to the other side. The intersection of the fault surface with any designated surface, such as the sea bottom, is called a fault line. If a fault is not a single clean fracture but a wide zone (hundreds or thousands of feet) with small interlacing faults and filled with breccia, it is called a fault zone.

fish - 1. any towed sensing device.
2. a member of the class Pisces, which includes the true fishes (elasmobranches excluded) having a bony endoskeleton, paired fins, and an operculum covering the gills.

flocculation - an aggregation into lumps, as when fine or colloidal clay particles in suspension in fresh water clump together upon contact with salt water and settle out of suspension.

flotsam - see *jettison*.

flushing time - the time required to remove or reduce to a permissible concentration any dissolved or suspended contaminant in any estuary or harbor.

food chain - the sequency of organisms in which each is food for a higher member of the sequence.

food cycle - the production, consumption, and decomposition of food in the sea, and the energy relationships involved in this cycle. Decomposition products are transformed by bacteria into inorganic nutrients suitable for use by the producers (marine plants) which, directly or indirectly, are the food source for all animals in the sea.

fossil - the remains or traces of animals or plants which have been preserved by natural causes in the earth's crust, exclusive of organisms which have been buried since the beginning of historic time.

fouling - the mass of living and nonliving bodies and particles attached to or lying on the surface of a submerged manmade or introduced object; more commonly considered to be only the living or attached bodies.

G

gastropod - (or snail). One of a class (Gastropoda) of mollusks in which the animals possess a distinct head, generally with eyes and tentacles, and a broad flat foot and usually are enclosed in a spiral shell.

geodesy - the investigation of any scientific question with the shape and dimensions of the earth. The term geodesy is often used to include both the science which must depend upon determinations of the figure and size of the earth from direct measurements made on its surface (triangulation, leveling, astronomic, and gravity determinations), and the art which utilizes the scientific determinations in a practical way.

geological oceanography - the study of the floors and margins of the oceans, including description of submarine relief features, chemical and physical composition of bottom materials, interaction of sediments and rocks with air and sea water, and action of various forms of wave energy in the submarine crust of the earth.

geologic time scale - the divisions of time, from the formation of the earth to the present, into eras, periods, and epochs based primarily upon fossil evidence.

geomorphology - that branch of both geography and geology which deals with the form of the earth, the general configuration of its surface, and the changes that take place in the evolution of land forms.

geosyncline - a large generally linear subsident trough in which many thousands of feet of sediments are accumulating or have accumulated. Deep oceanic trenches paralleling island arcs are considered to be developing geosynclines.

grab - an instrument in which jaws enclose a portion of the bottom for retrieval and study. The sample may be unrepresentative in coarse sediments where the jaws may be propped open by gravel or stones permitting part of the sample to wash out.

gravimeter - a weighing device or instrument of sufficient sensitivity to register variations in the weight of a constant mass when the mass is moved from place to place on the earth and thereby subjected to the influence of gravity at those places.

gravity corer - any type of *corer* that achieves bottom penetration solely as a result of gravitational force acting upon its mass.

groin - a low artificial wall-like structure of durable material extending from the land to seaward for a particular purpose, such as to protect the coast or to force a current to scour a channel.

Gulf Stream - a warm, well-defined, swift, and relatively narrow ocean current which originates north of Grand Bahama Island where the Florida Current and the Antilles Current meet. The Gulf Stream extends to the Grand Banks at about 40°N, 50°W where it meets the cold Labrador Current, and the two flow eastward as the North Atlantic Current.

The Florida Current, Gulf Stream, and North Atlantic Current together form the Gulf Stream system. Sometimes the entire system is referred to as the Gulf Stream.

H

halogen - any of four elements (chlorine, bromine, iodine, and fluorine) found as ions in sea water.

harbor - an area of water affording natural or artificial protection for ships.

hummock - 1. A mound or hill in pressure ice; the corresponding submerged portion is called a bummock.
2. Occasionally, any form of pressure ice which has been smoothed and weathered is called a hummock.
3. Ice pieces piled one over another on a rather smooth ice surface.

hummocky - pertaining to a hummock, a mound or hill (as in pressure ice).

hurricane - a severe tropical cyclone in the North Atlantic Ocean, Caribbean Sea, Gulf of Mexico, and the eastern North Pacific off the west coast of Mexico.

hurricane delta - a deposit formed in a lagoon by sand carried by storm waves washing across a reef.

hydrofoil - any surface, such as a wing or rudder, designed to obtain reaction upon it from the water through which it moves. In recent usage, it connotes a ship equipped with planes which provide lift when the ship is propelled forward.

hydrophone - an electroacoustic transducer that responds to water-borne sound waves and delivers essentially equivalent electric waves.

hydraulic dredging - the transportation of solid material by mixing solids with water and pumping this liquid mixture with special hydraulic pumps.

