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TEXAS COASTAL ZONE BIOTOPES:
AN ECOGRAPHY

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Both annual personal ($30) and library subscriptions ($80) are welcomed. Inquiries should be sent to T. Villareal, *Contributions in Marine Science*, Marine Science Institute, The University of Texas at Austin, 750 Channel View Dr., Port Aransas, TX 78373 (cms@utmsi.utexas.edu). Selected back issues prior to 1998 (Vols. 32 and earlier) are available at $10 per volume plus shipping. Potential manuscripts are welcomed, but please contact the Editor prior to submission.

Front Cover: Nicolas de Fer, *Les Costes aux Environs de la Riviere de Misisipi*. Engraving. *L'Atlas Cureux* (Paris, 1700-1704). Martin, J.C. and R.S. Martin. 1984. *Maps of Texas and the Southwest, 1513-1900*. Univ. New Mexico Press, Albuquerque. A French nobleman, René Robert Cavalier, Sieur de la Salle, reconnoitered the Mississippi from the north in 1682, claiming for France the lands the river drained. He returned to Paris and secured permission to establish a colony at the mouth of the Mississippi to formalize the French claim. When he returned, he missed the Mississippi delta and landed on the Texas coast near Matagorda Bay, an error probably due to his inability to calculate longitude and because prominent maps of the period ... grossly misjudged the location of the Mississippi, placing it far to the west of its true location. Nevertheless, La Salle established Fort Saint Louis in 1685 on the Texas coast, an act which greatly exacerbated France's rivalry with Spain in North America. The French royal family's official geographer, Nicolas de Fer, produced this map to show the progress the French were making in exploring their vast claims in North America.

This work was provided by the Corpus Christi Museum of Science and History (512-883-2862).

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EDITOR'S FORWARD

Volume 33 marks the resumption of publication after an 8 year hiatus in *Contributions in Marine Science.* The Journal has a new Editor, a new format, and a new focus. The series will now emphasize reviews and monographs. This is due, in part, to our limited staff and funding, but also is a reflection of the increasing scarcity of extended monographs, reviews and taxonomic keys focusing on the Gulf of Mexico and Texas coast. The *Contributions* series cannot compete with the large journals for short papers, but we believe there is a need for longer, synthetic publications that rarely get published elsewhere. We will publish at least one volume a year with additional volumes published as funds permit.

Our choice of material for the first issue was based on a desire to publish a work that represented the scientific contributions of the Institute during our 50 year celebration, but material that was also accessible to a lay audience. Oppenheimer et al.'s *Biotopes* seemed the best choice. As noted in the Author's forward, this work played a pivotal role in the formulation of a coastal zone management program in Texas. By its nature, it is a teaching document as well, and we hope it can be used by educators along the Texas coast. It has been expanded by addition of two more biotopes and has been reorganized. However, it is also a snapshot in time and is a historical retrospective on the Texas coast of approximately 1972. We note with satisfaction that the brown pelican, near extinction in 1972 and missing from the *Biotopes*, is now a common sight along the Texas coast.

The satisfaction in continuing the *Contributions in Marine Science* is tempered by the recent loss of our librarian, Ruth Grundy. Her efforts kept the *Contributions in Marine Science* published for many years and was instrumental in the early formulation of the *Biotopes* volume. She carefully preserved the manuscript and artwork, and it is likely that the *Contributions in Marine Science* would not have continued except for her encouragement and determination to see it published again. It is to her memory, and with gratitude for all she provided to the UT Marine Science Institute over the years, that we dedicate this issue.

Tracy Villareal
Editor

Barbara Dorf
Technical Editor

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TEXAS COASTAL ZONE BIOTOPES: AN ECOGRAPHY

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PREFACE

The concept of a biotope description of environments of the Texas coast began in 1971. It was developed to scientifically identify the respective ecological niches of the Texas coast in order to encourage the sensible management of potential ecological changes caused by coastal development. A description of the coastal environment was needed to provide background for the constructive use of our valuable coastal environment during inevitable growth of population, industry, and tourism.

The project began with a $25,000 grant (Interagency Cooperation Contract No. IAC-0685) from then Governor Preston Smith to Jim Goodwin. This was the beginning of the Coastal Zone Management program for the State of Texas and was a forerunner of the U.S. development of Coastal Zone Management.

As Jim was to head the Southern States Nuclear Board, and I was director of the Port Aransas Marine Institute, we decided to direct the grant to the late Prof. Gus Fruh in the Dept. of Engineering at Austin. Dr. Fruh and I organized a team and obtained matching funding from the National Academy of Science (GI-34780X). This team produced an eight volume series of final reports on Establishment of Operational Guidelines for Texas Coastal Zone Management that complemented the work of Prof. Flawn of the Bureau of Economic Geology who was at that time developing a series of Environmental Geological Atlases of the Texas Coastal Zone, under Dr. Brown, Project Coordinator. The entire project was coordinated through the Division of Natural Resources and Environment of The University of Texas at Austin during the period May 1972 to May 1974.

The biotope illustrations were painted in watercolor by a wildlife ecologist and artist Marsha Kier. The pictures are a scientifically accurate artist's rendition developed by a field team of ecologists, who sketched in the field, identified the individual living organisms, and aided in the niche perspective. The result is a pictorial summary of the environment, plant, and animal population of the various identified ecological systems we called biotopes.

One of the important achievements of this group was the development of an effective two-dimensional model of estuarine-bay circulation that allowed the prediction and evaluation of nutrient flux, waste input, dilution, and coastal interchange in the system. Various scenarios for maximum and minimum rainfall, tidal variations, and hurricane effects were incorporated in the model. The materials from the study were later used by me in conjunction with Bernard Johnson for the two volume report, Regional Assessment Study-Houston Ship Channel-Galveston Bay, prepared under a contract with the National Commission on Water Quality, 1975.

The best example of the use of the biotopes may be illustrated by a 1973 report made for the Nueces County Navigation District No. 1, called An Environmental Impact Statement for the Development of a Multi-Purpose Deep-Draft Inshore Port on Harbor Island, Texas to Accommodate VLCC Vessels, published by the Port of Corpus Christi, author Carl Oppenheimer. This report started by identifying the historical changes of Aransas Pass as recorded in charts and reports of the jetty construction by the Corps of Engineers. Aerial photographs were used to show the 1972 distribution of water and land and the projected changes that were to be made. Tables and figures in the report showed the visual and acreage changes in the six impacted biotopes for Phases 1 and 2 of the deep port development. The visual presentation of the biotopes clearly showed the various potential changes to the ecology of the area.

The pioneering biotope project was the backbone for Coastal Zone Management Criteria. In a modern context, the biotopes and other criteria provide a historical baseline for the environmental ecology of the Texas coast for 1972-74. The color illustrations of Marsha Kier accurately describe the environmental niches in that time period.

Carl H. Oppenheimer
Austin, Texas 1998

INTRODUCTION

Today's* concern about the state of our coastal environment is primarily related to esthetics, recreation, or sport and commercial fisheries. We tend to associate any change

*Editor's note: The text has been left as originally written as much as possible. Readers should note that "today" refers to the early 1970's. Species nomenclature has been updated to reflect modern (1990's) revisions. Where nomenclature has been revised since the 1970's, revised names are shown in brackets ([]).

created by human industry with the above parameters. As human interest in the coastal zone continues, it is essential that we define the above terms so that natural or artificial changes can be evaluated. We must also recognize that our present day bays have been altered by many human activities with both beneficial and adverse results. The original shallow bays and estuaries (Fig. 1) with restricted passes to the Gulf of Mexico were subjected to large fluctuations in salinity as alternate weather patterns of rainfall and drought occurred. To some degree, humans have changed these variable conditions through increasing control of the bays resulting from construction of dams and ship channels. Along with these alterations of the physical environment, human perceptions have changed as well.

Esthetics is a very difficult concept to evaluate or identify. To some, the change of an estuary to a modern well-designed marina is acceptable, and many would agree that a marina, with its picturesque sailboats, motor cruisers and accompanying buildings with tennis courts and swimming pools, is attractive. Yet such modifications alter the biological community in some ways and certainly alter the natural environment. At the same time, our natural environment is finite. Therefore, some form of management must be developed to assure both esthetic and functional uses of the coastal zone.

Because esthetics, biological environment and physiography are so interrelated and have changeable meanings in various environments, we are obligated to think of the environment in terms of biological change, as environmental protection is presently a basis for much dialogue and sometimes controversy. Estuarine inventories of plants and animals in the Gulf are not difficult, and many are on hand in a variety of manuscripts, monographs and check lists. However, often the inventories either concern specialized groups of organisms for specific localities, or long lists of scientific names. We have chosen an old concept and adapted it to identify the relationships among biological communities that may be changed when humans or nature modifies the coastal environment. The chosen term is BIOTOPE, which is defined in Webster's as a region uniform in environmental conditions and in populations of animals and plants for which it is the habitat. Although the biological environment may appear to the layperson as either diverse or uniform without pattern, there are recognizable biotic assemblages that have some degree of relationship in their composition. Such recognizable assemblages may cover wide areas, such as the extensive turtle grass flats, or may be discrete small units, such as an oyster reef. Thus we have adapted the term BIOTOPE to identify such assemblages and initially suggest the following 22 examples listed in Table 1. Seventeen of them plus an overview are illustrated.

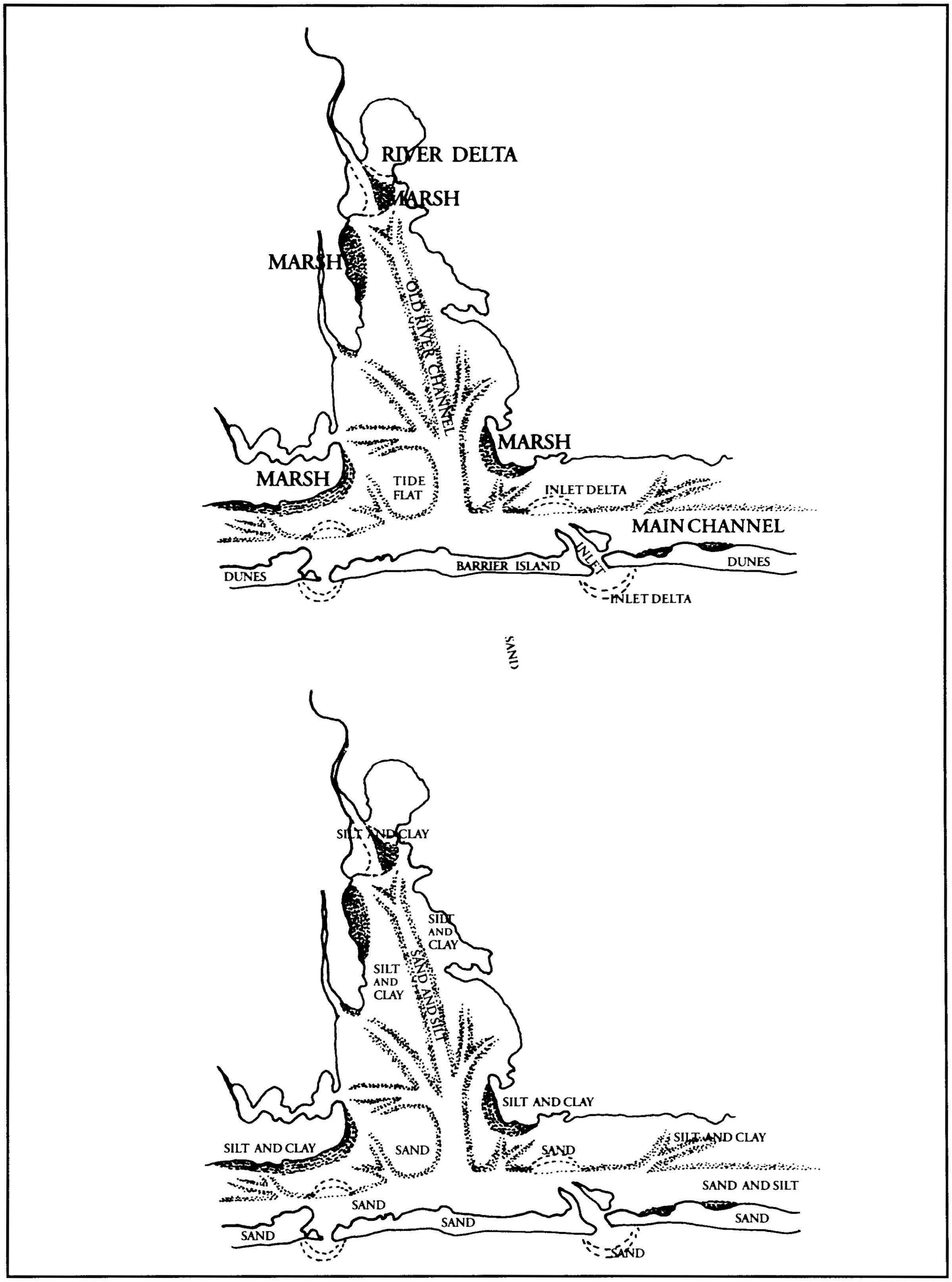

FIG. 1. Typical estuary topography. Adapted from Phleger (1969).

TABLE 1

Biotopes of the Texas Coastal Zone

Continental Shelf
Artificial Reef
Jetty and Bulkhead
Open Beach
Dune
Barrier Flat
Marina
Spartina Salt Water Marsh
*Hypersaline
*Channel
Spoil Bank
Cyanobacteria (Blue-Green Algal) Flat
Mud Flat
Thalassia Grass Flat
Sand Flat
Bay Planktonic
Oyster Reef
Juncus Fresh Water Marsh
*River Mouth
River Floodplain Forest
*Prairie Grassland
*Upland Deciduous Forest

*These biotopes have not been illustrated.

If the concept of the biotope is to be used to describe common, recognizable Texas Gulf coast communities, then we can use these descriptions to demonstrate the results of changes. For example, if one plans to dredge a grass flat to produce a spoil bank and a channel, the biotopes of these three areas can be compared to allow the decision maker to evaluate how the change may affect the area involved. Because the decision maker is not always scientifically oriented, we have elected to describe the biotope by artists' renditions accompanied with lists of common and scientific names of major species of plants and animals and a description of the relative productivity of the major organisms in the area.

To make use of the biotope concept, we must set some initial guidelines. As most communities are dependent on the physical and chemical features of the coastal zone, we can assume that some average conditions exist, with the recognition that natural forces such as excessive rainfall or storms may momentarily change these conditions and thus may change the assemblage of living organisms. Figure 2 compares the annual primary production rate of organic carbon for several biotopes versus their estimated worldwide area. These rates show how productive estuaries are compared to most other marine environments. However, it is important to note that although algal beds and reefs have higher annual production rates than estuaries, they occupy a much smaller area, therefore their overall contribution is relatively small. These productivity estimates also suggest that estuaries have a tremendous role as a food (i.e., energy) source for coastal and offshore biota such as those that form the commercial fishery. Despite their relatively small size compared to the entire world ocean, estuaries are, by virtue of their proximity to humans, most susceptible to human-induced environmental perturbations.

We recognize the impossibility of listing and illustrating all the diverse living organisms from unicellular forms to large mammals in any biotope. However, there are identifying assemblages of organisms that can be used to show the biological balance of any specific biotope. Because of the migratory habits and seasonal life cycles of many coastal zone species, we must integrate such data to show the dominant groups for the major part of the year. We have provided in the following pages a brief description of the 17 biotopes. Artist's

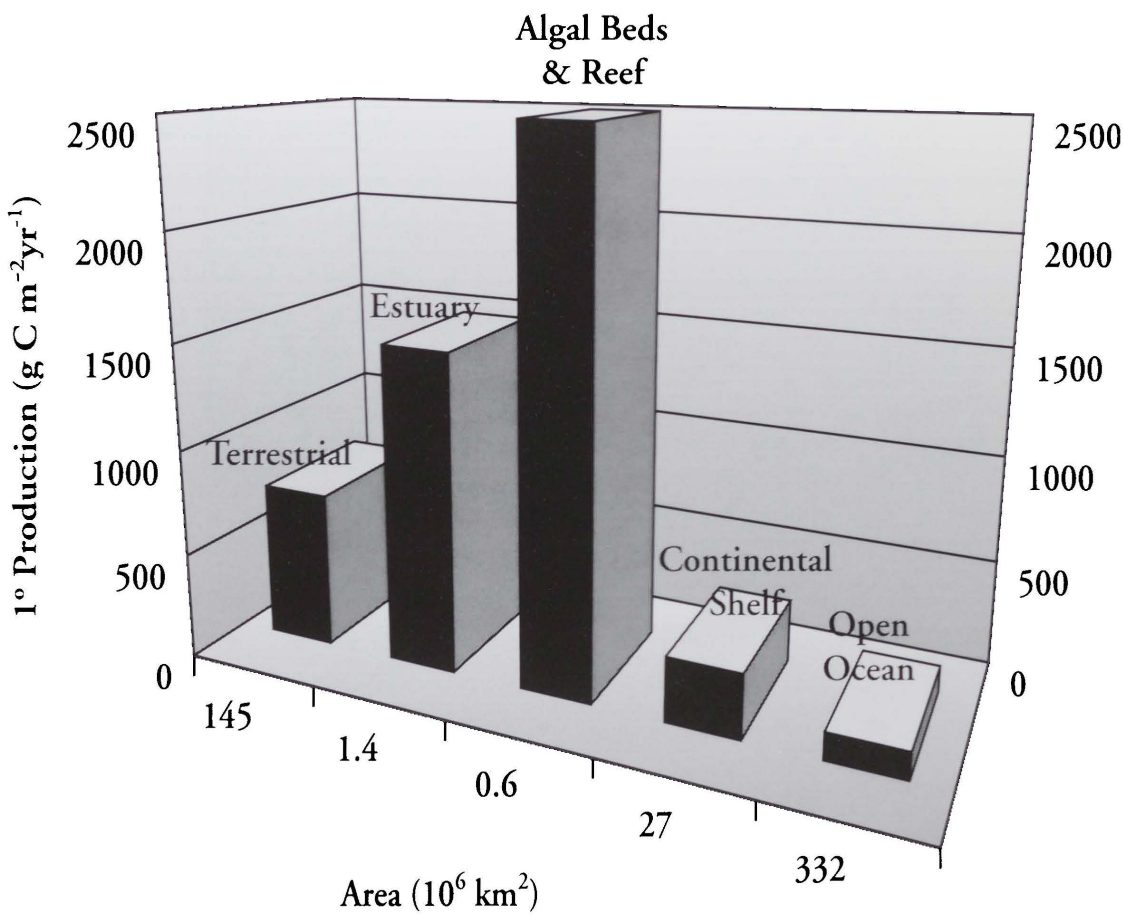

FIG. 2. Annual production rate of organic carbon versus worldwide area. Adapted from Valiela (1995).

renditions are included.

The biotope concept has been planned to augment the land use maps developed by the Bureau of Economic Geology. They may be superimposed to strengthen environmental evaluation by further identification of resource development units. We should like to build into the biotope concept not only the description of the environmental unit but the recognition that human changes may in some instances be advantageous as well as disastrous, while in other areas, change with the proper planning may allow development and preservation of some aspects of the natural environment to coexist.

Figure 3 is a chart that gives examples of the general spatial distribution of the biotopes in Corpus Christi, Nueces, and Aransas Bays. This figure, like Fig. 1, depicts a representative Texas estuarine environment. Two biotopes, the upland deciduous forest and the prairie grassland, are not indicated on Fig. 3 because this chart does not include any upland areas.

The biotope originals are in water color 18 by 24 inches in size. The individual species of organisms are scientifically correct in form, location and color. The artist concept allowed the license of grouping in one picture the representative organisms, whereas, at any one part of a biotope in nature, some species may be absent. The scientific and common names are given in separate listing and in the text. Approximately 350 references were used to document both the illustrations and the text. Representative references are provided in this report. In all illustrations, the individual organisms were sketched in the field or drawn from collected specimens.

SYSTEM OF BIOTOPES

We have attempted to show a hypothetical bay system by the artist's rendition, Fig. 3. This illustration contains most of the typical biotopes presented in the following pages numbered in order from Gulf to land, and is designed to show the relationships between the biotopes. While it does give a generalized overview, an inspection of the natural environments shows that in many areas of an acre or less one biotope may predominate while other biotopes are present in discrete patches within it. We do not propose to go into such intricate detail here but to show the relationships of the biotopes so that the information can be used to describe more general field situations in the bay systems and estuaries of the Texas Gulf Coast.

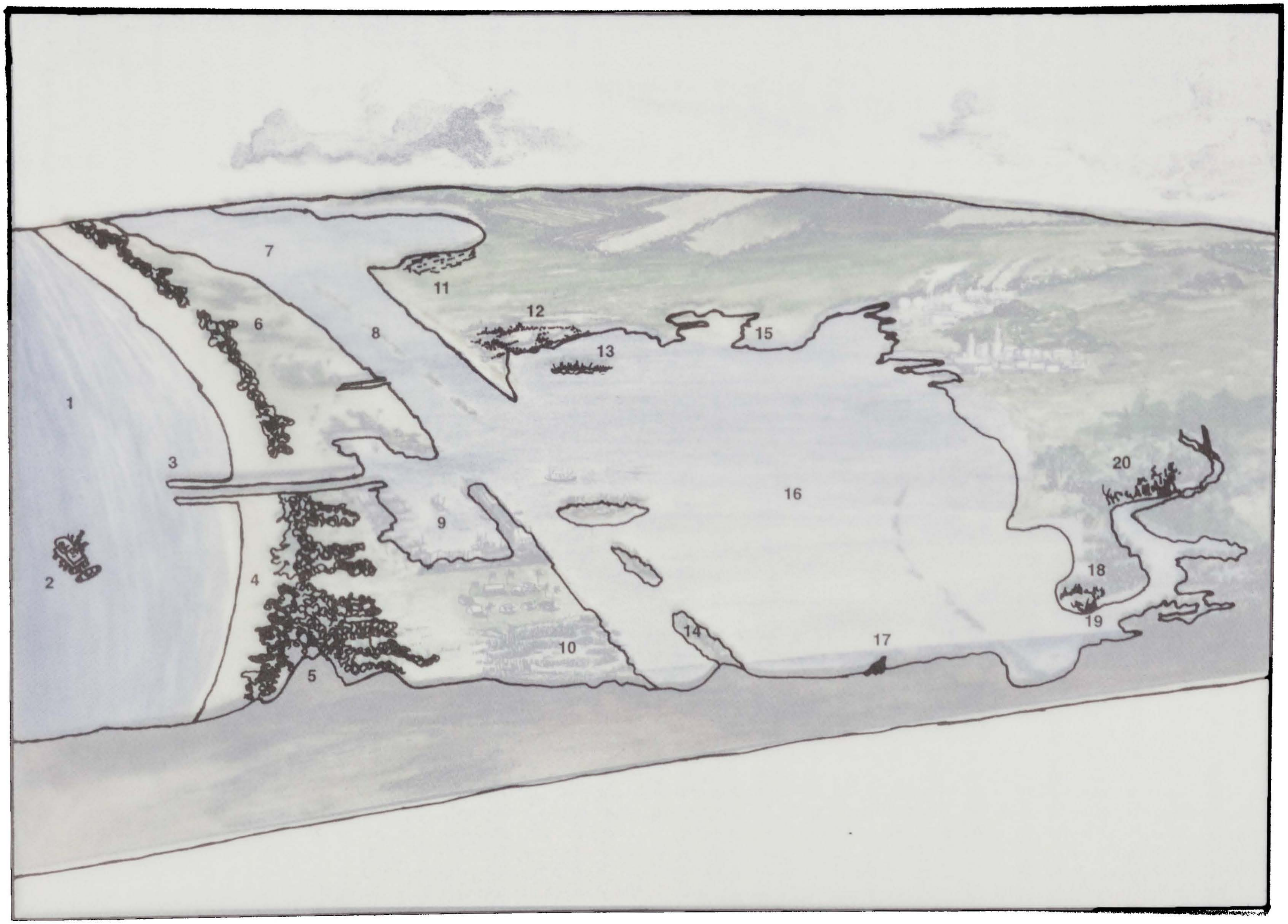

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Fig. 3. Schematic of biotopes for Texas coastal zone. Biotope key begins on the following page.

Fig. 3 (cont'd.). Schematic of biotopes for Texas coastal zone.