I

infrared - see *infrared radiation.*

infrared radiation - (abbreviated IR; also called long-wave radiation or infrared). Electromagnetic radiation lying in the wavelength interval from about 0.8 micron to an indefinite upper boundary sometimes arbitrarily set at 1,000 microns (0.01 centimeter). At the lower limit of this interval, the infrared radiation spectrum is bounded by visible radiation, while on its upper limit it is bounded by microwave radiation of the type important in radar technology.

infrared sensors - those sensors which measure the reflected radiation from an object as a result of illumination from natural sources, such as the sun, clouds, moon and stars.

in situ - a Latin term meaning "in place"; in the natural or original position.

intertidal zone - (also called *littoral* zone). Generally considered to be the zone between mean high water and mean low water levels.

isobar - 1. A line on a chart connecting all points of equal or constant pressure; an isopleth of pressure.

isobath - (sometimes called fathom curve, depth contour, and depth curve). A contour line connecting points of equal water depths on a chart.

J

jettison - the throwing overboard of objects, especially to lighten a craft in distress. Jettisoned objects that float are termed flotsam; those that sink, jetsam; and heavy articles that are buoyed for future recovery, lagan.

jetty - 1. In United States terminology a structure, such as a wharf or pier, so located as to influence current or protect the entrance to a harbor or river. A jetty extending into the sea to protect the coast from erosion is called a groin. A jetty which breaks the force of the sea at any place is called a breakwater. A jetty, wall, or bank, often submerged, built to direct or confine the flow of a river or tidal current is called a training wall. A wall or embankment along a waterfront, to resist encroachments of the sea, is called a sea wall.

K

karst - refers to an area of closely-spaced sinks similar to those found in Karst, Yugoslavia.

kelp - 1. One of an order (Laminariales) of usually large, blade-shaped, or vinelike brown algae (principally American usage). Representative species are the giant kelp (Macrocystis pyrifera), bull kelp (Nereocystis luetkeana or Durvillea antarctica), elk kelp (Pelagophycus porra), and laminarians (species of Laminaria).

Kelvin temperature scale - (abbreviated K; also called absolute temperature scale). An absolute temperature scale independent of the thermometric properties of the working substance. For convenience the Kelvin degree is identified with the Celsius degree (0°K=-273.16°C). Therefore, the *ice point* in the Kelvin scale is 273.16°K.

kinetic energy - the energy which a body possesses as a consequence of its motion; defined as one-half the product of its mass and the square of its speed, $1/2\ mv^2$.

knolls - elevations rising less than 500 fathoms from the sea floor with limited expanse across the summit.

L

lagoon - a shallow sound, pond, or lake generally separated from the open sea.

laguna - a shallow coastal sound, channel, or lake connected with the sea.

larva - an embryo which becomes self-sustaining and independent before it has assumed the characteristic features of its parents.

limnology - the physics and chemistry of fresh water bodies and of the classification, biology, and ecology of the organisms living in them.

littoral - (or *interidal*). the benthic zone between high and low water marks. According to some authorities the benthonic zone between the shore and water depths of approximately 100 fathoms (200 meters). It is also called the littoral benthal which is subdivided into the eulittoral and the sublittoral. The usage and interpretation of this term varies widely in the literature.

littoral drift - the material moved in the littoral zone under the influence of waves and currents.

longshore current - the resultant current produced by waves being deflected at an angle by the shore. In this case the current runs roughly parallel to the shoreline.

Loran - a long-range electronic navigation system which uses the time divergence of pulse-type transmission from two or more fixed stations. (This term is derived from the words "*lo*ng-*ra*nge *n*avigation.")

M

macroplankton - plankton organisms within the size range 1 millimeter to 1 centimeter. Sometimes referred to as mesoplankton. Formerly the term included megaloplanktonic forms.

magnetic field intensity - (also called <u>magnetic intensity</u>, <u>magnetic field</u>, <u>magnetic field strength</u>.) The magnetic force exerted on an imaginary unit magnetic pole placed at any specified point of space. It is a vector quantity. Its direction is taken as the direction toward which a north magnetic pole would tend to move under the influence of the field. If the force is measured in dynes and the unit pole is a cgs unit pole, the field intensity is given in oersteds.

mangrove - one of several genera of tropical trees or shrubs which produce many prop roots and grow along low-lying coasts into shallow water.

marine biology - The study of the plants and animals living in the sea.

marine ecology - The science which embraces all aspects of the interrelations of marine organisms and their environment and the interrelations between the organisms themselves.

marsh - An area of soft wet land. Flat land periodically flooded by salt water is called a salt marsh. Sometimes called a slough.

mean sea level - (abbreviated MSL: or sea level datum). The mean surface water level determined by averaging heights at all stages of the tide over a 19-year period. Mean sea level is usually determined from hourly height readings measured from a fixed predetermined reference level (chart datum).

Mercator projection - (also called equatorial cylindrical orthomorphic projection). A conformal projection derived by mathematical analysis in which the meridians and parallels are portrayed as parallel straight lines at right angles to one another. The scale is chosen to be true along the Equator. This projection can be equivalently described as the development of a rhumb line on the earth, being protrayed as a straight line on the projection.

Mesozoic - an era in geologic time dating from 69 to 230 million years ago.

meter - The basic unit of length of the metric system, equal to 1,650,763.73 wavelengths of Kr^{86} orange-red radiation. On October 14, 1960 the 11th General Conference on Weights and Measures adopted this standard to replace the platinum-irridium meter bar which had been kept in Paris as the international standard of lengths since 1889 under the Treaty of the Meter.
2. A device for measuring, and usually indicating, some quantity.

metric cameras - specially designed cameras equipped for the production of photographs to be used in measuring. The prefix "metric" indicates that the camera is equipped with means for maintaining and indicating the interior orientation of the photographs with sufficient accuracy for measuring purposes.

mollusk - (also spelled mollusc). One of the phylum (Mollusca) of soft unsegmented animals, most of which are protected by a calcareous shell. The phylum is second only to the insects in number of species. Some members are an important food source, some are dangerous to man, some are notable fouling organisms, and other are destructive to wood, concrete, and other submerged materials. The group includes the snails, bivalves, chitons, squid, and octopus.

mound - an artificial bank or hill of earth or stones.

mudflats - muddy or sandy coastal strips usually submerged by high tide.

N

nansen bottle - a device used by oceanographers to obtain subsurface samples of sea water. The "bottle" is lowered by wire; its valves are open at both ends. It is then closed *in situ* by allowing a weight (called a messenger) to slide down the wire and strike the reversing mechanism. This causes the bottle to turn upside down, closing the valves and reversing the *reversing thermometers* which are mounted in a special thermometer case on it. If, as is usually done, a series of bottles is lowered, then the reversal of each bottle releases another messenger to actuate the bottle beneath it.

nautical mile - (abbreviated n. mile). In general a unit used in marine navigation equal to a minute of arc of a great circle on a sphere. Depending upon the radius of the sphere, various lengths of nautical miles have been defined. The adopted value in the United States since July 1, 1959 is one international nautical mile equals 6,076.11549 U.S. feet (approximately).

Naval Oceanographic and Meterological Automatic Device - (abbreviated (NOMAD). A deep sea moored buoy which provides automatic radio transmission of surface weather and subsurface temperature.

nekton - those animals of the *pelagic division* that are active swimmers, such as most of the adult squids, fishes, and marine mammals.

neritic waters - those waters from the low water level to the approximate edge of a continental shelf.

nitrogen cycle - the series of chemical changes that nitrogen undergoes in its use by plants and animals. Inorganic nitrogenous compounds (nitrates, nitrites, and ammonium) and, to a small extent, organic nitrogenous compounds in the sea are utilized by marine plants, which form other nitrogenous compounds, such as amino acids. More complex amino acids and proteins are synthesized from these by the marine animals, which feed on the plants. Finally, these compounds, in the waste products and the dead bodies of the animals, are broken down by bacteria into inorganic compounds and simple organic compounds, completing the cycle.