1. Continental Shelf
2. Artificial Reef
3. Jetty and Bulkhead
4. Open Beach
5. Dune
6. Barrier Flat
7. Hypersaline
8. Channel
9. Marina
10. *Spartina* Saltwater Marsh
11. Cyanobacteria (Blue-Green Algal) Flat
12. Mud Flat
13. *Thalassia* Grass Flat
14. Spoil Bank
15. Sand Flat
16. Bay Planktonic
17. Oyster Reef
18. *Juncus* Freshwater Marsh
19. River Mouth
20. River Floodplain Forest

DESCRIPTIONS OF INDIVIDUAL BIOTOPES

The various biotopes given in Table 1 are individually described in the following pages.

CONTINENTAL SHELF

The continental shelf extends away from the shore and gradually increases in depth to where the bottom begins to slope off more steeply to form the continental slope. The width of the continental shelf in Texas is extremely variable, ranging from 125 miles wide at the Texas-Louisiana border to 62 miles wide at the mouth of the Rio Grande. Offshore, wave action has less impact than in nearshore areas and currents are more stable in direction. The bottom varies between sand, mud, and shell with occasional reefs, banks, shallow canyons and small hills. There may be stratification of temperature and oxygen levels in the deeper areas.

Common offshore bottom and near-bottom dwellers pictured in Fig. 4 include the sea urchin, *Pseudoboletia maculata* (29), hermit crab, *Clibanarius vittatus* (28), tricolor anemone, *Calliactis tricolor* (27), tomtate, *Haemulon aurolineatum* (25), Nassau grouper, *Epinephelus striatus* (24), sergeant major, *Abudefduf saxatilis* (23), spotted eagle ray, *Aetobatis narinari* (22), squirrelfish, *Holocentrus ascensionis* (21), vermilion snapper, *Rhomboplites aurorubens* (20), and the brown shrimp, *Penaeus aztecus* (17). Not shown are the white shrimp, *Penaeus setiferus* and the pink shrimp, *P. duorarum*. These commercially important penaeid shrimp spend much of their life cycles in this biotope.

Depicted from the water column is the diatom *Odontella* sp. (43), the copepod *Centropages* sp. (45), the pteropod mollusc, *Creisis* sp. (44) and early developmental stages of the brittle star, *Ophiothrix* sp. (42) and two crabs (40, 41). These are only a small selection of the multitudes of microscopic plants and animals found in this area.

The floating *Sargassum* community is also found along the coast and the *Sargassum* frequently washes up on Texas beaches. Shown are details and habit of *Sargassum* spp. (32, 33) with some of the specialized residents of these drifting brown algal masses. These animals include the *Sargassum* pipefish, *Sygnathus pelagicus* (31), the *Sargassum* crab, *Portunus gibbesii* (35; *[Portunus sayi]*), the *Sargassum* fish, *Histrio histrio* (37), and the *Sargassum* shrimp, *Leander tenuicornis* (39).

Finally, there are the actively swimming forms that move within this biotope and, in some cases, through the inlets into other biotopes. Those illustrated include the squid, *Loligo pealei* (14), manta ray, *Manta birostris* (1), dolphin fish, *Coryphaena hippurus* (3), blue marlin, *Makaira nigricans* (5), greater amberjack, *Seriola dumerili* (7), king mackerel, *Scomberomorus cavalla* (9), red snapper, *Lutjanus campechanus* (11), spot, *Leiostomus xanthurus* (19), bull shark, *Carcharhinus leucas* (15), black-tipped shark, *Carcharhinus limbatus** (10) and bottlenose dolphin, *Tursiops truncatus* (12). Not shown in Fig. 4, but important and common in the biotope are sea (hardhead) catfish, *Galeichthys felis* [*Arius felis*]*, tarpon, *Megalops atlanticus*, redfish, *Sciaenops ocellatus,* salt (star) drum, *Stellifer lanceolatus**, bumper, *Chloroscombrus chrysurus**, sheepshead, *Archosargus probatocephalus,* white mullet, *Mugil curema*, moonfish, *Vomer setapinnis* [*Selene setapinnis*], bluefish, *Pomatomus saltatrix*, pigfish, *Orthopristis chrysoptera*, silver sea trout, *Cynoscion nothus*, spotted sea trout, *Cynoscion nebulosus,* southern stargazer, *Astroscopus y-graecum*, pinfish,

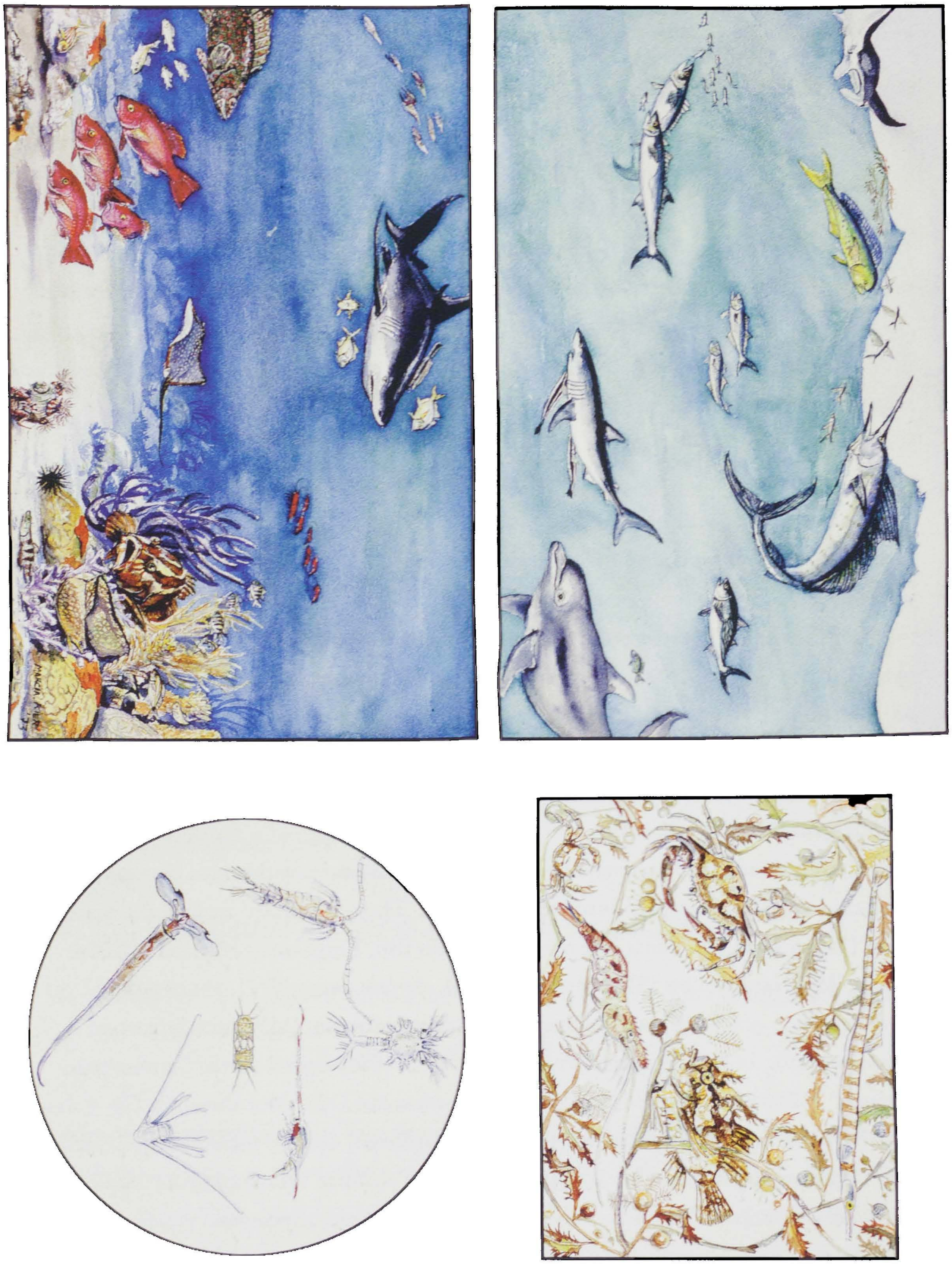
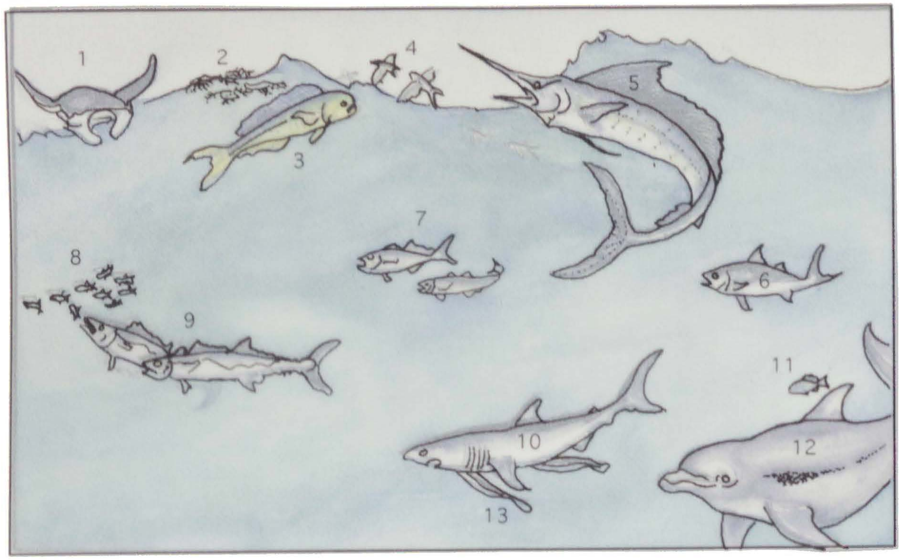


FIG. 4. Continental shelf. Species list begins on the following page.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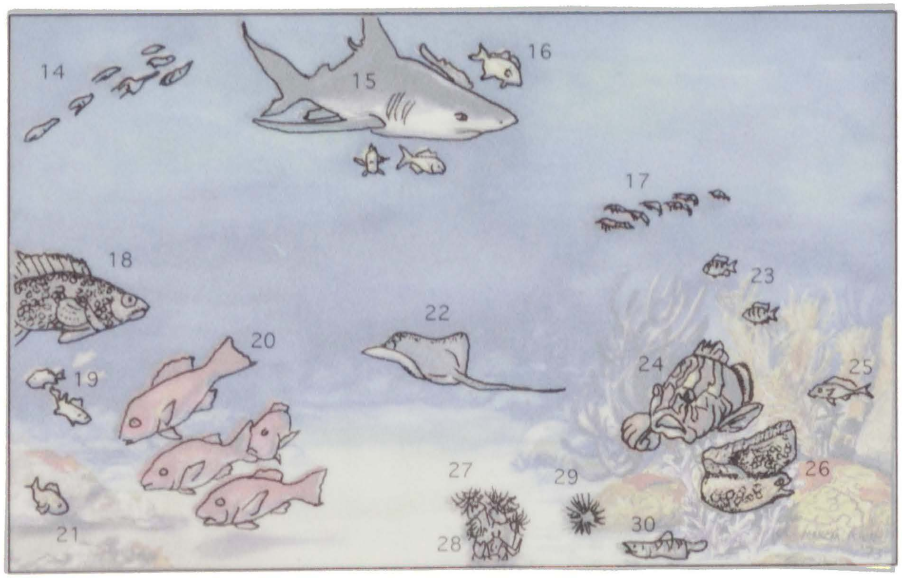
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FIG. 4 (cont'd.). Continental shelf species list.

1. *Manta birostris* - Manta ray
2. *Sargassum* spp.
3. *Coryphaena hippurus* - Dolphin, mahi-mahi, dorado
4. *Hirundichthys rondeleti* - Blackwing flyingfish
5. *Makaira nigricans* - Blue marlin
6. *Euthynnus alletteratus* - Little tunny, bonito
7. *Seriola dumerili* - Greater amberjack
8. *Anchoa hepsetus* - Striped anchovy
9. *Scomberomorus cavalla* - King mackerel, kingfish
10. *Carcharhinus limbatus* - Blacktip shark
11. *Lutjanus campechanus* - Red snapper
12. *Tursiops truncatus* - Bottlenose dolphin
13. *Echeneis naucrates* - Sharksucker
14. *Loligo pealei* - Squid
15. *Carcharhinus leucas* - Bull shark
16. *Calamus proridens* - Sheepshead porgy
17. *Penaeus aztecus* - Brown shrimp
18. *Rypticus subbifrenatus* - Spotted soapfish
19. *Leiostomus xanthurus* - Spot, flat croaker
20. *Rhomboplites aurorubens* - Vermilion snapper
21. *Holocentrus ascensionis* - Squirrelfish
22. *Aetobatis narinari* - Spotted eagle ray
23. *Abudefduf saxatilis* - Sergeant major
24. *Epinephelus striatus* - Nassau grouper
25. *Haemulon aurolineatum* - Tomtate
26. *Gymnothorax nigromarginatus*- Blacktail moray
27. *Calliactis tricolor* - Tricolor anemone
28. *Clibanarius vittatus* - Hermit crab
29. *Pseudoboletia maculata* - Sea urchin
30. *Synodus intermedius* - Sand diver
31. *Sygnathus pelagicus* - *Sargassum* pipefish

FIG. 4 (cont'd.). Continental shelf species list.

32. *Sargassum* leaf
33. *Sargassum* float
34. Epizoic bryozoan
35. *Portunus sayi* - *Sargassum* crab
36. Epizoic bryozoan
37. *Histrio histrio* - *Sargassum* fish
38. *Portunus sayi* (immature) - *Sargassum* crab
39. *Leander tenuicornis* - *Sargassum* shrimp
40. Crab larva (zooae)
41. Crab larva (zooae)
42. *Ophiothrix* sp. (larva) - Brittle star
43. *Odontella* sp. - Diatom
44. *Creisis* sp. - Pteropod mollusc
45. *Centropages* sp. - Copepod

Lagodon rhomboides, king whiting (southern kingfish), *Menticirrhus americanus**, gulf menhaden, *Brevoortia patronus**, leatherjacket, *Oligoplites saurus**, anchovy, *Anchoa mitchelli diaphana*, silver perch, *Bairdiella chrysoura*, rough silversides, *Membras martinica vagrans*, sand trout (sand seatrout), *Cynoscion arenarius*, and spadefish, *Chaetodipterus faber*.

*Asterisk indicates dominant species.

ARTIFICIAL REEF

Artificial reefs are non-natural structures placed by people, either accidently or deliberately, which create new habitat for marine organisms. Examples of artificial reefs include continental shelf oil and gas drilling and production platforms as well as sunken ships. Thousands of artificial reefs of various sizes are present in the off- and nearshore waters along the Texas coast. Initially, new artificial reefs are settled by encrusting organisms such as mussels, oysters and algae of various sorts, which in turn attract larger animals which feed upon them, on up the food web to large predatory fish, sea turtles and marine mammals. Fish populations can be enhanced in these areas either through recruitment of fish larvae via passive transport by currents or attraction of juvenile and adult fish to the reef from other areas. In addition to sport fishing, artificial reefs provide an opportunity for recreational scuba divers to view tropical reef fish seldom seen on the Texas coast with the exception of the Flower Garden Banks near the Texas-Louisiana border or futher south in the tropical southern Gulf of Mexico or Caribbean islands.

Our description of an artificial reef is based on an offshore oil production platform and is shown in Figure 5. Community composition can be extremely variable, but depends primarily on depth, turbidity and currents which supply organisms for colonization. Encrusting organsims can include barnacles, *Balanus* sp. (25) and tree oysters, *Isognomon bicolor* (23) with their associated hydroids (19, 20) and bryozoans (24). Other more mobile invertebrates are the grazers, the sea cucumber, *Isostichopus bandionotus* (8), sea urchin, *Pseudoboletia maculata* (14), and tulip shell, *Fasciolaria* sp. (22). Filter feeders include the anemones, *Aiptasiomorpha texaensis* (12) and the ascidians (21). The common octopus, *Octopus vulgaris* (11) occupies any shelter it can find, such as under rocks or in empty shells or debris on the sea floor.

A number of sport fish can be found around artificial reefs, drawn there by the availability of smaller fish living in association with the reef structure. These include the cobia, *Rachycentron canadum* (1), blue runner, *Caranx crysos* (2), great barracuda, *Sphyraena barracuda* (3), Atlantic spadefish, *Chaetodipterus faber* (6) and the common jack, *Caranx hippos* (9). Fish associated with the sea floor around artificial reefs are the jewfish, *Epinephelus itajara* (15) and the spotted scorpionfish, *Scorpaena plumieri* (13).

The most spectacularly colorful fish are the ones traditionally associated with tropical coral reefs. These are often brought in on currents as free-floating larvae to mature here at the far northern end of their natural range. These include the lookdown, *Selene vomer*, (5), sergeant major, *Abudefduf saxatilis* (7), blackbar soldierfish, *Mryipristis jacobus* (10), French angelfish, *Pomacanthus paru* (16), spotfin butterfly fish, *Chaetodon ocellatus* (17), queen triggerfish, *Balistes vetula* (18), slippery dick, *Halichoeres bivittatus* (26) and queen angelfish, *Holacanthus ciliaris* (27).

JETTY AND BULKHEAD

Jetties and bulkheads are human-made structures of rock, shell, concrete, wood and steel, placed to restrict sedimentation in channels or to provide docking areas. As a result, these structures are in areas where there is variable current energy and offer a surface and protection to a wide variety of organisms. Salinity does control the populations. Therefore,

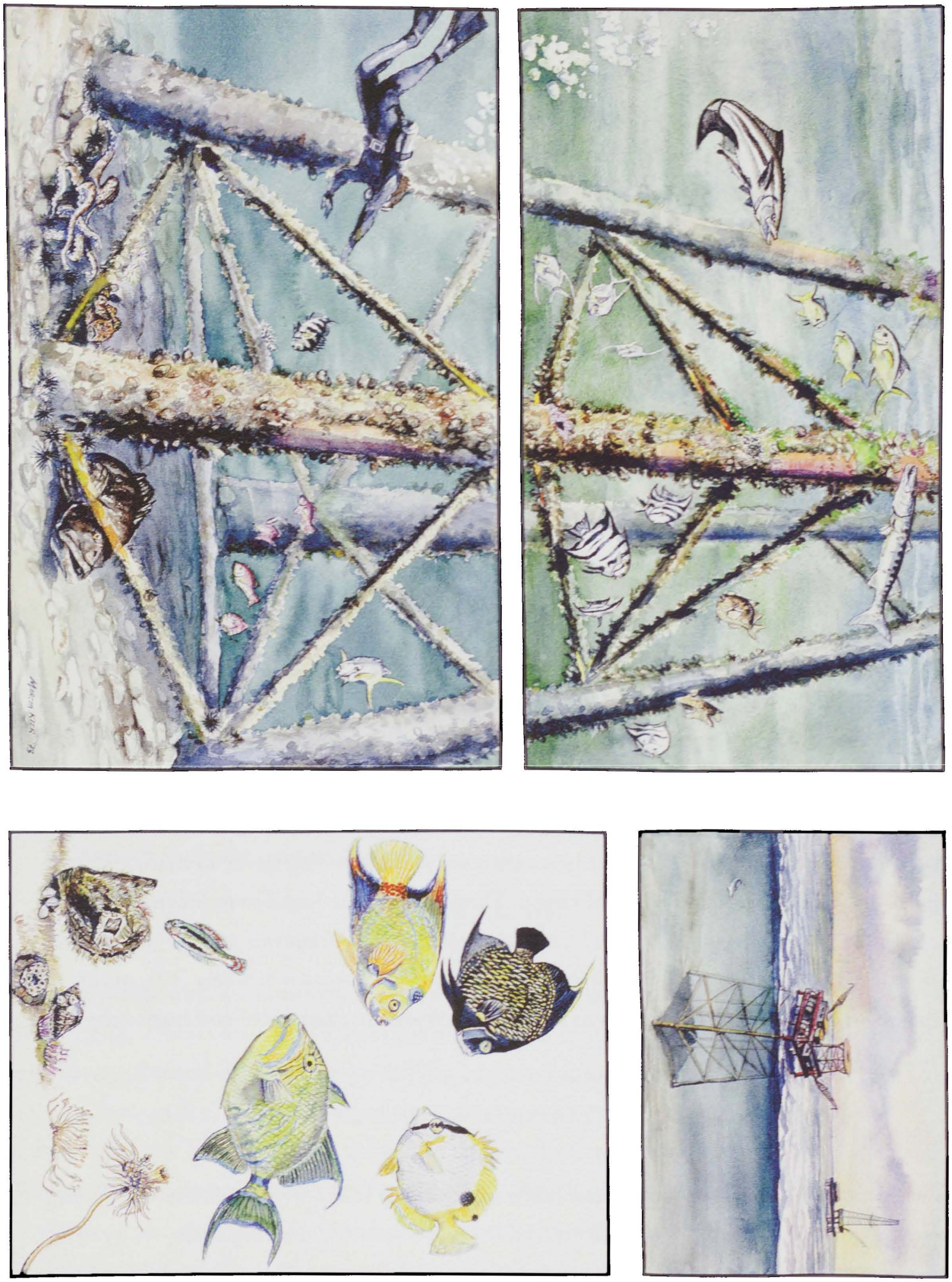

FIG. 5. Artificial reef. Species list begins on the following page.


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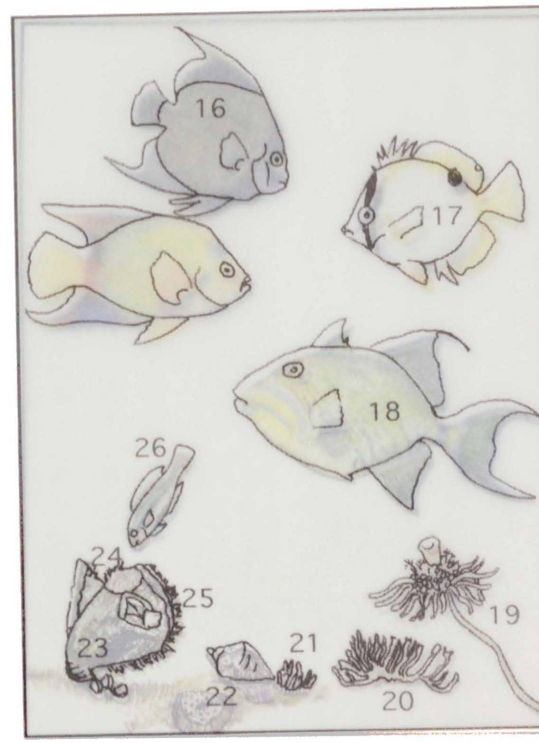
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FIG. 5 (cont'd.). Artificial reef species list.

1. *Rachycentron canadum* (juvenile) - Cobia, ling
2. *Caranx crysos* - Blue runner
3. *Sphyraena barracuda* - Great barracuda
4. *Balistes capriscus* - Gray triggerfish
5. *Selene vomer* - Lookdown
6. *Chaetodipterus faber* - Atlantic spadefish
7. *Abudefduf saxatilis* - Sargeant major
8. *Isostichopus bandionotus* - Sea cucumber
9. *Caranx hippos* - Common jack, crevalle
10. *Myripristis jacobus* - Blackbar soldierfish
11. *Octopus vulgaris* - Common octopus
12. *Aiptasiomorpha texaensis* - Anemone
13. *Scorpaena plumieri* - Spotted scorpionfish
14. *Pseudoboletia maculata* - Sea urchin
15. *Epinephelus itajara* - Jewfish
16. *Pomacanthus paru* - French angelfish
17. *Chaetodon ocellatus* - Spotfin butterfly fish
18. *Balistes vetula* - Queen triggerfish
19. Hydroid polyp
20. Hydroid colony
21. Ascidians - Tunicates
22. *Fasciolaria* sp. - Tulip shell
23. *Isognomon bicolor* - Tree oyster
24. Bryozoans
25. *Balanus* sp. - Barnacle
26. *Halichoeres bivittatus* - Slippery dick
27. *Holacanthus ciliaris* - Queen angelfish

our illustration depicts organisms adapted to salinities above 15 ppt. Thus, most of the forms which inhabit them are either adapted to clinging, physically fixed to the substrate or free swimming. The flora are predominantly brown, red and green algae, with some cyanobacteria (blue-green algae) in the splash zone. The fauna represent a wide variety of animals.

The dominant green algae pictured in Fig. 6 are of the genera *Ulva* (14), *Enteromorpha* (15), *Cladophora* (13) and *Chaetomorpha* (8). The dominant brown alga is of the genus *Padina* (22) with some *Dictyota* (18). The dominant red alga shown is of the genus *Agardhiella* (21), with *Hypnea* (20), *Gelidium* (9), *Giffordia* (16), *Bryocladia* (6), *Gracilaria* (27), and *Rhodymenia* (24). All of these forms are firmly attached to the rocks and are highly flexible in order to withstand the rigors found on the jetties.