nitrogen narcosis - (or rapture of the deep). An intoxicating or narcotic effect of gaseous nitrogen, produced in divers breathing air at depth. Usually the effect first becomes noticeable at a depth of 100 feet or more, although individuals vary in their susceptibility.

nodules - (or halobolite, pelagite). Concretionary lumps of manganese, cobalt, iron, and nickel found widely scattered on the ocean floor. Rocks of various sizes and shapes often are encrusted with these metals.

notochord - a rod-like embryonic structure which is the primitive backbone of the higher vertebrates, but which persists throughout life in certain of the lower forms.

nuclear oceanography - The study of the nuclear properties of the marine environment and the nuclear phenomena occurring therein. There is a broad oceanographic discipline which includes radioisotopic oceanography and the application of nuclear science and technology to oceanographic investigations.

nutrient - in the ocean any one of a number of inorganic or organic compounds or ions used primarily in the nutrition of primary producers. Nitrogen and phosphorus compounds are essential nutrients. Silicates are essential for the growth and development of diatoms. Vitamins such as B_{12} are essential to many *algae*.

O

ocean - (or *sea*). 1. the intercommunicating body of salt water occupying the depressions of the earth's surface.
2. One of the major primary subdivisions of the above, bounded by continents, the Equator, and other imaginary lines.

ocean basin - that part of the floor of the ocean that is more than about 100 fathoms below sea level.

ocean current - a movement of ocean water characterized by regularity, either of a cyclic nature or more commonly as a continuous stream flowing along a definable path.
Three general classes, by cause, may be distinguished: (1) currents related to sea water density gradients, comprising the various types of gradient currents; (2) wind-driven currents, which are those directly produced by the stress exerted by the wind upon the surface and ; (3) currents produced by long-wave motions. The last is principally the tidal currents, but may include currents associated with internal waves, tsunamis, and seiches. The major ocean currents are of continuous, stream-flow character, and are of first-order importance in the maintenance of the earth's thermodynamic balance.

oceanographic cast - a single lowering of a series of *Nansen bottles* at an oceanographic station.

oceanographic analysis - the science of manual or automatic production of charts of oceanographic *parameters* in which isopleths are drawn to indicated data by some rational theory.

oceanography - 1. The study of the sea, embracing and integrating all knowledge pertaining to the sea's physical boundaries, the chemistry and physics at sea water, and marine biology.
2. In strict usage oceanography is the description of the marine environment, whereas oceanology is the study of the oceans and related sciences.

offshore - the comparatively flat zone of variable width which extends from the outer margin of the rather steeply sloping shoreface to the edge of the continental shelf.

P

paleomagnetism - remanent magnetism produced by the earth's field when a material was initially formed.

panoramic photography - photography dealing with a more comprehensive view than usual.

paralytic shellfish poisioning - an intoxication in humans resulting from the ingestion of marine *mollusks*, usually mussels or soft clams, that become toxic during periods of high concentrations of certain dinoflagellates. The effects range from mild discomfort to fatal respiratory paralysis, with symptoms including tingling or burning of the lips, gums, tongue, and face followed by numbness of the extremities, a general feeling of weakness and dizziness, inability to coordinate muscular movements, and respiratory distress.

parameter - 1. In general, any quantity of a problem that is not an independent variable. More specifically, the term is often used to distinguish, from dependent variables, quantities which may be more or less arbitrarily assigned values for purposes of the problem at hand.

parts per thousand - see *per mille*.

pelagic - a primary division of the sea which includes the whole mass of water.

per mille -(symbol ‰). Per thousand or 10^{-3}; used in the same way as percent (%, per hundred or 10^{-2}). Per mile (by weight) as commonly used in oceanography for *salinity* and *chlorinity*; for example, a salinity of 0.03452 (or 3.452 percent) is commonly stated as 34.52 per mille (parts per thousand).

photosynthesis - the manufacturing of carbohydrate food from carbon dioxide and water in the presence of chlorophyll, utilizing light energy and releasing oxygen.

physical oceanography - the study of the physical aspects of the ocean, such as its density, temperature, ability to transmit light and sound, and sea ice; the movements of the sea, such as tides, currents, and waves; and the variability of these factors both geographically and temporally in relationship to the adjoining domains, namely, the atmosphere and the ocean bottom.

phytoplankton - the plant forms of *plankton*. They are the basic synthesizers of organic matter (by *photosynthesis*) in the pelagic division. The most abundant of the phytoplankton are the diatoms.