The attached fauna shown are sponges, coelenterates, two molluscs and a crustacean. The sponge are of the genera *Microciona* (25, 26) and *Haliciona* (38). The coelenterates are the anemone, *Bunodosoma cavernata* (23), sea whip, *Leptogorgia setacea* (36), and the remains of an alcyonarian, *Oculina* sp. (37), a sessile anthozoan. The oyster, *Crassostrea virginica* (10), mussel, *Modilus americanus* (42), and barnacles of the genus *Balanus* (1) complete the range of attached animals shown from this biotope.

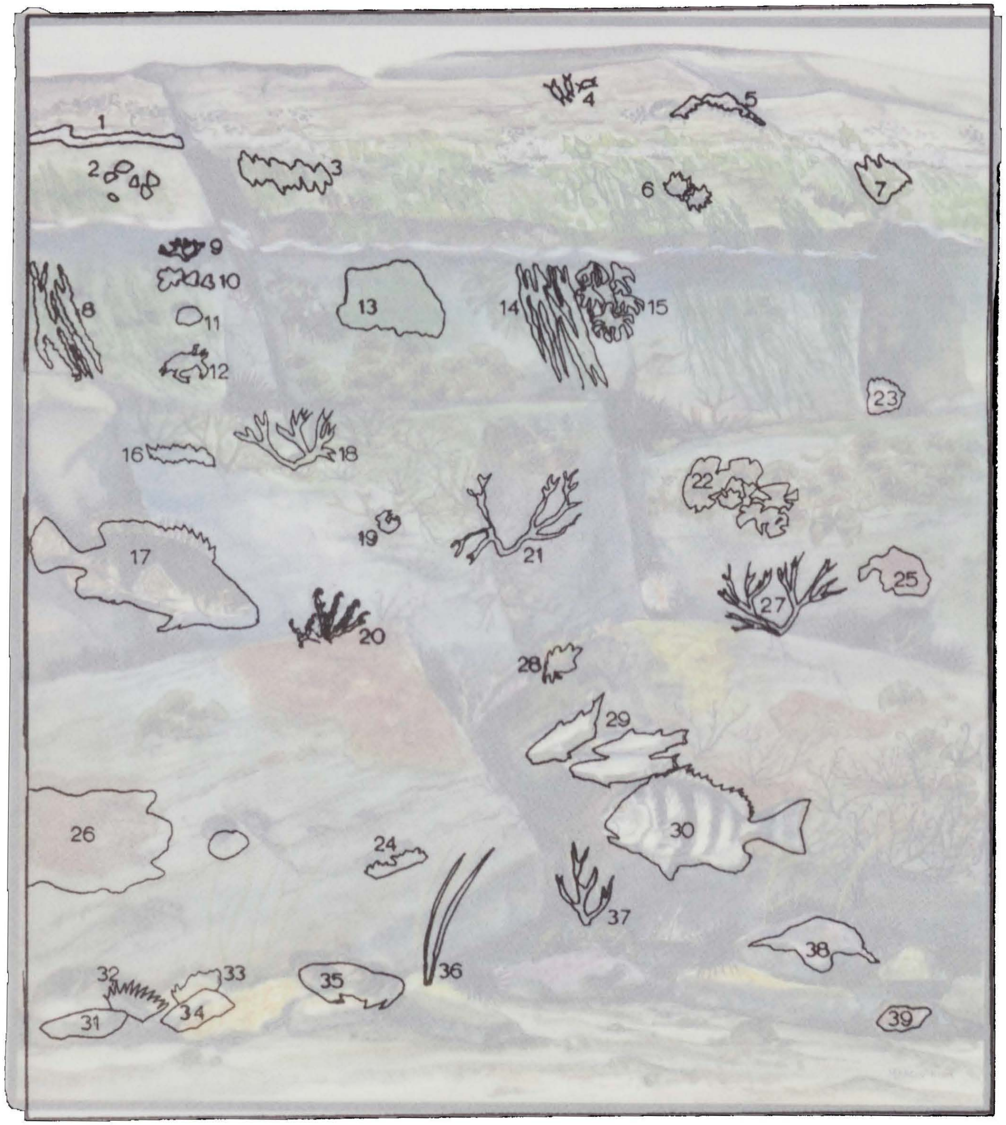
Motile forms which cling to the substrate include the gastropods *Thais haemostoma* (41; *[Stramonita haemostoma]*) and *Littorina irrorata* (5), the rock crab, *Menippe mercenaria* (35), hermit crab, *Clibinarius vittatus* (28), the sea urchin, *Arbacia punctulata* (32), and the isopod wharf roach, *Ligia exotica* (4). The crested blenny, *Hypleurochilus geminatus* (11), lives in the sheltered cracks of the jetties.

Strongly swimming forms shown include the spotted jewfish, *Promicrops itaiara* (17; *[Epinephelus itajara]*), sheepshead, *Archosargus probatocephalus* (30), mullet, *Mugil cephalus* (29), blue crab, *Callinectes sapidus* (12), and another portunid crab *Ovalipes ocellatus* (19).

OPEN BEACH

The open beach biotope (Fig. 7) extends from the upper tidal margin of the exposed coast to the edge of the continental shelf. The bottom profile gently slopes away from the coast at about eight feet per mile. Next to the surf zone, two to three underwater bars parallel the coast. The inshore area is characterized by variable wave action, fairly strong tidally influenced alongshore currents and a sandy bottom. The water is usually well mixed thermally and well oxygenated.

The economic and recreational importance of this area is well known. Several highly desirable sports fish, such as flounder, drum, redfish, croaker and several species of trout, are found within or moving through the biotope. Other recreational activities include



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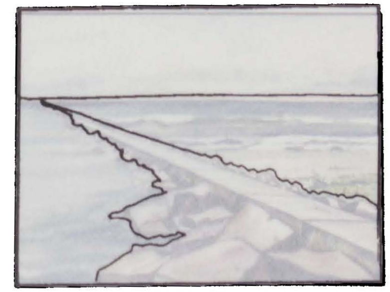

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FIG. 6. Jetty and bulkhead. Species list begins on the following page.

FIG. 6 (cont'd.). Jetty and bulkhead species list.

1. *Balanus* sp. - Barnacle
2. *Thais haemostoma* - Florida rock shell [*Stramonita haemostoma*]
3. *Enteromorpha flexosa* - Green alga
4. *Ligia exotica* - Wharf roach
5. *Littorina irrorata* - Periwinkle
6. *Bryocladia cuspidata* - Red alga
7. *Ulva lactuca* - Green alga
8. *Chaetomorpha* sp. - Green alga
9. *Gelidium* sp. - Red alga
10. *Crassostrea virginica* - American oyster
11. *Hypleurochilus geminatus* - Crested blenny
12. *Callinectes sapidus* - Blue crab
13. *Cladophora vagabunda* - Green alga
14. *Ulva fasciata* - Green alga
15. *Enteromorpha lingulata* - Green alga
16. *Giffordia* sp. - Red alga
17. *Promicrops itaiara* - Spotted jewfish [*Epinephelus itajara*]
18. *Dictyota dichotoma* - Brown alga
19. *Ovalipes ocellatus* - Swimming crab
20. *Hypnea musiciformis* - Red alga
21. *Agardhiella tenera* - Red alga
22. *Padina vickerisae* - Brown alga
23. *Bunodosoma cavernata* - Anemone
24. *Rhodomenia palmata* - Red alga [*Rhodymenia pseudopalmata*]
25. *Microciona* sp. - Sponge
26. *Microciona* sp. - Sponge
27. *Gracilaria prolifera* - Red alga [*Gracilaria foliifera*]
28. *Clibinarius vittatus* - Hermit crab
29. *Mugil cephalus* - Striped mullet
30. *Archosargus probatocephalus* - Sheepshead

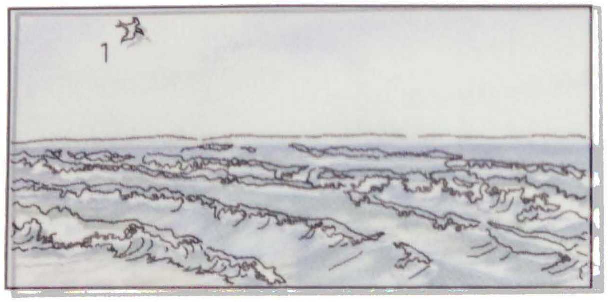
FIG. 6 (cont'd.). Jetty and bulkhead species list.

31. White sponge
32. *Arbacia punctulata* - Urchin
33. Hydroid
34. Yellow sponge
35. *Menippe mercenaria* - Rock crab
36. *Leptogorgia setacea* - Sea whip (octocoral)
37. *Oculina* sp. - Hard coral
38. *Haliciona* sp. - Pink sponge
39. *Microciona* sp. - Sponge
40. *Clibinarius vittatus* - Hermit crab
41. *Thais haemostoma* - Florida rock shell [*Stramonita haemostoma*]
42. *Modiolus* sp. - Mussel and attachments
43. *Ligia exotica* - Wharf roach
44. *Blennius cristatus* - Rock blenny [*Scartella cristata*, Molly miller]
45. *Microciona* sp. - Orange sponge
46. Hydroid
47. *Cladophora vagabunda* - Green alga
48. *Ulva flexosa* - Green alga
49. *Padina veckersae* - Brown alga
50. *Dictyota dichotoma* - Brown alga
51. *Bryocladia cuspidata* - Red alga

swimming, sailing and camping.

Due to the rigors of the inshore environment, the fauna of the open beach divide between burrowing and strongly swimming organisms. Among the crustacean burrowers are found the mole crab, *Emerita talpoida* (25), the ghost shrimp, *Callianassa islagrande* (*19; [Callichirus islagrande*]), and the mantis shrimp, *Squilla empusa*. The water column contains many microscopic organisms, including diatoms such as *Coscinodiscus* (14) and *Rhizosolenia* (17), and dinoflagellates such as *Ceratium* (13) and *Peridinium* [*Protoperidinium*](15). The swimming crabs, *Callinectes danae* and *C. sapidus* (34) are often found in the inshore area. Copepods of the genus *Acartia* (16) are often found in the wave wash and interstitially in the

FIG. 7. Open beach. Species list begins on the following page.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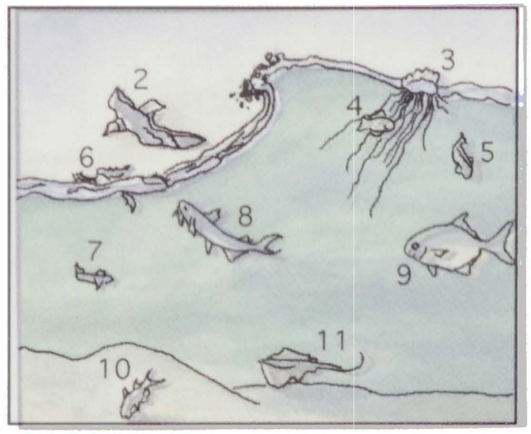
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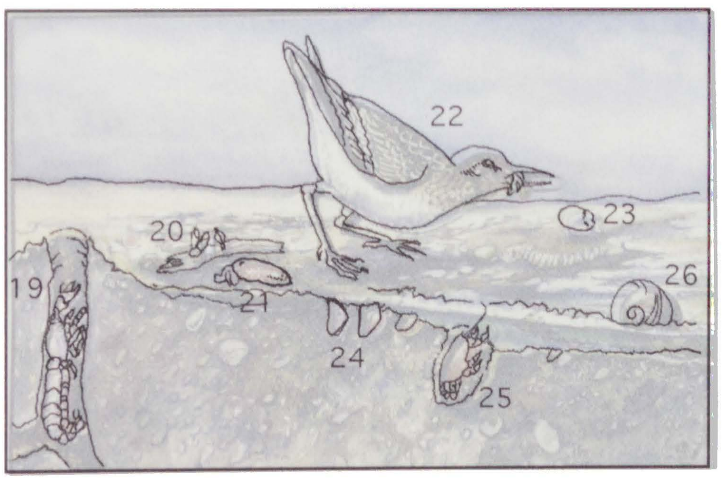
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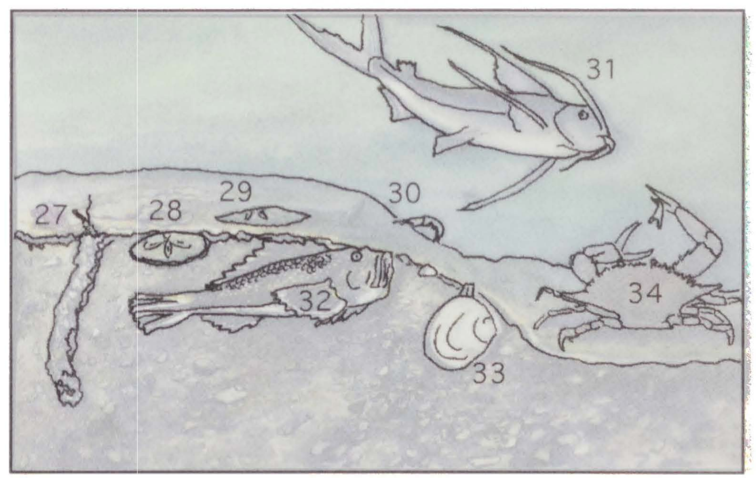
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FIG. 7 (cont'd.). Open beach species list.

1. *Sterna caspia* - Caspian tern
2. *Larus atricilla* - Laughing gull
3. *Physalia physalia* - Portuguese Man O' War
4. *Micropogon undulatus* - Atlantic croaker [*Micropogonias undulatus*]
5. *Leisostomus xanthurus* - Spot
6. *Mugil cephalus* - Striped mullet
7. *Pogonias cromis* - Black drum
8. *Galeichthys felis* - Hardhead catfish [*Arius felis*]
9. *Trachinotus carolinus* - Florida pompano
10. *Polydactylus octonemus* - Atlantic threadfin
11. *Dasyatis americana* - Southern stingray
12. *Callinectes sapidus* - Blue crab (megalops larva)
13. *Ceratium fusus* - Dinoflagellate
14. *Coscinodiscus radiatus* - Diatom
15. *Peridinium.* - Dinoflagellate [*Protoperidinium* sp]
16. *Acartia tonsa* - Copepod
17. *Rhizosolenia* sp. - Diatom
18. Foraminiferan
19. *Callichirus islagrande* - Ghost shrimp
20. *Lepas anatifera* - Gooseneck barnacle
21. *Oliva sayana* - Olive snail
22. *Calidris pusilla* - Semipalmated sandpiper
23. *Stomolophus meleagris* - Cabbagehead jellyfish
24. *Donax variabilis* - Coquina, bean clam
25. *Emerita talpoida* - Mole crab
26. *Polinices duplicatus* - Moon snail
27. *Diopatra cuprea* - Chimney tube worm
28. *Mellita quinquiesperforata* - Sand dollar (live)
29. *Mellita quinquiesperforata* - Sand dollar (dead)
30. *Penaeus aztecus* - Brown shrimp
31. *Bagre marinus* - Gafftopsail catfish

FIG. 7 (cont'd.). Open beach species list.

32. *Astroscopus y-graecum* - Southern stargazer
33. *Dosinia discus* - Disk dosinia
34. *Callinectes sapidus* - Blue crab

sand, as well as elsewhere in the water column. The coquina clam, *Donax variabilis* (24) and the olive shell, *Oliva sayana* (21), are found from the upper surf zone into deeper waters. Also represented from the area of surf action are the sand dollar, *Mellita quinquiesperforata* (28,29), the southern stingray, *Dasyatis americana* (11), the southern stargazer, *Astroscopus y-graecum* (32), and the southern flounder, *Paralichthys lethostigma.* Another important drifting organism, especially to those who wish to use the beaches for swimming, is the Portuguese Man O'War, *Physalia physalia* (3).

Some of the actively swimming forms which spend time within this biotope include the Atlantic croaker, *Micropogon undulatus* [*Micropogonias undulatus*] (4), striped mullet, *Mugil cephalus* (6), black drum, *Pogonias cromis* (7), hardhead catfish, *Galeichthys felis* [*Arius felis*](8), gafftopsail catfish, *Bagre marinus* (31), spotted seatrout, *Cynoscion nebulosus,* and the Florida pompano, *Trachinotus carolinus* (9).

DUNE

The barrier islands of the Texas coast are the result of depositional and aeolean (wind-related) processes since the present sea level was established. They cause the impoundment of the coastal lagoon system and offer protection from major storms. The dunes which are created on the open shore may be as high as forty feet above sea level, although they average between five and fifteen feet. These dunes are usually vegetated, which allows for accretion and allows them to remain intact and resist displacement by wind. Behind these large dunes, there are vegetated flats (described in the next section) punctuated by swales and freshwater potholes. Finally, along the lagoon edge, there are a series of smaller vegetated dunes.

It is in society's interest to maintain the dunes with dense vegetation, as they form a natural barrier to storm surges. Additionally, the vegetation retards sand migration, preventing them from covering roads, and dwellings. The permeable sands behind the dunes form a fresh water aquifer which is a vital supply in some areas for both plants and animals.

The number of species of plants found on the seaward face of the dunes (Fig. 8) is small compared to the variety found on the flats. The major sand trapping plant is the sea oat,


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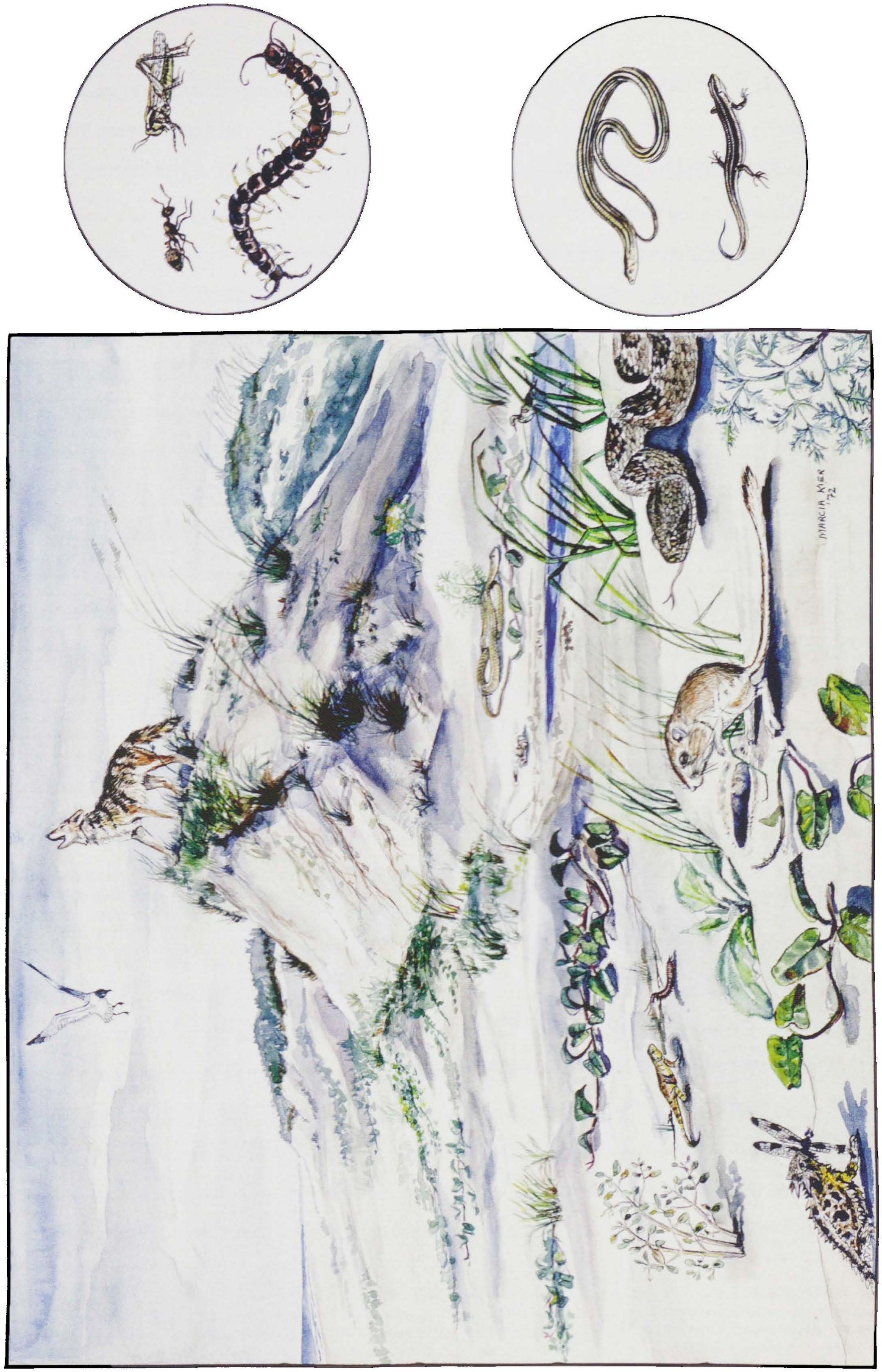


FIG. 8. Dune. Species list begins on the following page.

FIG. 8 (cont'd.). Dune species list.

1. *Larus atricilla* - Laughing gull
2. *Canis latrans* - Coyote
3. *Uniola paniculata* - Sea oats
4. *Andropogon littoralis* - Seashore bluestem [*Schizachyrium littorale*, Maritime bluestem]
5. *Cenchrus incertus* - Sand burr
6. *Ocypode quadrata* - Ghost crab
7. *Masticophis flagellum testaceus* - Western coachwhip
8. *Croton punctatus* - Beach tea
9. *Ipomoea pes-caprae* - Goatfoot morning glory
10. *Holbrookia propingua* - Keeled earless lizard
11. *Scolopendra* sp. - Centipede
12. *Panicum amarum* - Bitter panicum
13. *Crocethia alba* - Sanderling [*Calidris alba*]
14. *Phrynosoma cornutum* - Texas horned lizard
15. *Anax junius* - Dragonfly [*Celithemis eponina*, brown-spotted yellow-wing]
16. *Ipomoea stolonifera* - Morning glory
17. *Helianthus annus* - Sunflower
18. *Dipodomys ordii* - Kangaroo rat [*or Dipodomys compactus*, Padre Island kangaroo rat]
19. *Crotalus atrox* - Western diamondback rattlesnake
20. *Helianthus* sp. - Sunflower
21. *Monomorium minimum* - Little black ant
22. *Schistocerea americana* - Bird grasshopper
23. *Scolopendra* sp. - Centipede
24. *Ophisaurus attenuatus* - Glass lizard
25. *Eumeces fasciatus* - 5-lined skink

Uniola paniculata (3). Other plants found in close association with the sea oats are the bitter panicum, *Panicum amarum* (12), the morning glories, *Ipomoea pes-capre* (9) and *I. stolonifera* (16), and beach tea, *Croton punctatus* (8), as shown in Fig. 8. Other species trapping sand in the foredune area are seashore dropseed, *Sporobolus virginicus*, sea purselane, *Sesuvium* *portulacastrum* and beach ground cherry, *Physalis viscosa.*

Grassy areas transitioning to the barrier flat support seacoast bluestem, *Andropogon scoparius litoralis* (4; *[Schizachyrium littorale*, maritime bluestem]), beach tea, *Croton punctatus* (8) and sunflowers, *Helianthus annuus* (17), as shown in Fig. 8, as well as the grasses, *Spartina patens, Paspalum monostachyum*, and *Sporobolus virginicus* which are not pictured.

Dominant fauna shown for this biotope include the coyote, *Canis latrans* (2), kangaroo rat, *Dipodomys ordii* (18), western coachwhip snake, *Masticophis flagellum* (7) and western diamondback rattlesnake, *Crotalus atrox* (19). Other reptiles shown are the glass lizard, *Ophisaurus attenuatus* (24), five-lined skink, *Eumeces fasciatus* (25), keeled earless lizard, *Holbrookia propingua* (10), and Texas horned lizard, *Phyrnosoma cornutum* (14). The ghost crab, *Ocypode guadrata* (6) is found on the seaward face of the dunes and occasionally on the vegetated flats. The laughing gull, *Larus atricilla* (1) and the sanderling, *Crocethia* (13; *[Calidris alba]*) are commonly found. The dragonflies, genus *Anax* (15; *[Celithemis]*), the small black ant, *Monomorium minimum* (21), the grasshopper *Schistocerea americana* (22) and centipedes, genus *Scolopendra* (11, 23), are representative of the terrestrial arthropods.