plankton - the passively drifting or weakly swimming organisms in marine and fresh waters. Members of this group range in size from microscopic plants to jellyfishes measuring up to 6 feet across the bell, and included the eggs and larval stages of the *nekton* and *benthos*.

plankton bloom - (or *sea bloom*). an enormous concentration of *plankton* (usually *phytoplankton*) in an area, caused either by an explosive or a gradual multiplication of organisms (sometimes of a single species) and usually producing an obvious change in the physical appearance of the sea surface, such as discoloration. Blooms consisting of millions of cells per liter often have been reported.

pleistocene - a period in geologic history occurring approximately 1 million years ago.

primary production - (or gross primary production, primary productivity). The amount of organic matter synthesized by organisms from inorganic substances in unit time in a unit volume of water or in a column of water of unit area cross section and extending from the surface to the bottom.

Q

quasi-cratonic - terrain resembling areas of volcanic craters.

R

radar-sensors - those sensors which beam radio-frequency impulses to an object and then back.

radioactive age determination - the determination of the age of a rock or sediment by measuring the proportion of the radioisotope Carbon^{14} in the organic material it contains. A method (radiocarbon dating) is based upon the known rate of conversion of carbon to its isotope and is accurate to a maximum age of about 30,000 years. Other chemical elements can be used similarly for age determination.

radiocarbon age - This age is calculated from the specific activity, due to Carbon^{14}, of the carbon in a once-living object; such radiocarbon dating is possible because Carbon^{14} is produced in the atmosphere by cosmic rays and is incorporated into all living objects; after death the Carbon^{14} activity decays exponentially with a half-life of 5,568 years.

red tide - a red or reddish-brown discoloration of surface waters, most frequently in coastal regions, caused by concentrations of certain microscopic organisms, particularly dinoflagellates.

reflection - the process whereby a surface of discontinuity turns back a portion of the incident radiation into the medium through which the radiation approached.

refraction - the process in which the direction of energy propagation is changed as the result of a change in density within the propagating medium, or as the energy passes through the interface representing a density discontinuity between two media.

remote sensing - the gathering and recording of information without actual contact with the object or area being investigated.

reversing thermometer - a mercury-in-glass thermometer that records temperature upon being inverted and thereafter retains its reading until returned to the first position. It consists of a conventional bulb connected to a capillary in which a constriction is placed so that upon reversal the mercury column breaks off in a reproducible manner. The mercury runs into a smaller bulb at the other end of the capillary, which is graduated to read temperature. A 360° turn in a locally widened portion of the capillary serves as a trap to prevent further addition of mercury if the thermometer is warmed and the mercury expands past the break-off point.

In measuring temperatures at depths in the sea, both protected thermometers and unprotected thermometers are used, each of which is provided with an auxiliary thermometer. They are generally used in pairs on Nansen bottles. They are usually read to 0.01°C. and after the proper corrections have been applied, their readings are considered reliable to 0.02°C.

ridges - long, narrow elevations of the sea floor with steep sides and irregular topography.

river effluence - refers to river flow, generally from the river mouth.

rotary current - a *tidal current* that flows continually, with the direction of flow changing through all points of the compass during a tide cycle.

S

salinity - a measure of the quantity of dissolved salts in sea water. It is formally defined as the total amount of dissolved solids in sea water in parts per thousand (°/₀₀) by weight when all the carbonate has been converted to oxide, the bromide and iodide to chloride, and all organic matter is completely oxidized. These qualifications result from the chemical difficulty in drying the salts in sea water.

salt marsh - flat, poorly drained coastal swamps which are flooded by most high tides.

salt water wedge - an intrusion in a tidal estuary of sea water in the form of a wedge characterized by a pronounced increase in salinity from surface to bottom.

saprophytic - obtaining food by absorbing dissolved organic foods.

Sargasso Sea - the region of the North Atlantic Ocean to the east and south of the Gulf Stream system. This is a region of convergence of the surface waters and is characterized by clear, warm water, a deep blue color, and large quantitites of floating Sargassum or gulfweed.

scour - the downward and sideward erosion of a sediment bed by wave or current action.

sea - a subdivision of an ocean. All seas except inland seas are physically interconnected parts of the earth's total salt water system. Two types are distinguished, mediterranean and adjacent. Mediterraneans are groups of seas, collectively separated from the major water body of an individual sea. Adjacent seas are those connected individually to the larger body.

sea bloom - See *plankton bloom.*

sea state - (or state of the sea). The numerical or written description of ocean surface roughness. For more precise usage sea state may be defined as the average height of the highest one third of the waves observed in a wave train, referred to a numerical code which covers an increasing range of such heights as indicated by WMO Code 75 table below:

Code	Wave height (feet)
0	0
1	0-1/3
2	1/3-1 2/3
3	1 2/3-4
4	4-8
5	8-13
6	13-20
7	20-30
8	30-45
9	Over 45

secchi disc - a white, black, or varicolored disc, 30 centimeters (about 11.7 inches) in diameter, used to measure water transparency (clarity). The disc is lowered in the water and the depth (in meters) at which it disappears from sight is averaged with the depth at which it reappears. This average value is used to represent sea water transparency.

secondary production - the organic matter produced by herbivores of the *zooplankton* in a given area or volume in a given time. The second trophic level.

sediment - particulate organic and inorganic matter which accumulates in a loose unconsolidated form. It may be chemically precipitated from solution, secreted by organisms, or transported by air, ice, wind, or water and deposited.

sedimentary basin - a depression, often marine, in which sediments are deposited. The deposits are usually thickest in the center and thinner toward the edges.

seismic profile - the data resulting from a single series of observations made at one geographic location with a linear arrangement of seismometers.

seismic profiler - a continuous deep sea reflection system used to study the structure beneath the ocean floor to depths of 10,000 feet or more. The reflections are recorded on a drum whose rotation is actuated by the initial explosion.

seismic reflection - the measurements, and recording in wave form, of the travel time of acoustic energy reflected back to detectors from rock or sediment layers which have different elastic wave velocities.

semidiurnal - (or semidaily). Having a period or cycle of approximately half a lunar day (12.42 solar hours). The tides and tidal currents are semidiurnal when two flood and two ebb periods occur each lunar day.

semidiurnal tide - the type of tide having two high waters and two low waters each tidal day, with small inequalities between successive high and successive low water heights and durations.

sensor - a technical means, usually electronic, to extend man's natural senses by means of energy emitted or reflected. The energy may be nuclear, electromagnetic, including the visible and invisible portions of the spectrum, chemical, biological, thermal, or mechanical.

sessile - 1. Attached directly by base, without stipe or stalk.
2. Permanently attached; not free to move about.

setting - the act of attaching to a surface, such as oyster *"spat"* attaching to bottom material.

shelf edge - the line along which there is a marked increase of slope at the outer margin of a continental (or island) shelf.
Note: Conventionally the shelf edge has been taken at 100 fathoms (200 meters).

shellfish - any aquatic invetebrate with a hard external covering, but more commonly any *crustacean* or *mollusk*, especially the edible commercial species.

shoal - 1. A submerged ridge, bank, or bar consisting of or covered by unconsolidated sediments (mud, sand, gravel) which is at or near enough to the water surface to constitute a danger to navigation. If composed of rock or coral, it is called a reef.

shore - the narrow strip of land in immediate contact with the sea, including the zone between high and low water lines.

shoreline - the boundary line between a body of water and the land at high tide (usually mean high water).

sill - the low part of the ridge or rise separating ocean basins from one another or from the adjacent sea floor.

sofar - 1. An acronym derived from the expression "*so*und *f*ixing *a*nd *r*anging."
2. A position-fixing system by which hyperbolic lines of position are determined by measuring, at shore listening stations, the difference in the time of reception of sound signals produced in a sound channel in the sea.

solar tide - the tide caused solely by the tide producing forces of the sun.

sonar - 1. An acronym derived from the expression "*so*und *n*avigation *a*nd *r*anging." The method or the equipment for determining by underwater sound techniques the presence, location, or nature of objects in the sea.
2. A system for determining distance of an underwater object by measuring the interval of time between transmission of an underwater sonic or ultrasonic signal and return of its echo.

sonobuoy - a free floating or anchored device that includes a buoy with radio telemetering equipment and a *hydrophone* suspended beneath. Sound signals received at the hydrophone are transmitted to a nearby receiver for analysis.

spat - the spawn or young of bivalve *mollusks*.

specific valume - the volume per unit mass of a substance, or the reciprocal of density.