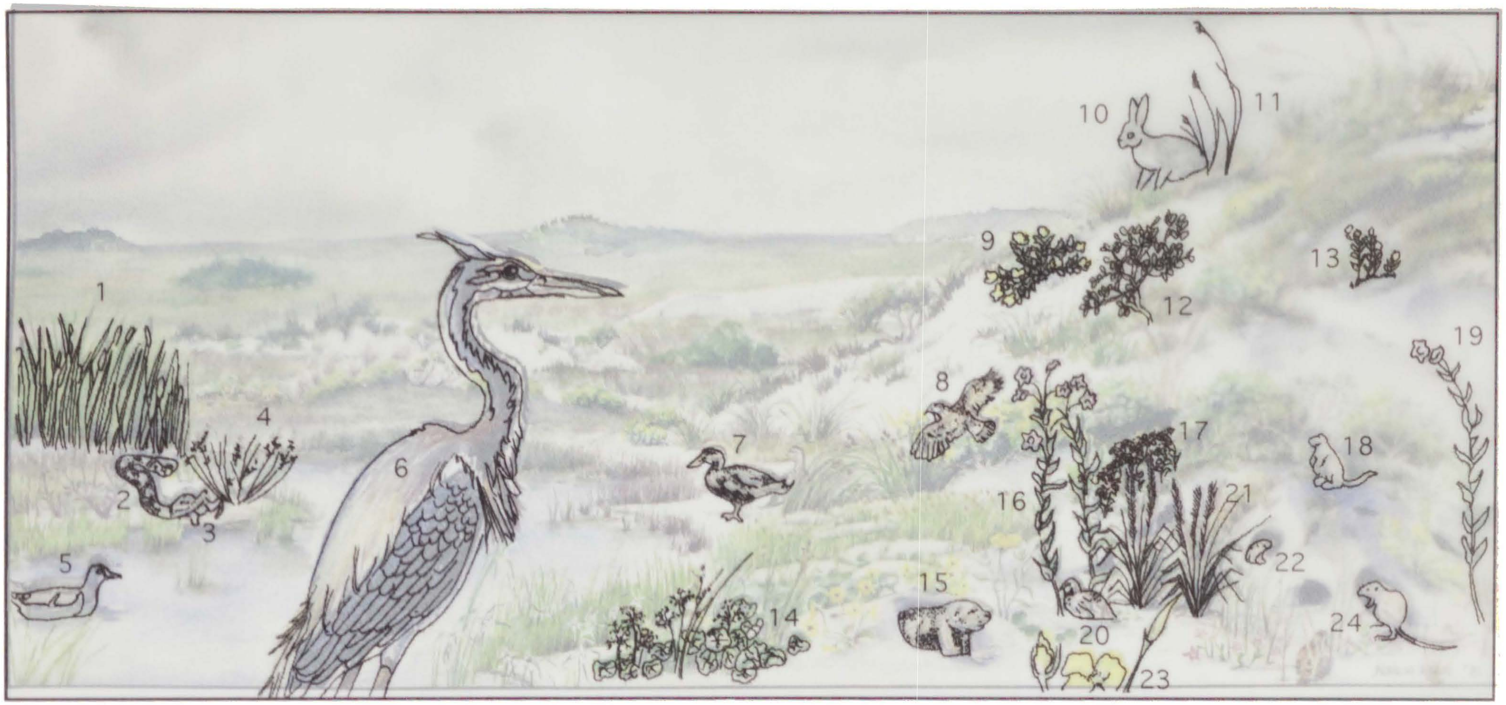
BARRIER FLAT

Between the large dunes facing the open Gulf of Mexico and the smaller dunes along the lagoon edge, there are vegetated flats punctuated by swales and freshwater potholes. Although some of the same species are present as are found in the vegetated dune areas, many more and different species are located on the barrier flats associated with the presence of surface fresh and brackish water and subsurface aquifers. This biotope is illustrated in Fig. 9.

Shoregrass, *Monathachloe littoralis* (not shown), is the dominant grass bordering mudflat areas. Seasonal dominants are the evening primrose, *Oenothera durmmondii* (23) and whitestem wild indigo, *Baptisia laevicaulis* in the spring, and western ragweed, *Ambrosia psilostchya*, camphorweed, *Heterotheca subaxillaris* (9), groundsel, *Senecio spartioides*, and an indico, *Indigofera mineata*, in the fall. Occasionally found on the barrier flats are sweet acacia, *Acacia farnesiana*, salt cedar, *Tamarix gallica*, the introduced *Tamarix aphylla*, the Australian pine, *Casuarina equisetifolia*, and willows of the genus *Salix.*

Variations in vertical elevation influence the vegetation of the barrier flat. Hummocks have relict stands of the sea oat, *Uniola paniculata* (11), while swales and potholes may contain either marshhay cordgrass, *Spartina patens*, cattails, genus *Typha* (1) and Drummond

FIG. 9. Barrier flat. Species list begins on the following page.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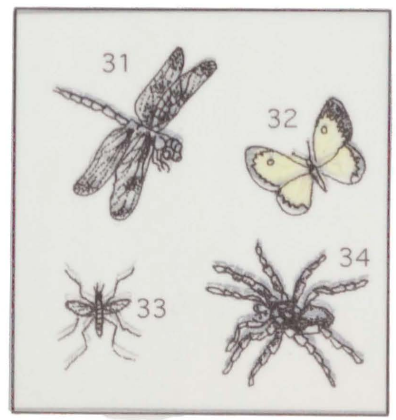
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FIG. 9 (cont'd.). Barrier flat species list.

1. *Typha domingensis* - Cattail
2. *Nerodia rhombifera* - Diamond-back watersnake
3. *Rana berlandieri* - Rio Grande leopard frog
4. *Juncus megacephalus* - Large-headed rush
5. *Fulica americana* - American coot
6. *Ardea herodias* - Great blue heron
7. *Anas fulvigula* - Mottled duck
8. *Colinus virginianus* - Northern bobwhite quail
9. *Heterotheca subaxillaris* - Camphorweed
10. *Lepus californicus* - Blacktailed jackrabbit
11. *Uniola paniculata* - Sea oats
12. *Croton punctatus* - Silver-leaf croton
13. *Borrichia frutescens* - Sea ox-eye daisy
14. *Hydrocotyle bonariensis* - Seaside pennywort
15. *Geomys personatus* - Pocket gopher
16. *Kosteletzkya virginica* - Seashore mallow
17. *Gaillardia pulchella* - Fire-wheel
18. *Spermophilus spilosoma annectens* - Spotted ground squirrel
19. *Ipomoea sagittata* - Arrow-leaf morning glory
20. *Colinus virginianus* - Northern bobwhite quail
21. *Andropogon capillipes* - Chalky broomsedge
22. *Onychomys leucogaster* - Short-tailed grasshopper mouse
23. *Oenothera drummondii*- Beach evening primrose
24. *Dipodomys compactus* - Padre Island kangaroo rat
25. *Schizachyrium scoparium littoralis* - Seacoast bluestem
26. *Eleocharis tuberculosa* - Spike rush
27. *Dichromena colorata* - Whitetop sedge
28. *Croton punctatus* - Silver-leaf croton
29. *Hydrocotyle bonariensis* - Seaside pennywort
30. *Agalinis maritima* - False foxglove
31. *Anax junius* - Dragonfly

FIG. 9 (cont'd.). Barrier flat species list.

32. *Colias eurytheme* - Orange (alfalfa) sulfur butterfly
33. *Aedes taeniorhynchus* - Black saltmarsh mosquito
34. *Dugesiella hentzi* - Tarantula

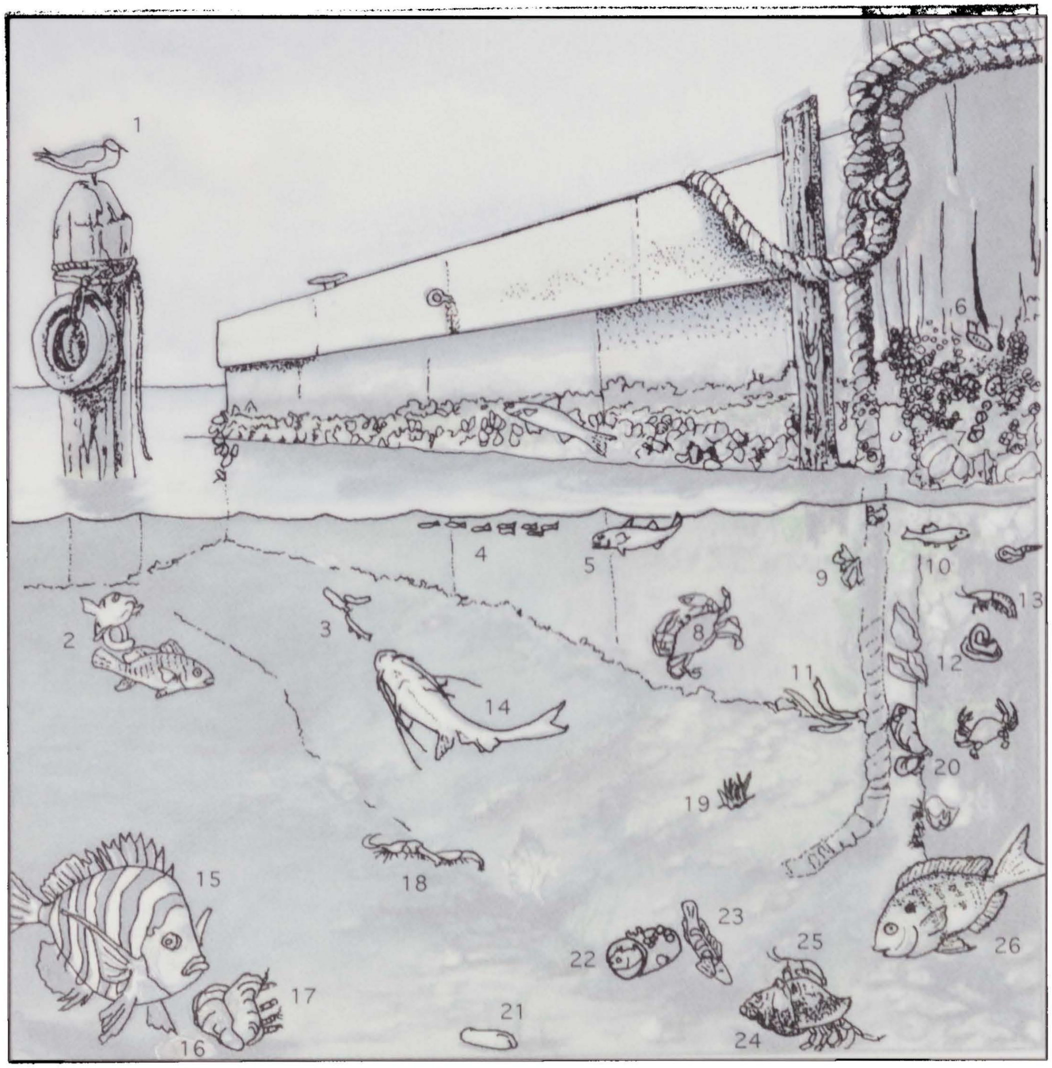
rattlebox, *Sesbanis drummondii,* if they have water standing for long periods, or the saltworts *Salicornia bigelovii* and *S. perennis* and seashore dropseed, *Sporobolus virginicus* if they are subject to intermittent drying.

Some of the more common waterfowl include the great blue heron, *Ardea herodias* (6), the American coot, *Fulica americana* (5) and the mottled duck, *Anas fulvigula* (7), while terrestrial birds such as the northern bobwhite quail, *Colinus virginianus* (8, 20), make the drier parts of the same region their habitat. Also associated with freshwater sources are the nonpoisonous diamond-back watersnake, *Nerodia rhombifera* (2) and the Rio Grande leopard frog, *Rana berlandieri* (3). Dominant mammals include the coyote, *Canis latrans,* blacktailed jackrabbit, *Lepus californicus* (10) and several species of rodents. Among the most visible of these is the spotted ground squirrel, *Spermophilus spilosoma annectens* (18), which can be seen running from burrow to burrow on the surface. Also present are other burrowing rodents such as the pocket gopher, *Geomys personatus* (15), the Padre Island kangaroo rat, *Dipodomys compactus* (24) and the short-tailed grasshopper mouse, *Onychomys leucogaster* (22). Aerial insects include the predatory and territorial dragonfly, *Anax junius* (31) and the black saltmarsh mosquito, *Aedes taeniorhynchus* (33). The tarantula, *Dugesiella hentzi* (34) is a voracious terrestrial hunter.

MARINA

Marinas provide structure and habitat for species which would not normally be found on a natural Texas sand or marsh shoreline. Community composition depends, in part, on where the marina is relative to the open Gulf of Mexico, freshwater inputs, tidal fluxes, currents, cities and towns, etc. A representative marina is shown in Figure 10.

Marinas are usually constructed on concrete or wooden pilings treated with creosote or some other chemicals to reduce destruction by borers, with each material supporting its own community of organisms often similar to, and recruited from, oyster reefs or jetties. Most immediately visible are organisms on vertical surfaces periodically exposed by the tides. Some of these include barnacles, *Chthamalus fragilis* (7), the green algae, *Ulva lactuca* (9) and *U. fasciata* (11), sea roach, *Ligia exotica* (6) and blue crabs, *Callinectes sapidus* (8). Below the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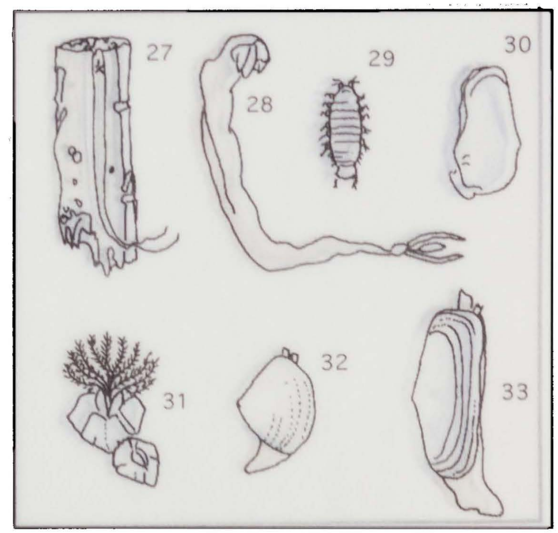
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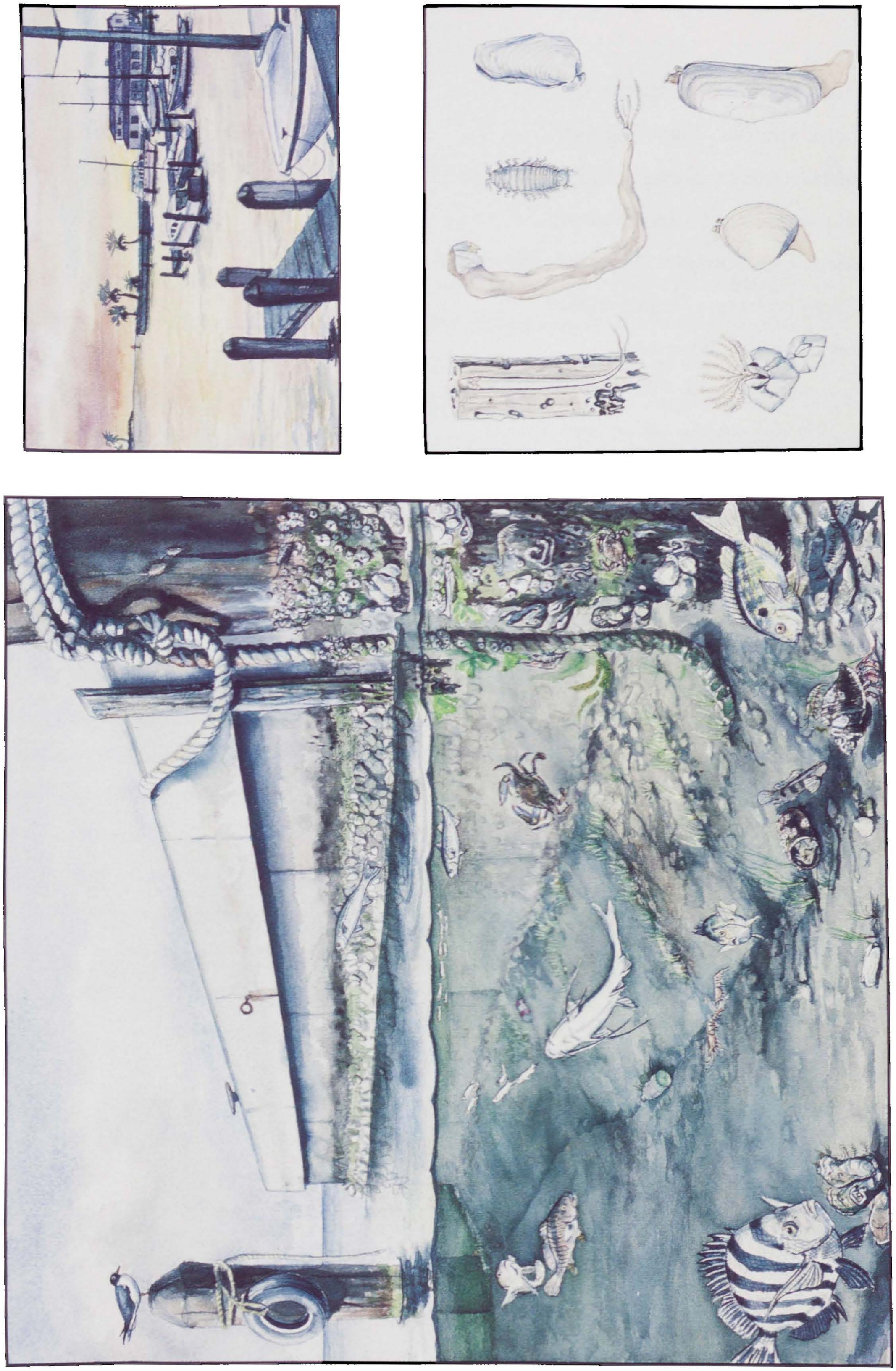

FIG. 10. Marina. Species list begins on the following page.

FIG. 10 (cont'd.). Marina species list.

1. *Larus atricilla* - Laughing gull
2. *Micropogon undulatus* - Atlantic croaker [*Micropogonias undulatus*]
3. *Anchoa mitchilli* - Bay anchovy
4. *Menidia peninsulae* - Tidewater silversides
5. *Mugil cephalus* - Striped mullet
6. *Ligia exotica* - Sea roach
7. *Cthamalus fragilis* - Barnacle
8. *Callinectes sapidus* - Blue crab
9. *Ulva lactuca* - Sea lettuce, green alga
10. *Menidia peninsulae* - Tidewater silversides
11. *Ulva fasciata* - Green alga
12. *Hydroides dianthus* - Serpulid worms
13. *Palaemonetes vulgaris* - Grass shrimp
14. *Bagre marinus* - Gafftopsail catfish
15. *Archosargus probatocephalus* - Sheepshead
16. *Crassostrea virginica* - Oyster
17. Hydroid
18. *Pennaeus aztecus* - Brown shrimp
19. *Thalassia testidinum* - Turtlegrass
20. *Brachidontes recurvus* - Hooked mussel
21. *Tagelus divisus* - Purplish tagelus
22. *Hypleurochilus geminatus* - Crested blenny
23. *Gobiosoma bosc* - Naked goby
24. *Clibanarius vittatus* - Hermit crab
25. *Palaeomonetes vulgaris* - Grass shrimp
26. *Lagodon rhomboides* - Pinfish
27. Teredinidae (habitat) - True shipworm
28. Teredinidae - True shipworm (wood-boring mollusc)
29. *Limnora tripunctata* - Gribble (wood-boring isopod)
30. *Martesia fragilis* - Fragile martesia (wood-boring mollusc)
31. *Balanus* sp. - Barnacle

FIG. 10 (cont'd.). Marina species list.

32. *Corbula swiftiana* - Swift's corbula
33. *Tagelus plebius* - Stout tagelus

water's surface are found serpulid worms, *Hydroides dianthus* (12) and another barnacle, *Balanus* sp. (31), often found attached to hard surfaces such as pilings, the oyster, *Crassostrea virginica* (16) or even discarded trash thoughtlessly thrown into the water by marina users. Destructive to the wooden pilings are boring organisms such as the shipworms, family Teredinidae (27, 28), gribbles, *Limnora tripunctata* (29), and fragile martesia, *Martesia fragilis* (30) which actually digest wood while burrowing within it. Grazers include grass shrimp, *Paleomonetes vulgaris* (13, 25), brown shrimp, *Penneaus aztecus* (18), and the hermit crab, *Clibinarius vittatus* (24).

Besides housing boats, marinas provide sportfishing opportunities for those who do not have access to boats. Night lights are often set up to draw a great variety of fish which are attracted to feed at night on their smaller, phototactic prey. Some of the fish found in proximity to marinas include baitfish such as the bay anchovy, *Anchoa mitchilli* (3) and tidewater silversides, *Menidia peninsulae* (4, 10) and the often caught pinfish, *Lagodon rhomboides* (26) and hardhead catfish, *Galeichthys felis* [*Arius felis*]. More preferred by fishers are the Atlantic croaker, *Micropogon undulatus* [*Micropogonias undulatus*] (2), gafftopsail catfish, *Bagre marinus* (14) and sheepshead, *Archosargus probatocephalus* (15).

Often present, but seldom caught, are the striped mullet, *Mugil cephalus* (5), and the common, but inconspicuous, bottom dwelling fish, the crested blenny, *Hypleurochilus geminatus* (22) and the naked goby, *Gobiosoma bosc* (23).

SPARTINA SALT WATER MARSH

This biotope (Fig. 11) is subjected to intermittent inundation due to tidal action. Fluctuations in temperature, salinity, water depth and sediment have exerted a strong selective effect, limiting the numbers of organisms found. The dominant grass in this biotope is smooth cordgrass, *Spartina alterniflora* (11). Like the *Thalassia* grass flat biotope, the plant material produced in this biotope, mostly *S. alterniflora* (11), makes a large contribution to the food chain of the estuarine ecosystem. The sediments may range from fine anaerobic silt to sand or shell. Occasionally oyster reefs are found in this biotope. The productivity of the area is high and the grass blades offer protection and attachment for

FIG. 11. *Spartina* salt water marsh. Species list begins on the following page.


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FIG. 11 (cont'd.). *Spartina* (salt water marsh) species list.

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

many organisms below and above water. The decayed grass adds to the fertility of the surrounding water areas.

Other common plants shown in Fig. 11 for this biotope are the woody glasswort, *Salicornia bigelovii* (8), and saltwort, *Batis maritima* (17), in the lower areas, and beach tea, *Croton punctatus* (15), saltgrass, *Distichlis spicata* (22), sea purselane, *Sesuvium portulacastrum* (16) and black mangrove, *Avicennia germinans* (6, 19, 21), in the higher, better drained areas.

There are numerous birds that nest or feed in this biotope. Those shown are the great blue heron, *Ardea herodias* (1), green heron, *Butorides virescens* (2; *[Butorides striatus]*), blue winged teal, *Anas discors* (3), roseate spoonbill, *Ajaia ajaja* (4), common egret, *Casmerodius albus* (5), white ibis, *Eudocimus albus* (7), clapper rail, *Rallus longirostris* (12) and longbilled marsh wren, *Telmatodytes palustris* (14; *[Cistothorus palustris]*).

Grazing and scavenging are accomplished by a variety of animals. Those shown include the hermit crabs, *Pagurus* (13), the fiddler crab, *Uca pugnax* (18; *[Uca longisignalis]*) and the periwinkle *Littorina irrorata* (20). The raccoon, *Procyon lotor* (9) is a common visitor, feeding on such shellfish as mussels, cockles and snails. In the substrate, there are untold numbers of annelid and nematode worms, soil arthropods, and bacteria which contribute to final decomposition of detritus.

HYPERSALINE

Where sea water flows into shallow lagoons in climates with more evaporation than runoff, salinities rise and briny conditions develop. The Laguna Madre is an example of a hypersaline lagoon. Organisms living in this high salinity (hypersaline) biotope require special adaptations to take up food and excrete excess salt. Diversities diminish and highly characteristic systems develop with a few species of phytoplankton, zooplankton, clams and fish in waters with salinities above 50‰. High organic levels develop because of the generally poor efficiency of the simple system in processing organic food chains.

On the landward side of hypersaline lagoons are extensive areas known as pans and flats. These shallow, flat areas are important for nutrient circulation and net transport of water. There is a significant increase in salinity with increase in distance from the sea-lagoon connection, with as much as a 25 to 40‰ different between the upper (landward) and lower (seaward) margins.