In oceanographic practice, specific volume is taken as the reciprocal of specific gravity.

spectrum - a visual display, a photographic record, or a plot of the distribution of the intensity of energy dispersion of a given kind as a function of its wavelength, energy, frequency, momentum, mass, or any related quantity.

spoil area - an area where dredged material is deposited.

Spilhaus-Miller sea sampler - a *bathythermograph* with attached containers designed to collect sea water samples at predetermined depths. The sample bottles are triggered to close at both ends by the pressure sensing element of the bathythermograph.

sterols - complex, chiefly unsaturated solid alcohols found in animals and plants.

stratigraphy - the branch of geology which treats of the formation, composition, sequence, and correlation of layered or bedded rocks.

sublittoral - that benthic region extending from mean low water to a depth of about 100 fathoms (200 meters), or the edge of a continental shelf.

surface current - a general term meaning that part of a directly observed movement of water which, in nearshore areas, does not extend more than 3 to 10 feet (1 to 3 meters) below the surface; in deep, or open ocean areas, surface currents generally are considered to extend from the surface to depths of about 33 feet (10 meters).

syncline - a fold or arch of rock in which strata dip inward toward the plane of the axis.

T

tectonics - (a) pertaining to the structure of the earth; (b) referring to the forces or conditions within the earth that cause movements of the crust, as earthquakes, folds, faults, or the like.

thecate - an enveloping sheath or case of an animal. *Athecate* - without this sheath or case.

thermal gradients - the rate of increase or decrease with respect to temperature.

thermocline - a vertical negative temperature gradient in some layer of a body of water, which is appreciably greater than the gradients above and below it; also a layer in which such a gradient occurs. The principal thermoclines in the ocean are either seasonal, due to heating of the surface water in summer, or permanent.

tidal current - (sometimes called tidal stream). The alternating horizontal movement of water associated with the rise and fall of the tide caused by the astronomical tide-producing forces.

tidal pool - a pool of water remaining on a beach or reef after recession of the tide.

tide - the periodic rising and falling of the earth's oceans and atmosphere. It results from the tide-producing forces of the moon and sun acting upon the rotating earth. This disturbance actually propagates as a wave through the atmosphere and through the surface layer of the oceans.

tide gage - a device for measuring the height of tide. It may be simply a graduated staff in a sheltered location where visual observations can be made at any desired time; or it may consist of an elaborate recording instrument (sometimes called marigraph) making a continuous graphic record of tide height against time.

tide range - the difference in height between consecutive high and low waters. Where the type of tide is diurnal the mean range is the same as the diurnal range.

tidewater - (or tidal water). Water affected by tides or sometimes that part of it which covers the tideland. The term is sometimes used broadly to designate the seaboard.

Tongue of the Ocean - (abbreviated TOTO). A steep-sided, deepwater embayment approximately 100 nautical miles long, 20 nautical miles wide, and one nautical mile deep, connected to the Atlantic Ocean by Northeast Providence Channel and Northwest Providence Channel and trends south-east into the Great Bahama Bank, terminating in a circular cul-de-sac.

tsunami - (or tunami, tidal wave, seismic sea wave). A long-period sea wave produced by a submarine earthquake or volcanic eruption. It may travel unnoticed across the ocean for thousands of miles from its point of origin and builds up to great heights over shoal water.

turbidites - deposits characterized by both vertically and horizontally graded bedding.

turbidity currents - (or density currents, mud flows, suspension currents) - Highly turbid, relatively dense currents carrying large quantities of clay, silt and sand in suspension, which flow down submarine slopes through less dense sea water.

U

undercurrent - a water current flowing beneath a surface current at a different speed or in a different direction.

undertow - a seaward flow near the bottom of a sloping beach.

upwelling - the process by which water rises from a lower to a higher depth, usually as a result of divergence and offshore currents.

V

volume transport - the volume of moving water measured between two points of reference and expressed in cubic meters per second. It is determined by measuring the cross-sectional areal limits of the current and multiplying this figure by the current speed.