Due to the need for osmotic stress adaptation, the diversity of organisms in hypersaline waters is low. The magnitude of the stress involved is a function of the energy drains of adaptive work required for the species to remain as a part of the particular system. Primary producers are the cyanobacteria (blue-green algae), diatoms and other algae. In the Laguna Madre, the vast underwater beds of *Diplanthera* [*Halodule*] and, less significantly, *Thalassia* permit the development of more complex food webs based on the higher primary productivity of the benthic systems.

Migrating populations of breeding fishes and associated invertebrate animals contribute to the balanced coupling of production with consumption. Detritivores feeding on bottom organic matter include mullet (*Mugil*), croaker (*Micropogon* [*Micropogonias*]), and shrimp

(*Penaeus*). Detritivores feeding on suspended organic material include the barnacle (*Balanus*), crabs (*Callinectes*), croaker (*Micropogon* [*Micropogonias*]), redfish (*Sciaenops*), flounder (*Paralichthys*), pinfish (*Lagodon*), and sea (hardhead) catfish (*Galeichthys* [*Arius*]). Tertiary consumers include flounder (*Paralichthys*), croaker (*Micropogon* [*Micropogonias*]), trout (*Cynoscion*), redfish (*Sciaenops*), and drum (*Pogonias*). The Laguna Madre and Baffin Bay are of great ecological importance because they constitute the most extensive hypersaline biotope in the United States. In addition, they are of considerable value to the commercial fishery of the Texas coast.

CHANNEL

A channel is the bed of a natural stream of water or the deeper part of a river, bay, harbor, strait, etc. Some channels are developed by natural hydrologic processes while others are artificially constructed. Both types are the major arteries through which aquatic organisms move to spawn, feed and grow and may provide protection from rapid weather induced changes of temperature and salinity. Channels, like the open bay, are relatively low in terms of primary productivity. They are, nevertheless, important links between biotopes.

Turbidity, relatively high current flow, and sedimentation prevent complex ecosystems in channels in certain cases, but in others, such as in fresh and saltwater marshes, they may become a habitat for a considerable number of species. Seasonal migrations of crustaceans and fishes, at times, create very heavy temporary concentrations of these animals. The entrance of penaeid shrimp into a bay system such as Corpus Christi Bay, Texas corresponds to high flow of the Nueces River during spring and autumn. This coupling of peak migration and increased river flow is essential for the propagation of penaeid shrimp. Fluxes of important materials occur in bay systems via the channel systems during seasonal high river flows. These include vitamins and other dissolved organic compounds (Birke, 1968), nutrients (Nash, 1947), lowered salinity (Odum and Wilson, 1962) and flushing and mixing activities (Prichard, 1967). The indirect stimulus of incoming nutrients enhances photosynthetic productivity (Nash, 1947; Odum and Wilson, 1962). Hoese and Jones (1963) reported populations of fish and invertebrates in Redfish Bay, Texas during spring and autumn, corresponding to periods of maximum productivity and food availability.

The composition of the flora and fauna in the channel biotope fluctuates with habitat conditions. It would be difficult to categorize the channel communities in static terms. However, when the channels are examined over a longer period (20 or 30 years), a fairly consistent, seasonally related community can be identified.

Present year round are hogchokers (*Trinectes*), spot (*Leiostomus xanthurus*), flounder (*Paralichthys lethostigma*), pinfish (*Lagodon rhomboides*), blue crab (*Callinectes sapidus*), various species of shrimp, in different life stages from larval to late juvenile, and mullet (*Mugil cephalus*).

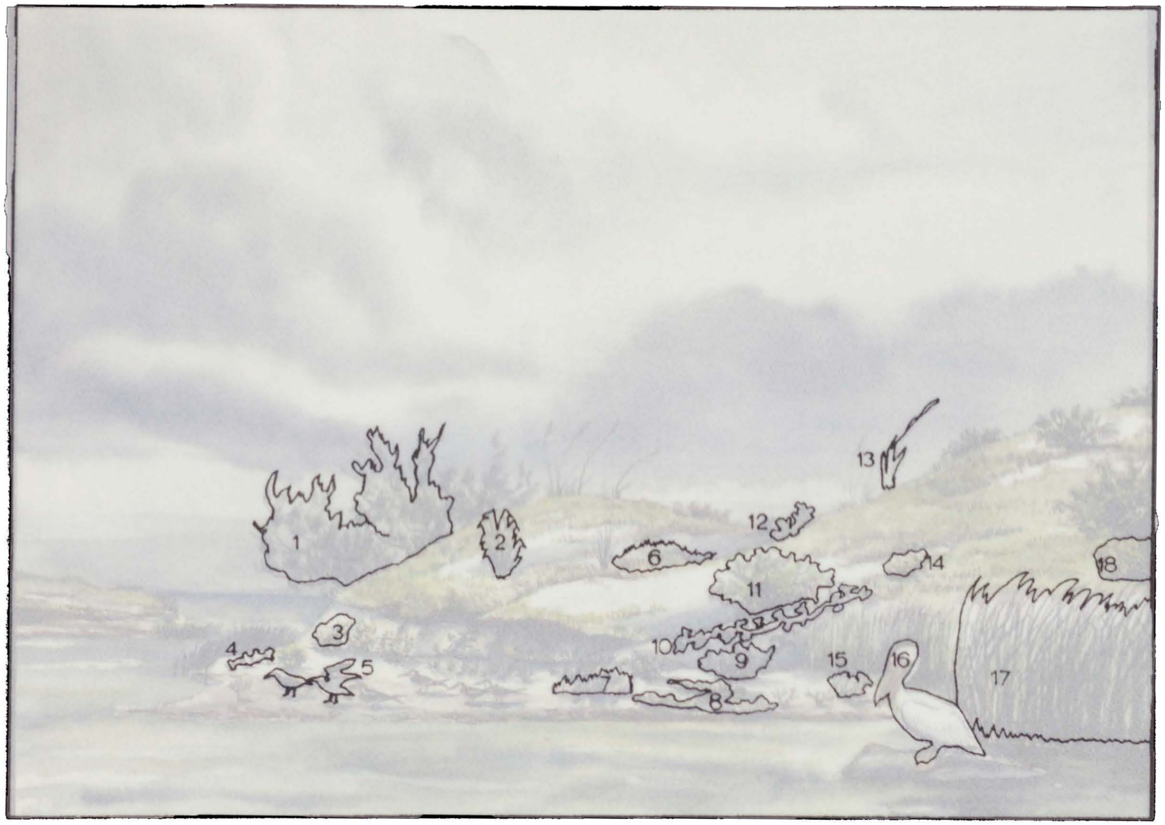
Benthic organisms include molluscs, particularly bivalves, snails, polychaetes, and several crab species.

SPOIL BANK

Spoil banks are composed of mud, sand and shell dredged from several layers of sediments and deposited in mounds extending above the water surface, often parallel to the channels created. These islands vary in shape from circular to elongate with vertical elevations of up to twenty feet. Eventually, these areas are colonized by the organisms shown in Fig. 12.

The upper reaches are inhabited by several higher plants, among them, salt cedar, *Tamarix gallica* (1), honey mesquite, *Prosopis glandulosa* (11), low prickly pear, *Opuntia compressa* (12), seashore bluestem, *Andropogon scoparium littoralis* (2; [*Schizachyrium littorale*, maritime bluestem]), Gulf cordgrass, *Spartina spartinae* (31), sea oats, *Uniola paniculata* (13), and goatfoot morning glory, *Ipomoea pes-caprae* (10), as shown in Fig. 12. In the intermediate areas, those reached only by the highest tides, are found sea purselane, *Sesuvium portulacastrum* (8), and marsh hay cordgrass, *Spartina patens* (6). At the water's edge are found saltgrass, *Distichlis spicata* (7), the woody glassworts, *Salicornia virginica* (4) and *S. bigelovii* (15) and smooth cordgrass, *Spartina alterniflora* (17). Finally, the submerged grasses often found near the islands include, turtle grass, *Thalassia testudinum* (25), shoal grass, *Diplanthera wrightii* (21; [*Halodule beaudettei*]), as shown in Fig. 12, and sometimes widgeon grass, *Ruppia maritima* and *Halophila engelmannii.*

Animals found ashore include numerous insects, ghost crabs, fiddler crabs of the genus *Uca*, and hermit crabs, among them *Clibinarius vittatus* (20) and *Pagurus policharus.* The hermit crabs are also found in the adjacent waters, along with blue crabs, *Callinectes sapidus* (29), brown shrimp, *Penaeus aztecus* (27), oysters, *Crassostrea virginica* (30), as shown, and the clams *Ranga cuneata* and *Mercenaria mercenaria.* The fish depicted include sand trout, *Cynoscion arenarius* (23), golden croaker, *Micropogon undulatus* (24; [*Micropogonias undulatus*]), black drum, *Pogonias cromis* (26), flounder, *Paralichthys lethostigma* (28), and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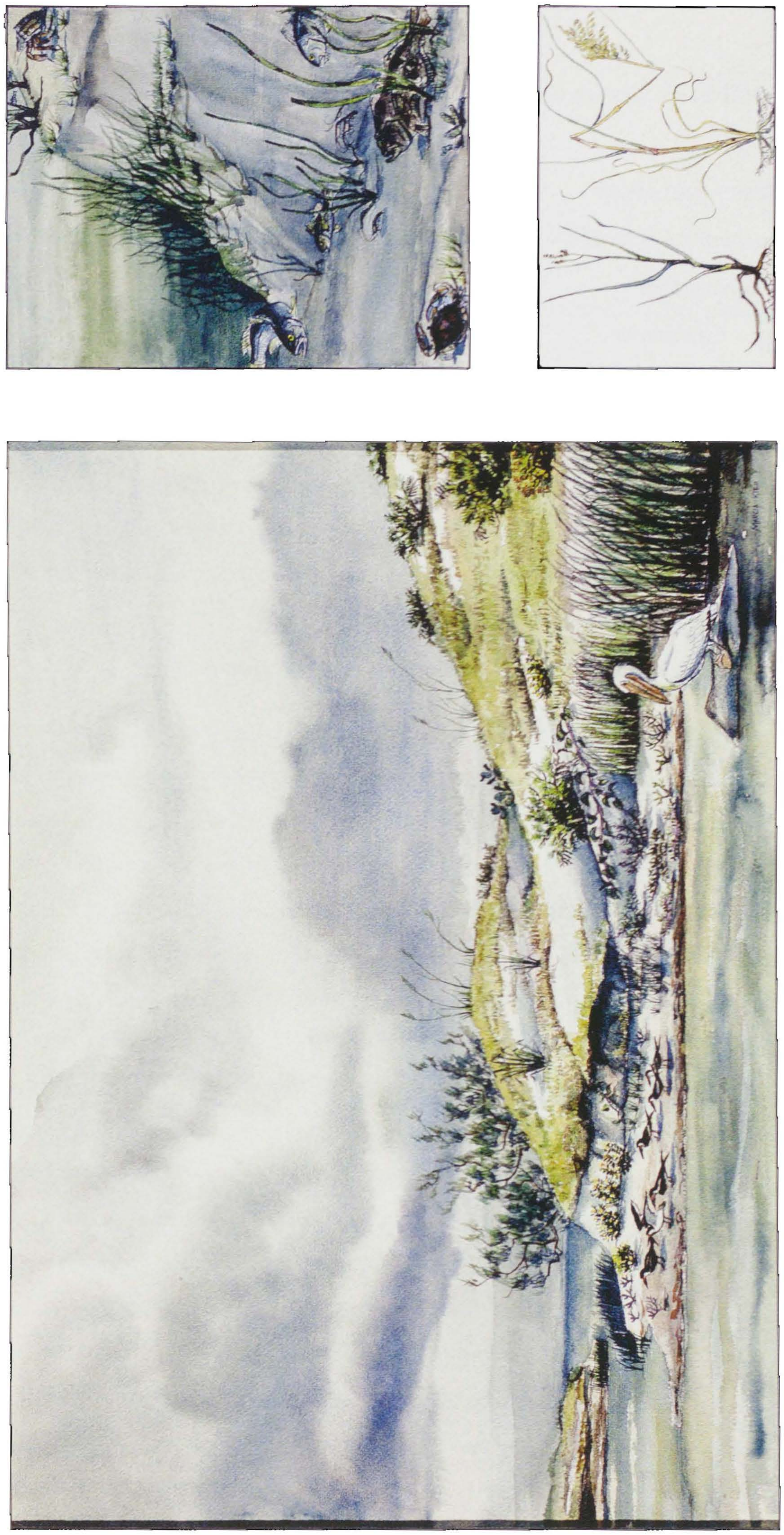

FIG. 12. Spoil bank. Species list begins on the following page.

FIG. 12 (cont'd.). Spoil bank species list.

1. *Tamarix gallica* - Salt cedar
2. *Andropogon scoparius littoralis* - Seashore bluestem [*Schizachyrium scoparium littoralis*]
3. *Senecio* sp. - Groundsel
4. *Salicornia* sp. - Glasswort
5. *Rynchops nigrer* - Black skimmer
6. *Spartina patens* - Marshhay cordgrass
7. *Distichlis spicata* - Salt grass
8. *Sesuvium portulacastrum* - Sea purselane
9. *Baptistia leucophaea* - Whitestem wild indigo
10. *Ipomoea pes-caprae* - Goatfoot morning glory
11. *Prosopis juliflora glandulosa* - Honey mesquite [*Prosopis glandulosa*]
12. *Opunita compressa* - Low prickly pear
13. *Uniola paniculata* - Sea oats
14. *Senecio* sp. - Groundsel
15. *Salicornia bigelovii* - Saltwort
16. *Pelecanus erythrorhynchos* - White pelican
17. *Spartina alterniflora* - Smooth cordgrass
18. *Gallardia pulchella* - Indian blanket
19. *Spartina alterniflora* - Smooth cordgrass
20. *Clibinarius vittatus* - Hermit crab
21. *Diplanthera wrightii* - Shoalgrass [*Halodule wrightii*]
22. *Diplanthera wrightii* - Shoalgrass (sprouts) [*Halodule wrightii*]
23. *Cynoscion arenarius* - Sand trout
24. *Micropogon undulatus* - Croaker [*Micropogonias undulatus*]
25. *Thalassia testudinum* - Turtle grass
26. *Pogonias cromis* - Black drum
27. *Penaeus aztecus* - Brown shrimp
28. *Paralichthyes lethostigma* - Flounder
29. *Callinectes sapidus* - Blue crab
30. *Crassotrea virginica* - American oyster

FIG. 12 (cont'd.). Spoil bank species list.

31. *Spartina spartinae* - Gulf cordgrass
32. *Uniola paniculata* - Sea oats

spot, *Leiostomus xanthurus* (not shown). These fish feed both in the open water and among the grass beds.

Spoil banks offer good nesting and resting places for birds since they are often above the tides, and vegetated, offering physical protection. Common birds are the black skimmer, *Rynchops niger* (5), and the white pelican, *Pelacanus erythrorhychos* (16).

While this biotope is a relatively low producer, it has a value to society as a retreat for fisherman, boaters, picnickers and campers.

CYANOBACTERIA (BLUE-GREEN ALGAL) FLAT

Cyanobacteria (blue-green algal) flats (Fig. 13) are common along the floodplains adjacent to the estuaries and on marsh areas just above the tidal range where they are occasionally inundated with fresh or brackish water. The sediment is normally fine sand or silt on which the filamentous cyanobacteria infiltrate to form a leathery mat. The underlying sediment is usually anaerobic. When these areas are covered by a wind tide, or rain runoff, the photosynthetic activity produces gas bubbles, which cause large pieces of the cyanobacteria mat to float on the water surface. At times of high tide, these floating cyanobacteria mats will wash into adjacent waters. The mats also act as a wick during the almost continuous wind. Thus the nutrient byproducts from the underlying sediments and water from the water table are drawn by capillary action to the mat surface. This results in incrustations of halite and nutrients. These nutrients act as fertilizer for the cyanobacteria mat and at times when the area is covered by wind tides or rainfall, these salts are washed into the adjacent waters, increasing their productivity.

The area may extend over many miles or be restricted to a small shallow depression along the shore where conditions are right for the cyanobacterial growth. These areas are quite productive, extending into the sediment for several millimeters and actively stabilize the sediments. The cyanobacteria mats contain a wide variety of microorganisms.

The major constituent of this mat is the cyanobacterium *Lyngbya majuseula* (8). Also found are the cyanobacteria *Holopedia irregularis* (9), *Nodularia sphaerocarpa* (10) and *N. tenuis* (11), *Oscillatoria limosa* (12), the diatoms *Pleurosigma angulatum* (14), *Navicula*

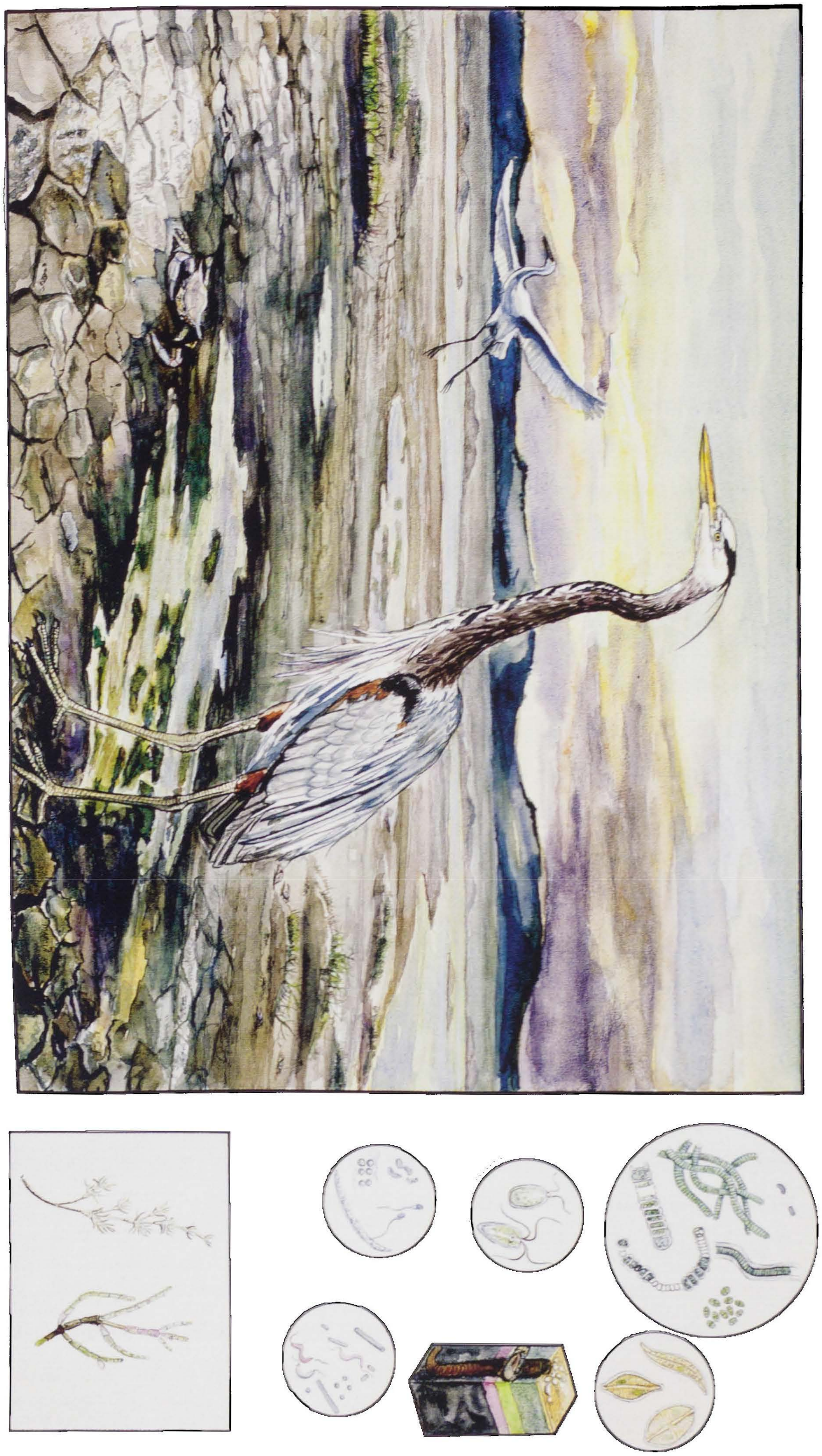

FIG. 13. Cyanobacteria (blue-green algal) flat. Species list begins on the following page.


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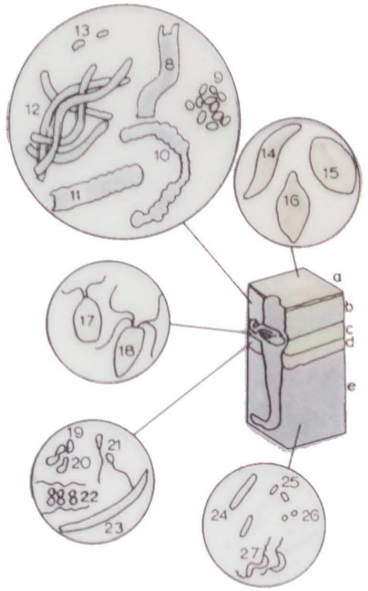
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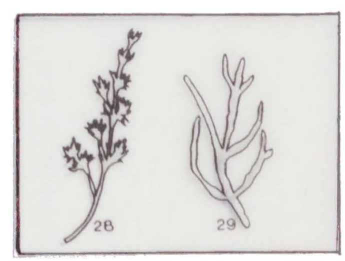
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FIG. 13 (cont'd.). Cyanobacteria (blue-green algal) flat species list.

1. *Leucophoyx thula* - Snowy egret [*Egretta thula*]
2. *Ardea herodias* - Great blue heron
3. *Salicornia* sp. - Glasswort
4. *Distichlis spicata* - Saltgrass
5. *Callinectes sapidus* - Blue crab
6. Floating algal mat - Mixed microflora
7. *Crassostrea virginica* - Oyster (dead)
8. *Lyngbya majuseula* - Cyanobacterium (blue-green alga)
9. *Holopedia irregularis* - Cyanobacterium (blue-green alga)
10. *Nodularia sphaerocarpa* - Cyanobacterium (blue-green alga)
11. *Nodularia tenuis* - Cyanobacterium (blue-green alga)
12. *Oscillatoria limosa* - Cyanobacterium (blue-green alga)
13. *Chlorococcum* sp. - green alga
14. *Pleurosigma angulatum* - Diatom
15. *Navicula punctigera* - Diatom
16. *Navicula diversistriata* - Diatom
17. *Chlamydomonas snowiae* - Green flagellates
18. *Pyramimonas tetrarhynchos* - Green flagellates
19. *Rhodospirillum fulvum* - Sulfur bacterium
20. *Rhodopsuedomonas palustris* - Sulfur bacterium
21. *Rhodomicrobium vannieli* - Sulfur bacterium
22. *Beggiatoa* sp. - Sulfur bacterium
23. *Thiocapsa* sp. - Sulfur bacterium
24. Rod shaped*
25. Short rods*
26. Coccoid*
27. Spirilla*
28. *Monanthochloe littoralis* - Saltgrass
29. *Salicornia virginica* - glasswort

* Various bacteria.

punctigera (15) and *N. diversistriata* (16), the green alga *Chlorococcus* (13), the green flagellates *Chlamydomonas snowiae* (17) and *Pyramimonas tetrarhynchos* (18). Bacterial components of the mat are *Rhodospirillum fulvum* (19), *Rhodopseudomonas palustris* (20), *Rhodomicrobium vannieli* (21), species of the genera *Beggiatoa* (22) and *Thiocapsa* (23), and numerous others.

The banks of this biotope are lined with saltgrass, *Distichlis spicata* (4, 28) and glasswort, *Salicornia virginica* (3, 29). Numerous crustacean browsers feed on the algae, which are in turn fed upon by cyprinodontid fish and blue crabs, *Callinectes sapidus* (5), during periods of high water levels. There are also the snowy egret, *Leucophoyx thula* (1; [*Egretta thula*]) and great blue heron, *Ardea herodias* (2).

Numerous nematodes, diatoms and protozoans grow both in and below the cyanobacteria layer. The anaerobic sediments are rich in various bacteria such as *Desulforibrio* spp. and pseudomonads.

MUD FLAT

Mud flats are extensive regions in the highest backwaters of the estuarine system. They consist of mobile fine silt that is quite drained, with some ponding. This does not allow larger organisms to stabilize the substrate. Consequently, most of the biota are interstitial. This biotope grades into cyanobacteria (blue-green algal) mats in areas subject to wind tides and frequent ponding. In general, mud flats are hydrated enough to be anaerobic at depths of a few centimeters. While they do not appear to be permanently inhabited by larger organisms, the interstitial organisms consisting of both plants and animals are quite productive. Where plants do colonize, mounds of stabilized sediment stand above the mud flat.

The flats are often bounded by banks which are covered with saltgrass, *Distichlis spicata* (1), and glassworts, *Salicornia bigelovii* and *S. perennis* (2, 8, 11), as shown in Fig. 14.

There are huge numbers of small organisms living both on and in the mud. Due to the numbers, the productivity is high although the area may appear barren. These include aerobic bacteria (16), which may reach densities as high as 10,000,000 per gram of mud, diatoms, *Navicula* (12) and *Coscinodiscus* sp. (15), protozoans, such as *Euplotes* (13), and green algae, *Euglena* sp. (14), dinoflagellates, nematodes, copepods, amphipods, ostracods, as well as anaerobic bacteria. Other infaunal organisms include the gem clam, *Gemma gemma* (17), polychaete, *Amphitrite* (18) and the clam *Tagelus* sp. Organisms which


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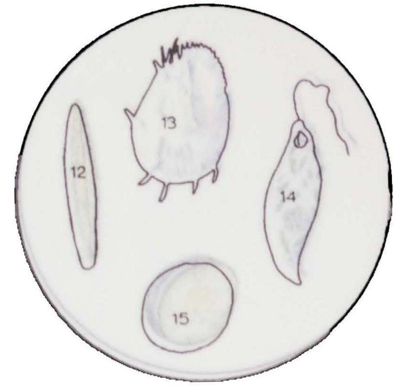
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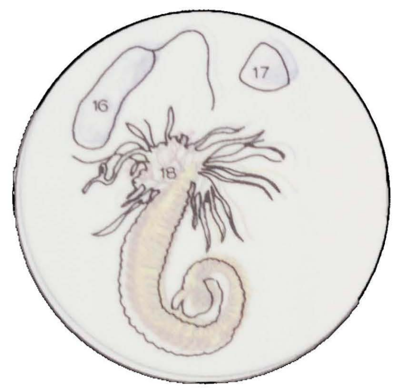
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FIG. 14. Mud flat. Species list begins on the following page.

FIG. 14 (cont'd.). Mud flat species list.

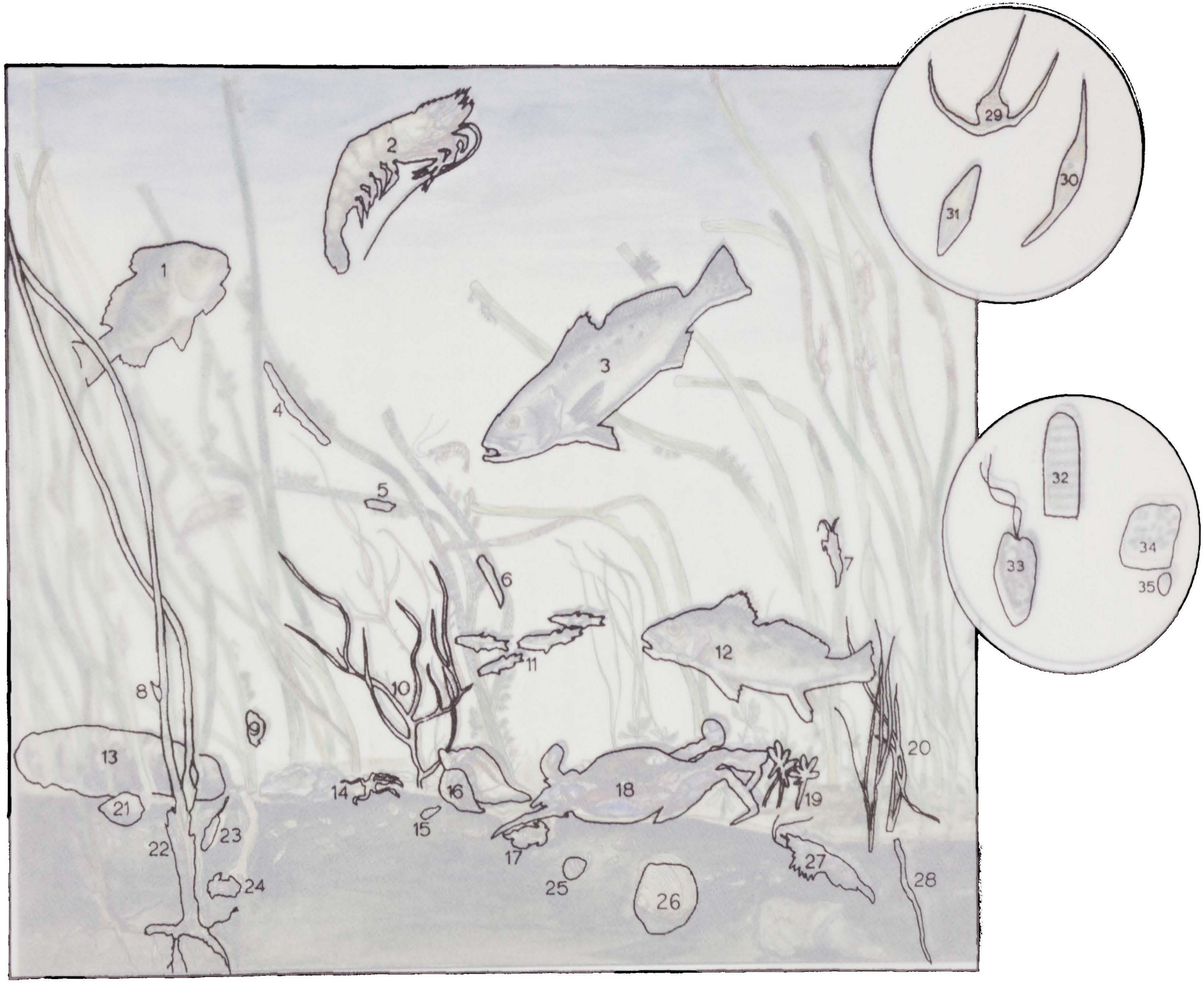
1. *Distichlis spicata* - Salt grass
2. *Salicornia* sp. - Glasswort
3. *Himantopus mexicanus* (female) - Black necked stilt
4. *Himantopus mexicanus* (male) - Black necked stilt
5. *Ereunetes mauri* - Western sandpiper [*Calidris mauri*]
6. *Limosa fedoa* - Marbled goodwit
7. *Crassostrea virginica* - Oyster
8. *Salicornia bigelovii* - Glasswort
9. *Uca pugnax* - Fiddler crab [*Uca longisignalis*]
10. *Limnodromus scolopaceus* - Dowitcher
11. *Salicornia virginica* - Glasswort
12. *Navicula* sp. - Pennate diatom
13. *Euplotes* sp. - Protozoan
14. *Euglena* sp. - Green algae
15. *Coscinodiscus* sp. - Diatom
16. Aerobic bacterium
17. *Gemma gemma* - Gem clam
18. *Amphitrite* sp. - Polychaete

on firmer bank areas are oysters, *Crassostrea virginica* (7) and fiddler crabs, *Uca pugnax* (9; [*Uca longisignalis*]).

Many birds are common visitors. Those shown are black necked stilt, *Himantopus mexicanus* (3, 4), western sandpiper, *Ereunetes mauri* (5; [*Calidris mauri*]), marbled goodwit, *Limosa fedoa*, and the dowitcher, *Limnodromus scolopaceus* (10).

THALASSIA GRASSFLAT

This extensive and productive biotope is characteristically composed of moderate to dense growths of turtle grass, *Thalassia testudinum* (22), shoal grass, *Diplanthera wrightii* (20; [*Halodule wrightii*]), *Halophila engelmannii* (19) and widgeon grass, *Ruppia maritima*, as shown in Fig. 15 (*R. maritima* not shown). The distribution is usually in one to five feet of water along the margins and throughout bays and lagoons. Depths are controlled by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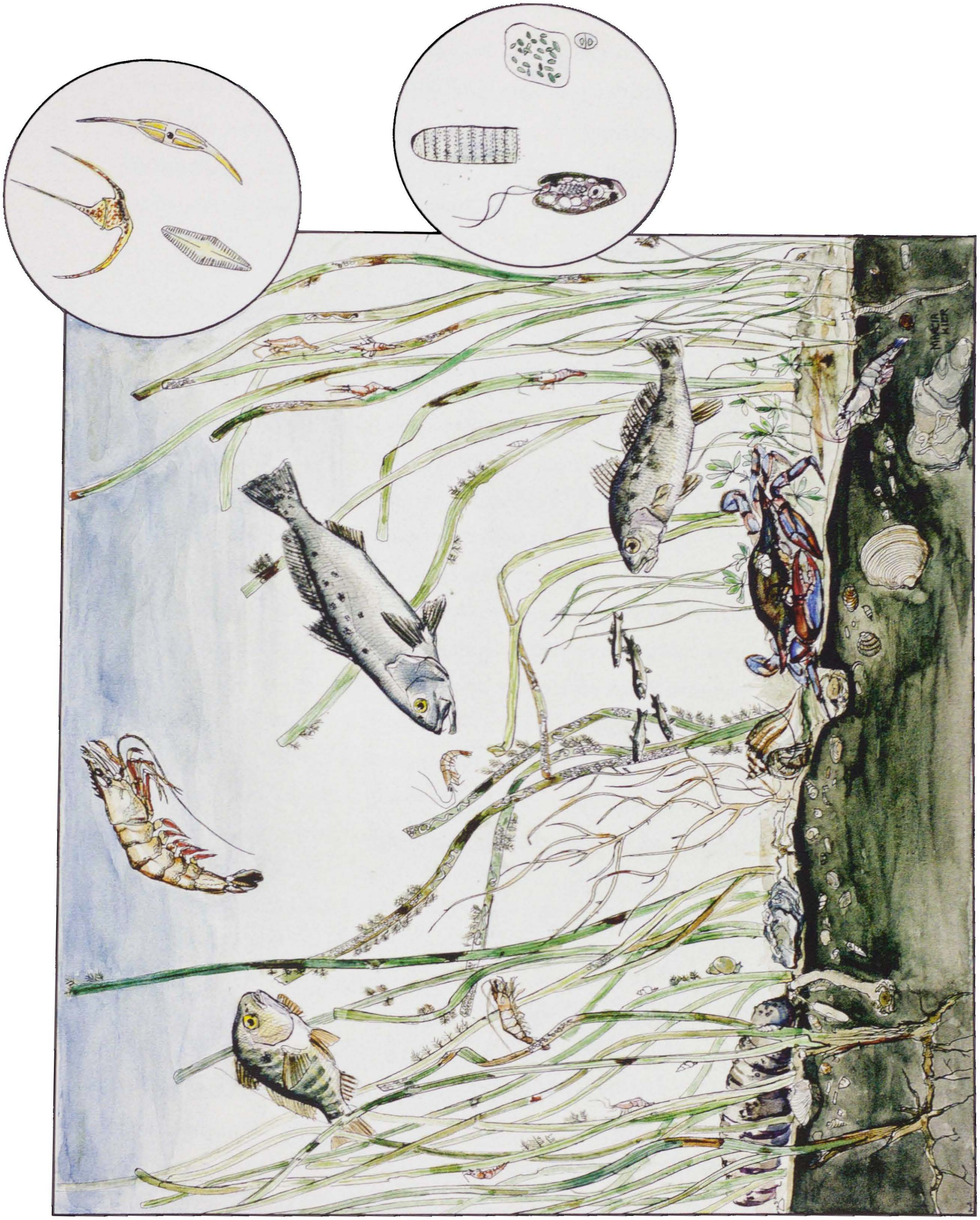

FIG. 15. *Thalassia* grassflat. Species list begins on the following page.

FIG. 15 (cont'd.). *Thalassia* grassflat species list.

1. *Lagodon rhomboides* - Pinfish
2. *Penaeus aztecus* - Brown shrimp
3. *Cynoscion nebulosus* - Spotted sea trout
4. Hydrozoan
5. *Spirorbus* sp. - Serpulid worm
6. *Spirorbus* sp. - Serpulid worm
7. *Paleomonetes vulgaris* - Grass shrimp
8. *Cerithidea turrita* - Horn shell [*Cerithidea pliculosa*]
9. *Neritina reclivata* - Olive nerite
10. *Gracilaria* sp. - Red alga
11. *Menidia beryllina* - Tidewater silverside
12. *Sciaenops ocellatus* - Juvenile redfish
13. *Thyone* sp. - Sea cucumber
14. *Ophiothrix* sp. - Brittle star
15. *Odostomia gibbosa* - Small gastropod
16. *Clibinarius vittatus* - Hermit crab
17. *Neopanope texana* - Mud crab
18. *Callinectes sapidus* - Blue crab
19. *Halophila engelmannii* - Star grass
20. *Diplanthera wrightii* - Shoal grass [*Halodule wrightii*]
21. *Phacoides pectinatus* - Lucina clam
22. *Thalassia testudinum* - Turtle grass
23. *Ensis minor* - Razor clam
24. *Rhithropanopeus harrissi* - Burrowing crab
25. *Chione cancellata* - Venus clam
26. *Phacoides pectinatus* - Lucina clam
27. *Penaeus duorarum* - Pink shrimp
28. *Phascolosoma gouldii* - Mud worm
29. *Ceratium* sp. - Dinoflagellate
30. *Nitzschia* sp. - Diatom [*Bacillaria*]
31. *Cymbella* sp. - Diatom

FIG. 15 (cont'd.). *Thalassia* grassflat species list.

32. *Oscillatoria* sp. - Cyanobacterium (blue-green alga)
33. *Dunaliella paupera* - Green alga
34. *Microcystis* sp. (colony) - Green alga
35. *Microcystis* sp. (individual) - Green algae

turbidity of the water which limits light penetration. Combined with the heavy growths of attached plants and animals, the biomass represented by the grass flats is large. When the plants die back in autumn, the leaves and stems break off and are distributed among the other biotopes where the material, whether grazed or decomposed, makes significant contributions to the food chain. The growth offers protection and is generally thought of as the major nursery area for the young of many species of fish and crustaceans.

The grass acts as a surface for many invertebrates and microalgae such as diatoms. This adds to the productivity of the area. The sediments, because of the quieting action of the grasses are generally soft and anaerobic due to entrapment of organic matter.

Due to the seasonal and diurnal fluctuations in temperature and migratory habits, few highly motile animals are found in this biotope on a permanent basis. Among the sedentary species found are large numbers of bryozoans (not shown), hydroids (4) and serpulid worms of the genus *Spirorbus* (5, 6). These organisms share the leaves and stems with equally large numbers of sessile diatoms such as *Cocconesis* sp. (not shown).

Many of the motile forms in this biotope are omnivores which function both as scavengers and grazers. These include the horn shell, *Cerithidea turrita* (8; [*Cerithidea pliculosa*]), olive nerite, *Neritina reclavita* (9) and a small gastropod, *Odostomia gibbosa* (15), as shown, as well as *Melampus* sp. and *Modulus* sp., among the gastropods. Crustacean members shown for this group are the grass shrimp, *Paleomonetes vulgaris* (7), hermit crab, *Clibinarius vittatus* (16), mud crab, *Neopanope texana* (17), blue crab, *Callinectes sapidus* (18), a crab known as *Rhithropanopeus harrissi* (24), the brown and pink shrimps, *Penaeus aztecus* (2) and *P. duorarum* (27), as well as the white shrimp, *Penaeus setiferus*, which is not shown. The shrimp appear in the grass flats as early larval stages and use the cover and food of this biotope as a nursery, migrating offshore to spawn upon maturity. Many larval fish species develop in the protection of this biotope, as well. Final members of this group, as shown, are the sea cucumber, genus *Thyone* (13), the brittle star, genus *Ophiothrix* (14), and the mud worm *Phascolosoma gouldii* (28).

The burrowing forms of this biotope are the razor clam, *Ensis minor* (23), Venus clam, *Chione cancellata* (25), and Lucina clam, *Phacoides pectinatus* (26), as shown, as well as those of the genera *Tellina, Tagelus* and *Laevicardium.*

Many fish frequent the grass flats. These include pinfish, *Lagodon rhomboides* (1), spotted sea trout, *Cynoscion nebulosus* (3), tidewater silversides, *Menidia beryllina* (11), redfish, *Sciaenops ocellatus* (12), as well as golden croaker, *Micropogon undulatus* [*Micropogonias undulatus*], mullets, *Mugil cephalus* and *M. curema*, and menhaden, *Brevoortia patronis.*

Several algae are represented from this biotope in addition to those mentioned as epiphytes. These include the large red alga *Gracilaria* (10), the diatoms *Nitzschia* (30; [*Bacillaria*]) and *Cymbella* (31), the dinoflagellate *Ceratium* (29), the green alga *Dunaliella* (33), the cyanobacterium *Oscillatoria* (32) and the colonial green alga, *Microcystis* (34, 35).

SAND FLAT

This biotope is characterized as a flat area sometimes inundated by wind tides. The bottom consists of unstable sand. The rigors of this substrate preclude organic sediments as well as attached plants or animals. Low energy currents and winds are responsible for moving the sand from place to place. As in the mud flats, the interstitial spaces in the sand offer a habitat for an extensive microflora. Evaporative processes replenish nutrients from deeper layers by capillary action. While not appearing to be productive, this biotope produces considerable biomass.

The banks are often bounded by salt grass, *Distichlis spicata* (11), and glassworts, *Salicornia bigelovii* and *S. perennis* (8, 12), as shown in Fig. 16. Also found on the banks are fiddler crabs, *Uca pugnax* (3, 7; [*Uca longisignalis*]). Bottom dwellers include razor clams, *Ensis minor* (13), occasional oysters, *Crassostrea virginica* (9), protochordates, *Saccoglossus* sp. (23), the tube-building worm, *Clymenella torquata* (22), nematode worms (24), the protozoan genera *Amoeba* (19), and *Euplotes* (17), the diatom *Navicula punctigera* (18), the cyanobacterium genus *Chroococcus* (20), and various sulfur bacteria such as *Desulfovibrio* (16) and *Beggiatoa* (21).

Common birds are the greater yellowlegs, *Totanus melanoleucus* (1; [*Tringa melanoleuca*]), caspian tern, *Hydropogone caspia* (2; [*Sterna caspia*]), sanderling, *Crocethia alba* (4; [*Calidris alba*]), avocet, *Recurvirostra americana* (5), ruddy turnstone, *Arenaria interpres* (6), semipalmated plover, *Charadrius semipalmatus* (10) and the oyster catcher, *Haematopus*


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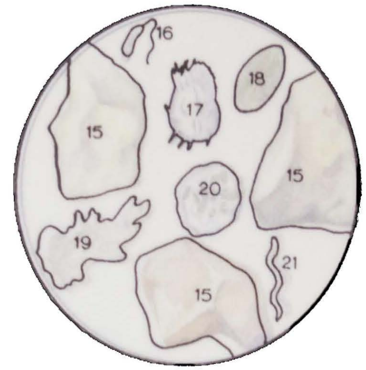
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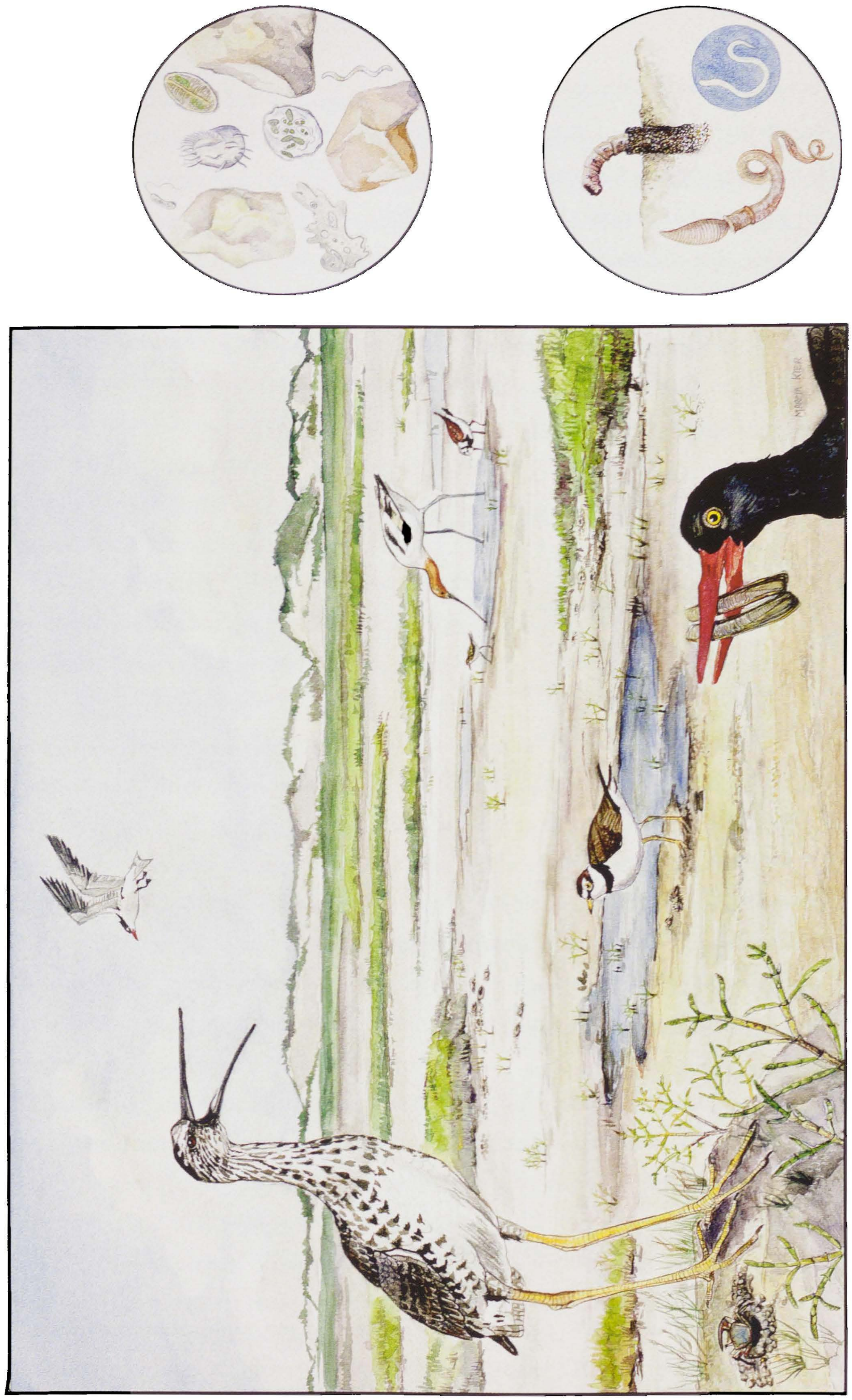

FIG. 16. Sand flat. Species list begins on the following page.

FIG. 16 (cont'd.). Sand flat species list.

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

palliatus (14).

BAY PLANKTONIC

It is difficult, if not impossible, to precisely delimit the geographical boundaries of the bay planktonic biotope because of the spatial and temporal variability exhibited by the plankton. Here the environment is a moving mass of water which may exist at one time as an independent, more or less homogenous patch, while at other times, it may mix indistinguishably into a larger mass. Planktonic organisms, possessing only feeble powers of locomotion, are constrained from travelling against currents and across physical and chemical boundaries. However, planktonic organisms have been shown to be capable of significant vertical migrations on a daily basis and by utilizing this ability in conjunction with tide and current fluctuations, have the ability to concentrate and maintain a relatively stable position within a water column for extended periods of time or to travel considerable distances to areas with more favorable environmental conditions.

The bay planktonic biotope may vary from a state of great uniformity in chemical and biotic composition to a state in which highly distinctive patches form a mosaic of different size patches with observable or poorly observable interfaces. An example of a well defined patch would be a phytoplankton "bloom" (11).