W

wake - the region of turbulence immediately to the rear of a solid body in motion relative to a fluid.

water color - the apparent color of the surface layers of the sea caused by the reflection of certain components of the visible light spectrum coupled with the effects of dissolved material, concentration of plankton, detritus, or other matter. Color of oceanic water varies from deep blue to yellow and is expressed by number values which are a variation of the Forel scale. Plankton concentrations may cause a temporary appearance of red, green, white, or other colors.

water mass - a body of water usually identified by its T-S curve or chemical content, and normally consisting of a mixture of two or more water types.

waterspout - usually, a tornado occurring over water; rarely, a lesser whirlwind over water, comparable in intensity to a dust devil over land. Waterspouts are most common over tropical and subtropical waters.

wave crest - the highest part of a wave. Also that part of the wave above still water level.

wave height - the vertical distance between a *wave crest* and the preceding *wave trough*.

wave length - the horizontal distance between points on two successive waves measured perpendicularly to the *wave crest*.

wave shoaling - the progression of the wave from deep to shallow water, characterized by an increase in wave height, a decrease in *wave length* and celerity.

wave trough - the lowest part of a wave form between successive *wave crests*. Also that part of a wave below still water level.

wind-driven current - (sometimes called wind drift, current). A current formed by the force of the wind.

wind set-up - the vertical rise in the still water level on the leeward side of a body of water caused by wind stresses on the surface of water.

Z

ZoBell bottle - a sterile bottle constructed to collect sea water samples at a desired depth for bacteriological analysis. Multiple sampling can be accomplished in a manner similar to an oceanographic cast.

zoea - an early larval form of certain decapod crustaceans.

zooplankton - The animal forms of *plankton*.

Centigrade-Fahrenheit
Conversion Table

FAHRENHEIT	CENTIGRADE or CELSIUS	FAHRENHEIT	CENTIGRADE or CELSIUS
104	40.0	50	10.0
102	38.9	48	8.9
100	37.8	46	7.8
98	36.7	44	6.7
96	35.6	42	5.6
94	34.4	40	4.4
92	33.3	38	3.3
90	32.2	36	2.2
88	31.1	34	+1.1
86	30.0	32	0.0
84	28.9	30	-1.1
82	27.8	28	2.2
80	26.7	26	3.3
78	25.6	24	4.4
76	24.4	22	5.6
74	23.3	20	6.7
72	22.2	18	7.8
70	21.1	16	8.9
68	20.0	14	10.0
66	18.9	12	11.1
64	17.8	10	12.2
62	16.7	8	13.3
60	15.6	6	14.4
58	14.4	4	15.6
56	13.3	2	16.7
54	12.2	0	-17.8
52	11.1		

Fathoms, Meters, Feet Equivalents

FATHOMS	METERS	FEET	FATHOMS	METERS	FEET	FATHOMS	METERS	FEET	FATHOMS	METERS	FEET
1	1.8	6	110	201.2	660	275	502.9	1650	1400	2560.3	8400
5	9.1	30	120	219.5	720	300	548.6	1800	1500	2743.2	9000
10	18.3	60	130	237.7	780	400	731.5	2400	1600	2926.1	9600
20	36.6	120	140	256.0	840	500	914.4	3000	1700	3109.0	10200
30	54.9	180	150	274.3	900	600	1097.3	3600	1800	3291.8	10800
40	73.2	240	160	292.6	960	700	1280.2	4200	1900	3474.7	11400
50	91.4	300	170	310.9	1020	800	1463.0	4800	2000	3657.6	12000
60	109.7	360	180	329.2	1080	900	1645.9	5400	3000	5486.4	18000
70	128.0	420	190	347.5	1140	1000	1828.8	6000	4000	7315.2	24000
80	146.3	480	200	365.8	1200	1100	2011.7	6600	5000	9144.0	30000
90	164.6	540	225	411.5	1350	1200	2194.6	7200	6000	10972.8	36000
100	182.9	600	250	457.2	1500	1300	2377.4	7800			

Nautical Miles, Kilometers, Statute Miles, Equivalents

NAUTICAL MILES	KILOMETERS	STATUTE MILES	NAUTICAL MILES	KILOMETERS	STATUTE MILES
1	1.9	1.2	20	37	23.0
2	3.7	2.3	30	56	34.5
3	5.6	3.5	40	74	46.1
4	7.4	4.6	50	93	57.6
5	9.3	5.8	60	111	69.1
6	11.1	6.9	70	130	80.6
7	13.0	8.1	80	148	92.1
8	14.8	9.2	90	167	103.6
9	16.7	10.4	100	185	115.2

A knot is a nautical measurement of speed. One knot equals one nautical mile per hour. 0.8684 knots equals one statute mile per hour. 0.5396 knots equals one kilometer per hour.

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