Phytoplankton (Fig. 17) are the primary producers within the system and certain plankton associations are the most constant biological feature of the biotope. Diatoms of the genera *Rhizosolenia* (1), *Asterionella Asterionellopsis* (2), *Coscinodiscus* (3), *Biddulphia* (4; [*Odontella*]), *Thalassiosira* (17), *Thalassiothrix* (18), *Thalassionema* (19), *Gyrosigma* (20), *Nitzschia* (21; [*Bacillaria*]), *Skeletonema* (22), and *Actinoptychus* (23), *Ditylum* (6), and dinoflagellates of the genera *Ceratium* (7), are microscopic phytoplankton normally present in enormous numbers. Both groups utilize light energy to fix carbon as "food reserves" or incorporate it as integral structural components of the organisms themselves. The fixed carbon of these tiny plants is consumed by barely visible invertebrate zooplankton such as copepods, *Acartia* sp. (24) and *Candacea* sp. (25), and *Peridinium* (8; *Protoperidinium*), (Fig. 17). In this way, organic carbon is moved upward in the food chain as these small zooplankton (animals) are consumed by even larger animals. Fish and shrimp larvae must have these lower organisms as food sources.

In general, diatoms dominate the winter flora, but share or yield dominance to dinoflagellates during the summer. Nanoflagellates (small, less than 10 micrometers in size) are usually present throughout the year, but may exhibit spring or fall blooms. Higher diversity levels tend to prevail in the lower margins of the bay or estuary signifying greater variety in ecological niches. Progressive diminution of diversity up bay indicates a reduced number of niches resulting from either unfavorable overall conditions or great variability (instability) in conditions originating at the end of the bay.

In addition to phytoplankton and zooplankton, larval and post-larval forms of numerous fish and crustacea, many of commercial importance, contribute to the total

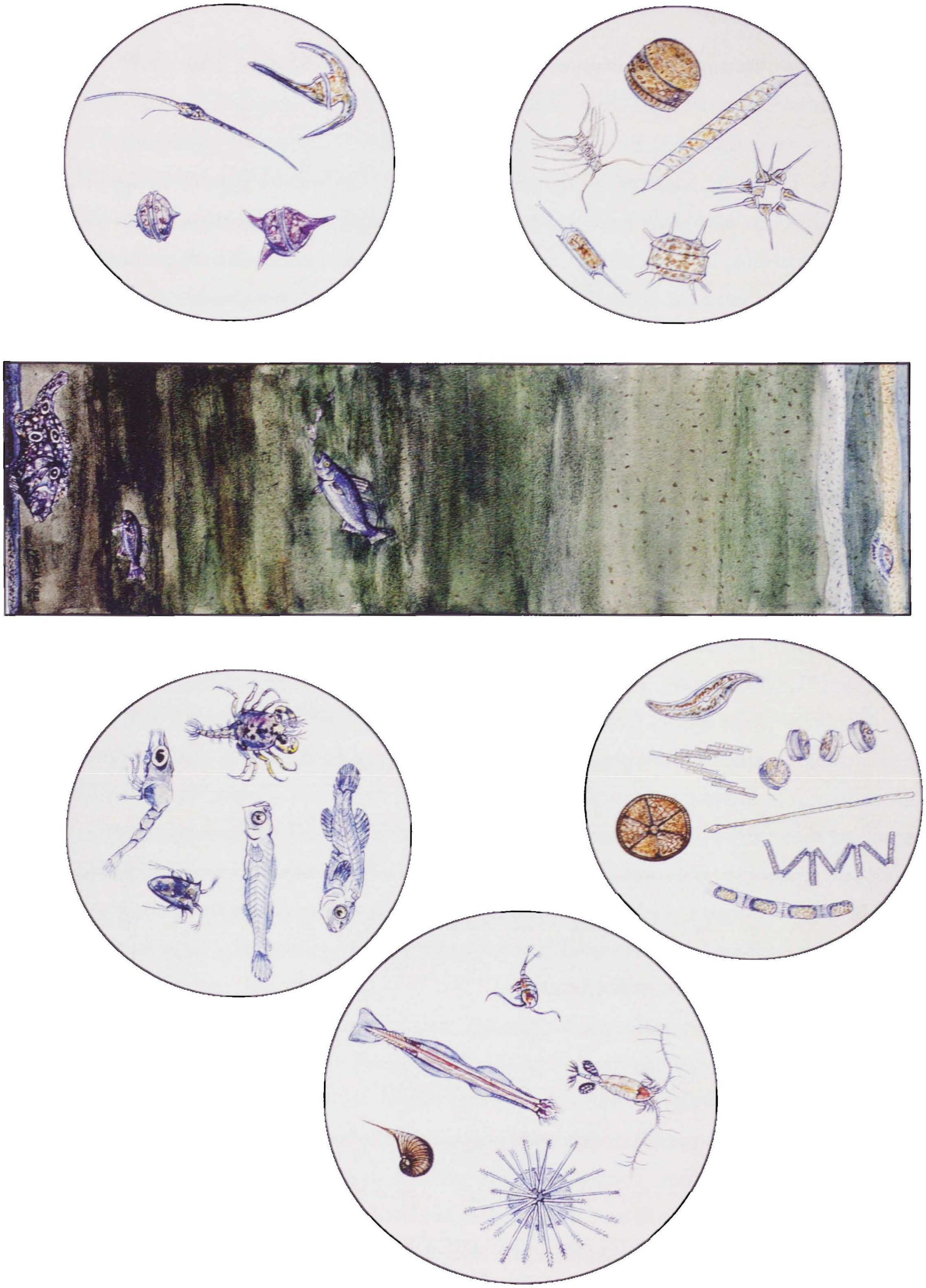

FIG. 17. Bay planktonic. Species list begins on the following page.

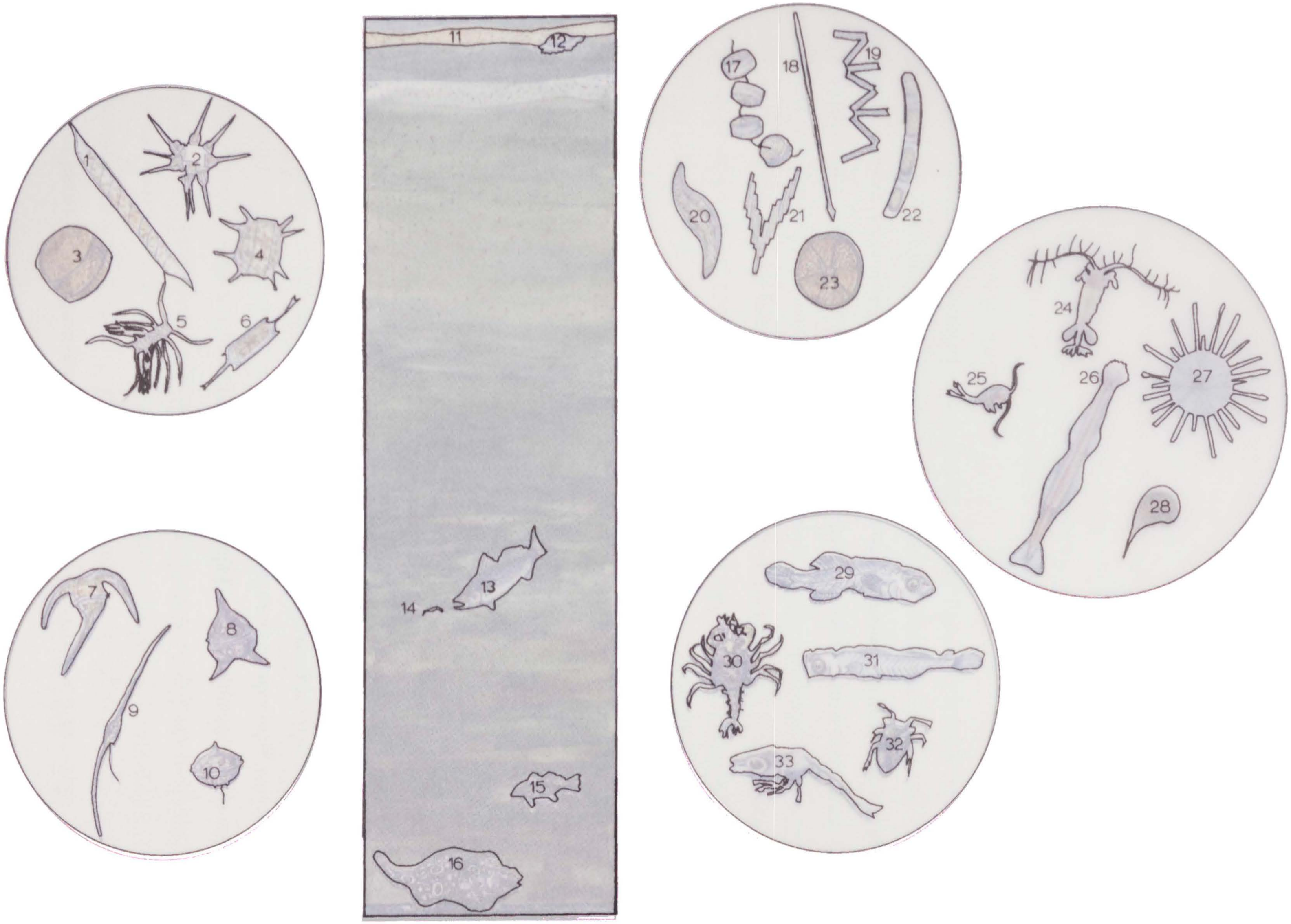
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FIG. 17 (cont'd.). Bay planktonic species list.

1. *Rhizosolenia styliformis* - Diatom
2. *Asterionella japonica* - Diatom *[Asterionellopsis]*
3. *Coscinodiscus radiatus* - Diatom
4. *Biddulphia mobiliensis* - Diatom [*Odontella*]
5. *Chaetoceras affinis* - Diatom
6. *Ditylum brightwellii* - Diatom
7. *Ceratium tripos* - Dinoflagellate
8. *Peridinium oceanicum* - Dinoflagellate [*Protoperidinium*]
9. *Ceratium fusus* - Dinoflagellate
10. *Peridinium ornatum* - Dinoflagellate [*Protoperidinium*]
11. Plankton bloom
12. *Aurelia aurelia* - jelly fish [*Aurelia aurita,* moon jelly]
13. *Cynoscion arenarius* - Sand trout
14. *Penaeus aztecus* - Brown shrimp
15. *Leiostomus xanthurus* - Spot
16. *Quadrocellatus ancyclopsetta* - Flounder [*Ancylopsetta quadrocellata,* Ocellated flounder]
17. *Thalassiora decipiens* - Diatom
18. *Thalassiothrix longissima* - Diatom
19. *Thalassionema nitzoides* - Diatom
20. *Gyrosigma* sp. - Diatom
21. *Nitzschia paradoxia* - Diatom [*Bacillaria*]
22. *Skeletonema costatum* - Diatom
23. *Actinoptychus undulatus* - Diatom
24. *Acartia* sp. - Copepod
25. *Candacea* sp. - Copepod
26. *Sagitta macrocephla* - Arrow worm
27. *Aulacantha scolymantha* - Siliculose amoeba
28. Foraminifera
29. Larva of *Orthopristes chrysopterus* - Hogchoker
30. Megalops stage of *Carcinus maenus* - Crab

FIG. 17 (cont'd.). Bay planktonic species list.

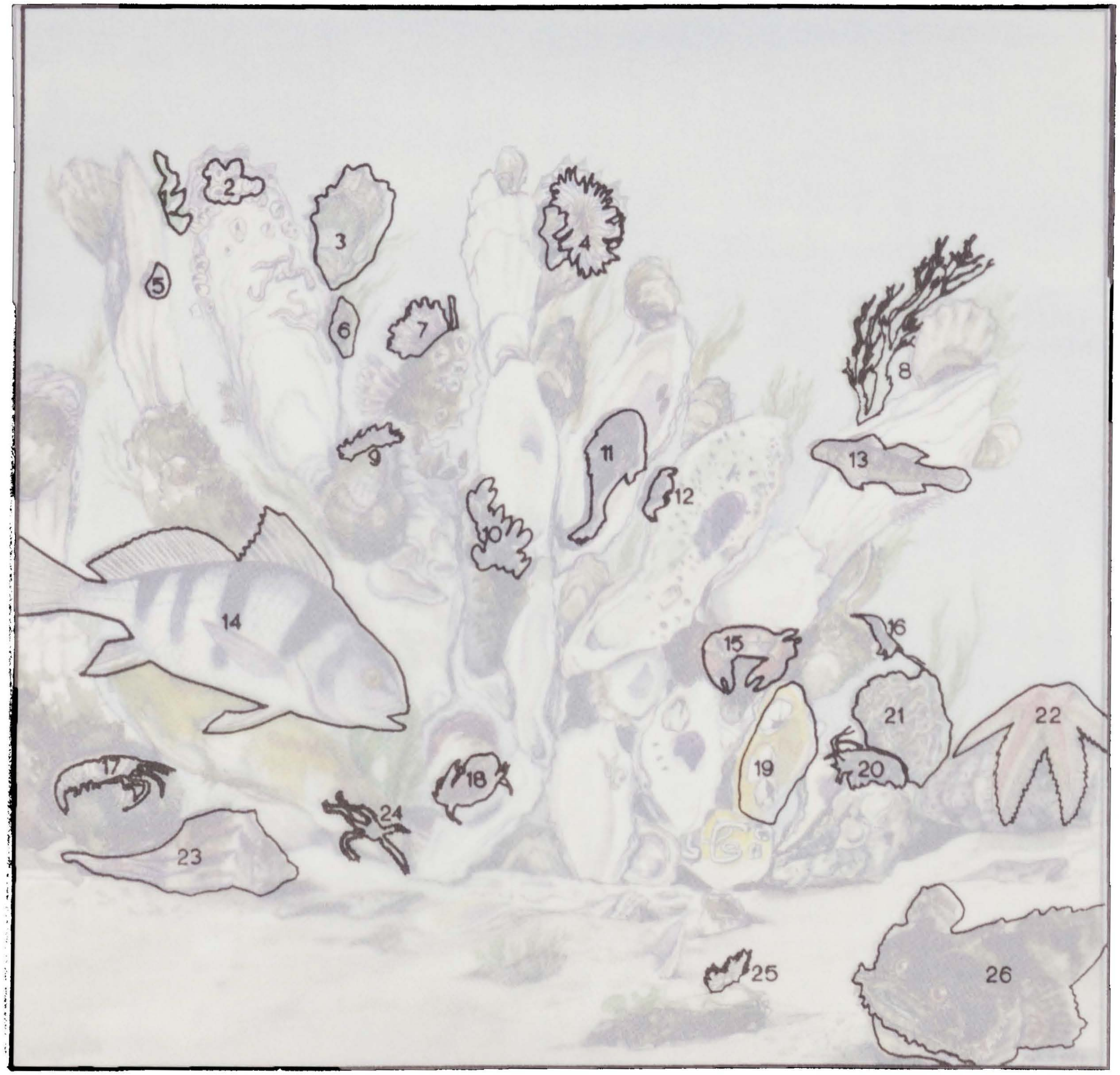
31. Larva of *Lagodon rhomboides* - Pinfish
32. Nauplius of *Balanus* - Barnacle
33. Zoea stage of *Pagurus* - Hermit crab

plankton biomass. Depending upon the life history of the species involved, these "meroplankton" may contribute a significant proportion of the primary and secondary consumers in the bay planktonic biotope. It is a well known fact that vast numbers of larval and post-larval shrimp (*Penaeus*) (14), mullet (*Mugil*), spot (*Leiostomus*) (15), croaker (*Micropogon* [*Micropogonias*]), trout (*Cynoscion*) (13), menhaden (*Brevoortia*), flounder (*Paralichthys* and *Quadrocellatus* [*Ancylopsetta*]) (16), and redfish (*Sciaenops*) are found seasonally in this biotope feeding on zooplankton such as *Acartia* (24) and "grazing" on the phytoplankton such as the diatoms *Thalassionema* (19), *Skeletonema* (22) and *Nitzschia* (21; [*Bacillaria*]).

OYSTER REEF

Wherever currents of sufficient velocity to transport suspended material are found in combination with solid substrates, sedentary filter feeding animals tend to cluster. With time, the hard exoskeletons of these organisms accumulate into sizeable mounds and ridges. Such vertical anomalies formed by the American oyster, *Crassostrea virginica* (3), and associated organisms constitute the oyster reef biotope (Fig. 18A and B). These reefs occur in all the major Texas bays except Baffin Bay and Laguna Madre, probably because of a requirement of lower salinities. In shallow waters, the reef may form a low island with a fringe of live oysters in the intertidal zone bordered by other biotopes such as grass, sand or mud flats, while in deeper waters, the reef may form a shoal rising several feet from the bottom, with live oysters covering its entire surface. Intertidal oysters will grow at higher salinities than submerged oysters.

Typical associated reef plants in the Texas coastal area are sea lettuce, *Ulva lactuca* (1A), the red algae *Hypnea musiformis* (9A), and the green algal genus *Cladophora* (8A). Nearby may be beds of turtle grass, *Thalassia testudinum* (10B) with their associated benthic organisms (1-9B) and sand flats with their own unique benthos (17-23B). Other sessile animals shown in the reef setting are barnacles, genus *Balanus* (2A), anemones, *Bunodosoma cavernata* (4A), various hydroids (25A), mussels, *Modiolus americanus* (10A, 12B), and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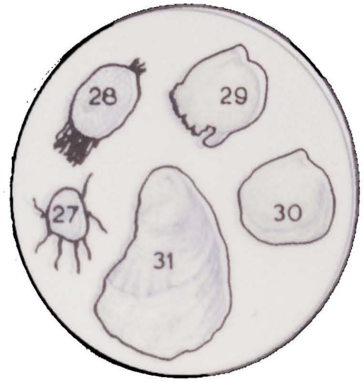
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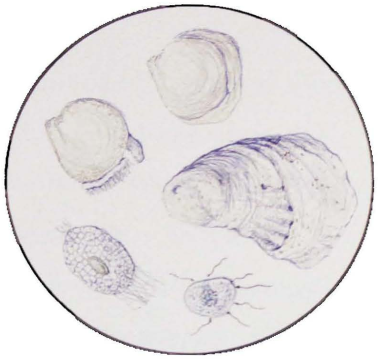

FIG. 18A. Oyster reef. Species list begins on the following page.

FIG. 18A (cont'd.). Oyster reef species list.

1. *Ulva lactuca* - Sea lettuce
2. *Balanus* sp. - Barnacle
3. *Crassostrea virginica* - Oyster
4. *Bunodosoma cavernata* - Anemone
5. *Ischnochiton papillosus* - Chiton
6. *Thais haemostoma* - Florida rock shell [*Stremonita haemostoma*]
7. *Thais h.* eggs [*Stremonita haemostoma*]
8. *Cladophora* sp. - Green alga
9. *Hypnea musiformis* - Red alga
10. *Modiolus americanus* - Mussel
11. *Gobiesox strumosus* - Skillet fish
12. *Eurypanopeus depressus* - Flat mud crab
13. *Hypleurochilus geminatus* - Crested blenny
14. *Pogonias cromis* - Black drum
15. *Menippe mercenaria* - Stone crab
16. *Paleomontes* sp. - Grass shrimp
17. *Alpheus estuariensis* - Snapping shrimp
18. *Panopeus herbstii* - Mud crab
19. *Cliona* sp. - Boring sponge
20. *Alpheus estuariensis* - Snapping shrimp
21. *Hydroides* sp. - Serpulid worms
22. *Luidia clathrata* - Starfish
23. *Busycon contrarium* - Whelk [*Busycon perversum*]
24. *Ophioroides* sp. - Brittle star [*Ophiothrix* sp.]
25. Hydroid
26. *Opsanus beta* - Gulf toadfish
27. Oyster egg undergoing fertilization*
28. Beginning of shell formation*
29. Last free-swimming stage*
30. Spat 5-6 hours after settling*

FIG. 18A (cont'd.). Oyster reef species list.

31. Adult *Crassostrea virginica**
32. *Crassostrea virginica* - American oyster*
33. *Polydora* sp. - Polychaete
34. *Diplothyra smithii* - Boring clam
35. *Pinnotheres ostreum* - Oyster crab

* Stages in the development of *Crassostrea virginica.*

serpulid worms, genus *Hydroides* (21A). Organisms dependent on the shellfish for food include the Florida rock shell, *Thais haemostoma* (6A; [*Stramonita haemostoma*]), a type of oyster drill, slipper limpets, *Crepidula fornicata* (17B), and stone crabs, *Menippe mercenaria* (15A) and *M. adina* (15B), starfish, *Luidia clathrata* (22A), and oyster crabs, *Pinnotheres ostreum* (35A). Burrowing forms include snapping shrimp, *Alpheus estuariensis* (20A, 14B), boring sponge, genus *Cliona* (19A, 13B), mud crab, *Panopeus herbstii* (18A), flat mud crab, *Eurypanopeus depressus* (12A, 11B), polychaete worms of the genus *Polydora* sp. (33A) and the boring clam, *Diplothyra smithii* (34A). The chiton, *Ischnochiton papillosus* (5A), grass shrimp, genus *Paleomonetes* (16A, B), brittle star, genus *Ophioroides* (24A; [*Ophiothrix*]), periwinkles, *Littorina* sp. (18B), moon snails, *Polinices duplicatus* (19B) and the whelk, *Busycon contrarium* (23A; [*Busycon perversum*]) are predominant grazers shown for this biotope. Several small fish are found associated with the reef, among them skillet fish, *Gobiesox strumosis* (11A), crested blenny, *Hypleurochilus geminatus* (13A), and gulf toadfish, *Opsanus beta* (26A). The black drum, *Pogonias cromis* (14A), is known to feed on oysters and other shellfish.

When the reef is exposed, various birds such as white pelicans, *Pelecanus erythrorhynchos*, great blue heron, *Ardea herodias* and laughing gull, *Larus atricilla* use it as a resting place.

JUNCUS FRESH WATER MARSH

The fresh water marsh biotope is found in permanent fresh water ponding or river areas which are maintained by permanently high water table levels or high rainfall. The dominant vegetation are reeds, genus *Juncus* (4), and rushes, genus *Scirpus* (5, 12, 20) as shown in Fig. 19. Also found here are the cordgrasses, *Spartina alterniflora* and *S. patens* (14) as well as cattails, genus *Typha* (11, 21), and bamboo briars, *Smilax* sp. (10). In areas where there is a

FIG. 18B. Oyster reef/grass flat. Species list begins on the following page.

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FIG. 18B (cont'd.). Oyster reef/grass flat species list.

1. *Petricola pholladiformis* - boring clam
2. *Cyrtopleura costata* - Angel wing
3. *Dentalium texasianum* - Tusk shell
4. *Diopatra cuprea* - Plumed tube worm
5. *Clymenella torquata* - Bamboo worm
6. *Anadera* sp. - Blood ark
7. *Amphitrite* sp. - Terebellid worm
8. *Bittium varium* - Variable bittium
9. *Chione cancellata* - Cross-barred venus
10. *Thalassia testudinum* - Turtle grass
11. *Eurypanopeus depressus* - Flat mud crab
12. *Modiolus americanus* - Tulip mussel
13. *Cliona* sp. - Boring sponge
14. *Alpheus estuariensis* - Snapping shrimp
15. *Menippe adina* - Stone crab
16. *Paleomonetes* sp. - Grass shrimp
17. *Crepidula fornicata* - Slipper limpet
18. *Littorina* sp. - Periwinkle
19. *Polinices duplicatus* - Moon snail
20. *Mediomastus californiensis* - Capitellid worm
21. *Callianassa louisianensis* - Ghost shrimp
22. *Clymenella torquata* - Bamboo worm
23. *Lucina pectinata* - Buttercup

salinity gradient, the community composition changes along the gradient into a *Spartina* dominated salt marsh. The sediments are usually soft mud, often anaerobic due to high organic content. The boundary area is often characterized by the submerged grass *Ruppia maritima* (not shown).

The large amounts of plant material produced annually provide food and nesting areas for many waterfowl. Among these are the Canada goose, *Branta canadensis* (1), green heron, *Butorides virescens* (2; [*Butorides striatus*]), coot, *Fulica americana* (8), and wood ibis [wood

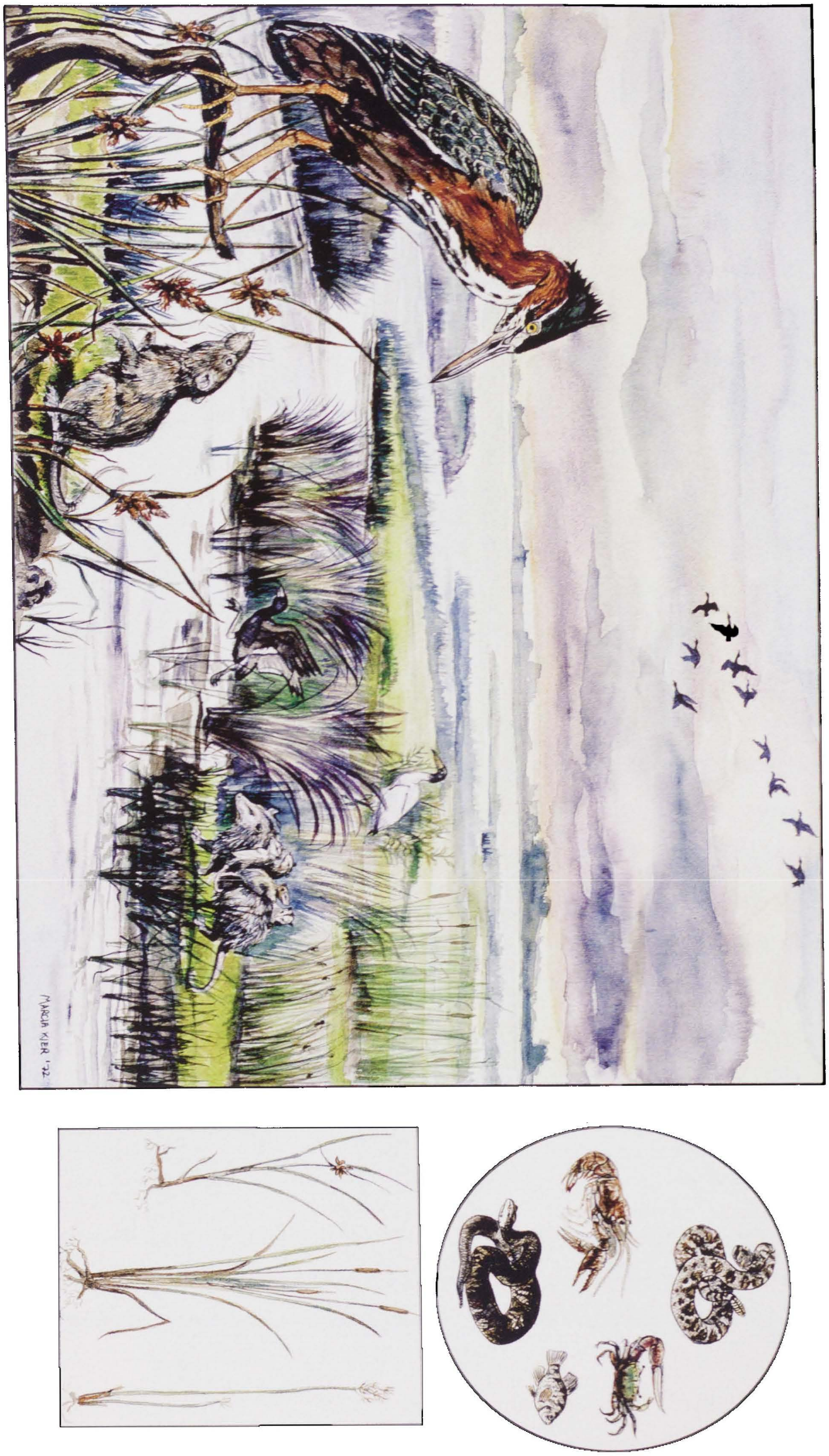

FIG. 19. *Juncus* fresh water marsh. Species list begins on the following page.

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FIG. 19 (cont'd.). *Juncus* fresh water marsh species list.

1. *Branta canadensis* - Canadian geese
2. *Butorides virescens* - Green heron [*Butorides striatus*]
3. *Spartina alterniflora* - Smooth cordgrass
4. *Juncus* sp. - Reed
5. *Scirpus* sp. - Bullrush
6. *Rattus norvegicus* - Norway rat
7. *Procambarus* burrow
8. *Fulica americana* - Coot
9. *Mycteria americana* - Wood ibis [Wood stork]
10. *Smilax* sp. - Bamboo briar
11. *Typha domingensis* - Cattails
12. *Scirpus* sp. - Bullrush
13. *Didelphis mesamericana* - Opossum and young [*Didelphis virginiana*]
14. *Spartina patens* - Marsh hay cordgrass
15. *Crotalus atrox* - Western diamondback rattlesnake
16. *Uca pugnax* - Fiddler crab [*Uca longisignalis*]
17. *Procambarus clarki* - Crayfish
18. *Cyprinodon variegatus* - Sheepshead minnow
19. *Agkistrodon piscivorus* - Western cottonmouth moccasin
20. *Scirpus* sp. - Bullrush
21. *Typha domingensis* - Cattail
22. *Sporobolus virginicus* - Seashore dropseed

stork], *Mycteria americana* (9). The crustaceans are also represented in the fresh water marsh, with crayfish, *Procambarus clarki* (7, 17) feeding on the abundant detritus produced. The sheepshead minnow, *Cyprinodon variegatus* (18), also feeds on this material. Common terrestrial vertebrate inhabitants are the western diamondback rattlesnake, *Crotalus atrox* (15), the western cottonmouth moccasin, *Agkistrodon piscivoris* (19), the opossum, *Didelphis mesamericana* (13; [*Didelphis virginiana*]) and the Norway rat, *Rattus norvegicus* (6).

With the flushing action due to high tides and heavy runoff, much of the detrital material and bacterial decomposition products are introduced into the economy of the bay.

Along drainage channels where there is an intertidal interface, the fiddler crab, *Uca pugnax* (16; [*Uca longisignalis*]), predominates along the banks, and the clams, *Mercenaria mercenaria* and *Taegelus divisus* (not shown), the channel bottoms. Also found, but not shown, is the marsh periwinkle, *Littorina irrorata*, which feeds on the grasses.

RIVER MOUTH

This is a low salinity area (from 0.5 to 8‰) found at the mouths of rivers where freshwater is discharged into the upper bays. Bottom sediments associated with this fluctuating regime are predominantly muds and sandy muds. Depths range from about 3 to 7 feet. The water is usually turbid. Heavy surges of river water and concurrent turbid conditions during high rains followed by surges of salt water during exceptional tides and low river discharge make the biotope unfavorable for supporting a diverse community of organisms. Plant species include the freshwater grasses *Najas* and *Potamogeton* and the brackish widgeon grass, *Ruppia maritima.* Common clams include *Rangia cuneata* near the lower boundaries and the deep digging *Mya* clam in the area near the upper margins. Other clams include *Palymosoda* and *Macoma.* The snail *Littoridina* [*Littoridinops*] is common in some localities. Crustaceans include *Callinectes* and *Macrobrachium.* The soft, muddy, organic-rich bottoms provide a habitat for abundant ostracods. Foraminifera are not abundant in this biotope, but a few including *Candona, Darwinula* and *Physocypria* are characteristic indicators of the lower, more saline margin. Microscopic benthic diatoms are usually abundant. The dominant phytoplankton are dinoflagellates.

The characteristic fresh to brackish water is usually high in humic acids from upstream runoff. Turbidity, low salinity, and low pH values from these humic acids preclude significant growth of oysters and other sessile benthic shellfish. These tend to flourish in salinities from 10-30‰. On the other hand, these conditions are favorable for young shrimp and crabs which feed largely on the organic detritus flushed down from the rivers and shelter in the widgeon grass, *Ruppia maritima.*

RIVER FLOODPLAIN FOREST

Many biotopes depend extensively on solar energy, fixed as plant material, that is imported from upstream sources. One of these sources is the river floodplain forest. This biotope provides a rich variety of habitats. Much of the plant material which falls or is blown into the rivers is finally introduced into the biotopes downstream. This material is composed of about sixty percent leaves, twenty percent branches and twenty percent representing a miscellany of bark, scale, flowers and fruit.

The vertical stratification of the floodplain forest is readily apparent. The upper canopy is approximately one hundred feet high and contains a mixture of broad-leafed deciduous. The middle story, between fifteen and fifty feet is composed of smaller individuals of the same types. Finally, the ground story consists of low tangled thickets dominated by shrubs. There are few unshaded patches. The soil is damp and has the firm, slightly sticky consistency of an alluvial clay loam. Occasional flooding produces numerous small hillocks and gullies. These periodic inundations disrupt the floral and faunal communities and this is reflected by the large number of species competing for life in this biotope. Abbott (1966) cited thirty-four species of woody plants from the river floodplain as opposed to fourteen from the upper deciduous forest. Trees and shrubs normally found in this biotope include the following, listed in tabular form by scientific and common names. Numbers in parentheses refer to Fig. 20.

<u>Predominant Trees</u>
Ulmus crassifolia Nutt. - Cedar elm
Ulmus americana L. - American elm
Celtis occidentalis L. - Common hackberry
Celtis laevigata Wild. - Sugar hackberry
Morus rubra L. - Red mulberry
Diospyros virginiana L. - Common persimmon (9)
Fraxinum pennsylvanica landeolata Sarg. - Green ash
Carya illinoensis (Wang.) Koch - Pecan
Carya cordiformis (Wang.) Koch - Bitternut hickory
Quercus falcata Michx. - Southern red oak
Quercus lyrata Walt. - Overcup oak
Planera aquatica (Walt.) Gmel. - Water elm

<u>Other Trees</u>
Quercus stellata - Post oak (1)
Quercus nigra - Water oak (2, 18)
Ulmus alata - Winged elm (3)
Salix nigra - Black willow (11)

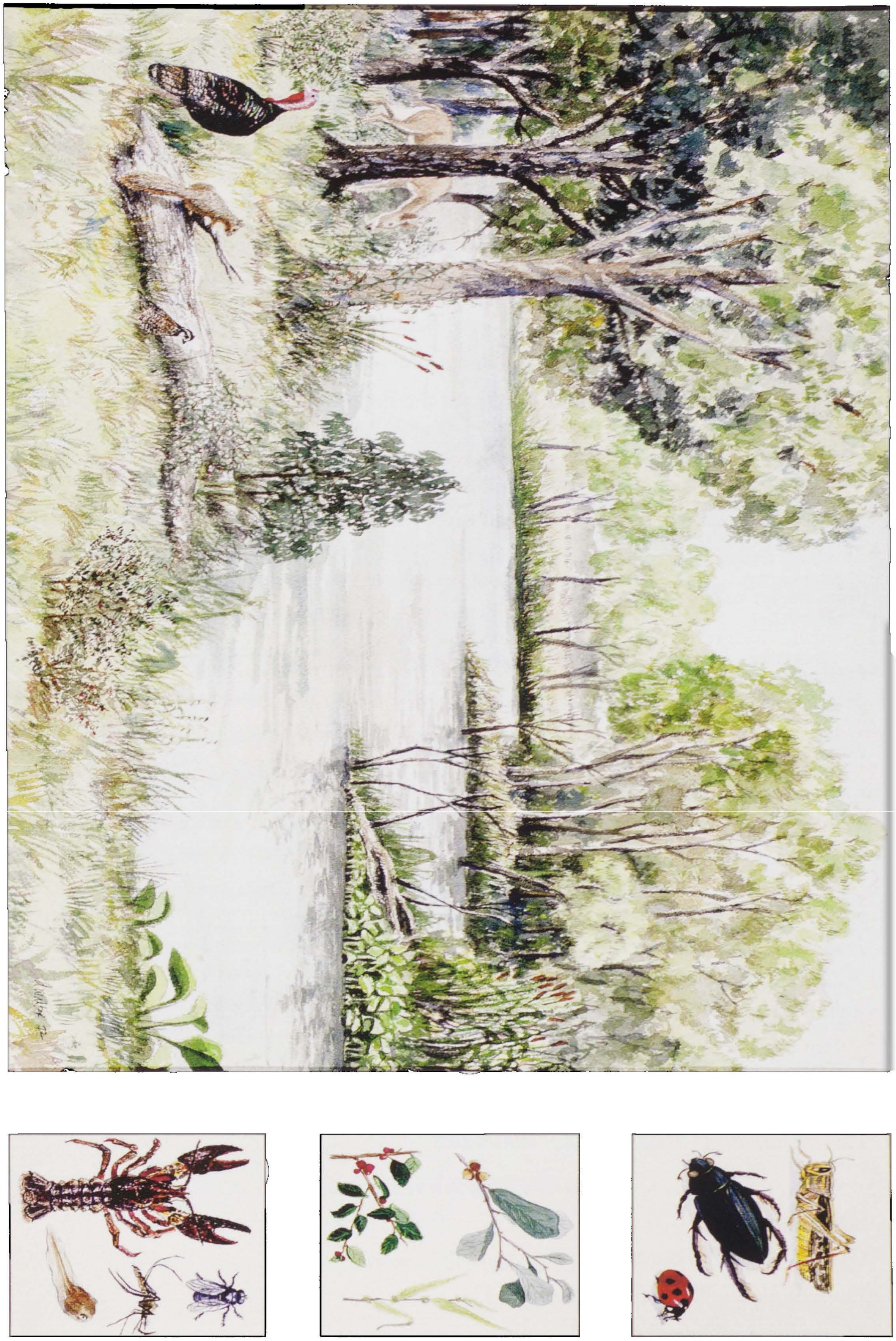

FIG. 20. River floodplain forest. Species list begins on the following page.

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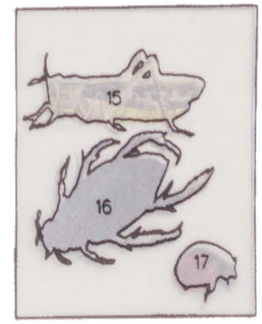

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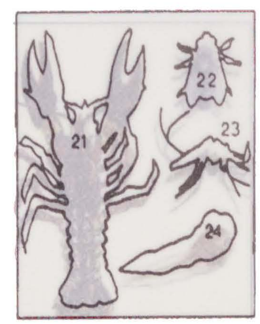

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FIG. 20 (cont'd.). River floodplain forest species list.

1. *Quercus stellata* - Post oak
2. *Quercus nigra* - Water oak
3. *Ulmus alata* - Winged elm
4. *Odocoileus virginianus* - Texas white tailed deer
5. *Smilax* sp. - Briar
6. *Meleagris gallopavo* - Wild turkey
7. *Sciurus carolinensis* - Gray squirrel
8. *Colinus virginianus* - Quail
9. *Diospyros virginiana* - Persimmon
10. *Ilex vomitoria* - Yaupon
11. *Salix nigra* - Black willow
12. *Salix caroliniana* - Coastal plain willow
13. *Typha domingensis* - Cattails
14. *Eichornia crassipes* - Water hyacinth
15. *Schistocerca lineata* - bird grasshopper [*Schistocerca americana*]
16. *Hydrophilus triangularis* - Water scavenger
17. *Coccinella novemnotata* - Spotted lady bug
18. *Quercus nigra* - Water oak
19. *Ilex vomitoria* - Yaupon
20. *Salix caroliniana* - Coastal plain willow
21. *Procambarus clarki* - Crayfish
22. *Calliphora* sp. - Blue bottle fly
23. *Culex* sp. - Common mosquito
24. *Rana* sp. - Tadpole

Salix caroliniana - Coastal plain willow (12, 20)

<u>Shrubs</u>

Rubus sp. - Dewberry

Crataegus sp. - Hawthorne

Ampelopsis arborea (L.) Rusby - Pepper vine

Vitis cinerea Engelm. - Sweet winter grape
Ilex decidua Walt. - Pollum-haw holly
Symphoricarpos sp. - Snowberry
Bigonia radicans L. - Common trumpet-creeper
Rhus sp. - Sumac
Zanthoxylum clava-herculis L. - Texas hercules-club prickly-ash

Also found are briars *Smilax* sp. (5) and yaupon, *Ilex vomitoria* (10, 19). Plants found growing in the water include cattails *Typha domingensis* (13) and water hyacinth *Eichornia crassipes* (14).

Only qualitative comparisons of the upland deciduous forest and the river floodplain forest biotope fauna can be made (Abbott, 1966). The upland forest, with low trees and heavy underbrush is capable of providing ample cover for terrestrial forms, while the dry, well drained soil can sustain burrowing forms. The floodplain forest is inhospitable to these groups during seasons in which occasional flooding of the ground level occurs. There are, however, many arboreal niches for squirrels *Sciurus carolinensis* (7), turkeys *Meleagris gallopavo* (6), as well as cover for such insects as the bird grasshopper *Schistocerca lineata* [*S. americana*] (15), nine-spotted lady bug *Coccinella novemnotata* (17), bluebottle fly *Calliphora* sp. (22) and mosquitos of genus *Culex* (23). Occasional grazers are quail *Colinus virginianus* (8) and Texas white tailed deer *Odocoileus virginianus* (4). Shown from the water are the water scavenger *Hydrophilus triangularis* (16), crayfish *Procambarus clarki* (21) and a tadpole *Rana* sp. (24).

A minute breakdown would undoubtedly reveal many more niches in the floodplain forest due to its greater complexity. Intensive competition among plants results in a high rate of net production in the river floodplain biotope, allowing large numbers of primary consumers with their associated predator chains.

At the lower border and at waterways, the river floodplain merges into the freshwater marsh biotope with its abundant growths of marsh hay cordgrass, *Spartina patens*, and black rush, *Juncus roemerianus*.

PRAIRIE GRASSLANDS

The prairie grasslands biotope includes the region defined by Tharpe (1952) on the coastal prairie region. This region comprises a strip thirty to fifty miles wide along the whole

Texas coast southward to northern Kenedy County, where it contacts the coastal dune region. Tharpe (1952) divides it into an upper subregion (north of San Antonio Bay to the Louisiana-Texas border) and a lower subregion (south of San Antonio Bay to the Laguna Madre). The upper subregion has an annual rainfall above 34 (up to 52) inches and the lower subregion less than 34 inches (down to 26 inches, and sometimes lower). The quantity of rainfall in the upper region is sufficient to produce tall grass prairie, traversed by timber on stream flood plains or on low sandy ridges and bordered by coastal marshes which occasionally extend several miles inland. The Neches River, for example, has marshes almost bare of trees up to the vicinity of Beaumont. Southward these marshes dwindle in size, and the stature of grasses on the adjacent prairie decreases and smaller grasses, prominent in the lower subregion, begin to appear. Small oak woodland alternates with strips of prairie (Costello, 1969).

Seasonal changes in plant, mammal and insect associations exemplify the prairie grassland biotope as one of the most complex ecosystems. The grasslands are typified by characteristic assemblages. Wooded and shrubby borders, particularly along streams and around ponds usually have specific populations of plants and animals (Costello, 1969).

In the vicinity of streams and ponds, red-shafted flickers, Lewis' woodpeckers, red-tailed hawks, crows, grossbeaks, and blackcapped chickadees are prevalent. Other frequent avian inhabitants of prairie waters and adjacent vegetated borders are mallards, kingfishers, great blue herons, marsh wrens and several species of blackbirds. The longbilled curlew (*Numenius americanus*), killdeer (*Charadrius vociferus*) and nighthawk (*Chordeiles minor*), meadowlark (*Sturnella neglecta* [*S. magna*]), several species of owls, including burrowing owls (*Speotyto cunicularia hypugaea*) and barn owls (*Tyto alba pratincola*), and eagles of the genus *Bubo* are representative birds of the open prairies.

Insects are extensive in this biotope. They include grasshoppers, katydids, crickets, beetles, butterflies, and bumblebees. Common grasshoppers are two-striped grasshopper (*Melanoplus bivitatus*), clearwinged grasshopper (*M. femurrubrium*), the lubber grasshopper (*Brachystola magna*), and the spotted bird grasshopper (*Schistocerca lineata* [*S. americana*]).

The katydids and crickets, are usually abundant including the common meadow katydid, (*Orchelium vulgare*) the round winged katydid (*Amblycorypha rotundifolia parvipennis*), true crickets of the family *Gryllidae* and the tree crickets (*Oecanthinae* var.). Other representative insects include the common beetle (*Canthon laevis*), butterflies including the red admiral (*Vanessa atalanta*), the painted lady (*V. cardui*), the goatweed butterfly (*Anaea andria*), the sulphur butterfly (*Phoebis sennae*) and the giant swallowtail butterflies with recurved hooks beyond the club of the antennae, such as the checkered skipper (*Pyrgus communis*) feed on plants of the mallow family. Several dozen kinds of bumblebees live in this biotope and are valuable as plant pollinators. One common variety is *Bombus ternarius*.

Reptiles found in the prairie biotope includes the prairie rattlesnake (*Crotalus viridis viridis*), bullsnake (*Pituophis melanoleucus sayi*), western diamondback rattlesnake (*C. atrox*) and the blind snake (*Leptotyphlops dulcis dulcis*). Other reptiles include the collared lizard (*Crotaphytus collaris collaris*), and the snapping turtle (*Chelydra serpentium serpentium* [*C. serpentina*]).

Amphibians with important roles are the spadefoot toad (*Scaphiopus bombifrons*), bullfrog (*Rana catesbeiana*) and leopard frog (*R. pipiens*).

A number of grasses, trees and herbs are associated with the prairie habitat. Predominant trees include mesquite (*Prosopis glandulosa*) and a variety of oaks (*Quercus spp.*). Grasses, the dominant plants, include little bluestem (*Andropogon scheoparius* [*Schizachyrium scoparium*]), big bluestem (*A. gerarai*), Indiangrass (*Sorghastrum spp.*), Gulf muhly grass (*Muhlenbergia capillaris* var. *Filipes*), eastern gamagrass (*Tripsacum dactyloides*), broomsedge bluestem (*A. virginicus*), smutgrass (*Sporobolus poiretii*) and tumblegrass (*Schendonardus paniculatus*). Herbs include western ragweed (*Ambrosia psilostachya*), and yankeeweed (*Eupatorium compositifolium*). Cacti include the prickly pear (*Opuntia spp.*).

UPLAND DECIDUOUS FOREST

Because plants play a heavy role as primary producers, slight changes in vegetation can exert strong influences on inhabitants of an area through the multiple food chains existing in the assemblage. Also, any significant change in vegetation reflects alterations in cover available to animals and tends to limit faunal distribution. Two representative biotopes, the upland deciduous forest and the river floodplain forest are found in the coastal zone. The former is described below, while the latter is described in this report under a separate heading because the composition and appearance of the two differ vastly, both qualitatively and quantitatively.

The upland forest is the normal climax for well drained areas such as Brazos County, wherever moisture conditions will support tree growth (Abbott, 1966). Drier upland areas are covered by coastal prairie when undisturbed.

In the upland forest, the canopy is low, usually less than 50 ft. in height, and is composed of small-leafed, deciduous trees, mostly post oaks (*Quercus stellata* Wangh.). Layering is indistinct, and the lower strata, mixtures of medium-to-small leafed deciduous and evergreen plants, may penetrate the canopy. Yaupon (*Ilex vomitoria* Ait.) is consistent as a shrub. Trees include blackjack oak (*Quercus marilandica* Muenchh.), post oak (*Quercus stellata* Wangh.), winged elm (*Ulmus alata* Michx.), and water oak (*Quercus nigra* L.). Shrubs include the eastern red cedar (*Juniperus virginiana* L.), blueberry (*Vaccinium* sp.), American beauty-berry (*Callicarpa americana* L.), St. Andrew's cross (*Ascyrum hypericoides* L.), wollybucket bumelia (*Bumelia laguginosa* (Michx.) Pers.), and Texas Hercules-club prickly ash (*Zanthoxylum clara-herculis* L.). Along the lower margin of the upland forest, where this biotope interfaces with the river floodplain biotope, the loblolly pine (*Pinus taeda*) predominates.

Representative animals include the Texas whitetail deer (*Odocoileus virginianus texanus*), bobcat (*Lynx rufus*), bluejay (*Cyanocitta christata*), quail, turkey, squirrels, and grey fox. The coachwhip (*Masticophis testaceus*) and the western diamondback rattler (*Crotalus atrox*) are typical reptiles.

The pronounced differences in numbers of species in each category suggest that the upland forest biotope is, relatively, a much less disturbed and more specialized habitat than the river floodplain (Abbott, 1966).

DISCUSSION

Gulf estuaries and coastal lagoons are among the most important productive areas of the world. The submerged and shoreline vegetation provides a substantial part of this productivity (Britton and Morton 1989), and with plankton and land runoff of organic matter and nutrients, account for large fish and shellfish populations. The areas have important recreational uses and are necessary nursery areas for many sport and commercial fisheries. Unfortunately, these delicate systems are presently threatened by man's activities. Some of these activities are summarized on Table 2. Such activities are components of a variety of economically important sectors such as agricultural (use of fertilizers and biocides), petrochemical industry (gaseous and liquid waste disposal), mining (well development), construction (excavation, drainage, filling) and navigation (canals, channels). Competition for coastal zone resources, including rivers, bays, estuaries and lagoons will become more intense as development continues. It is imperative that sensible forms of land and water use

BIOTOPES

COASTAL ZONE ACTIVITIES	1. Continental Shelf	2. Artificial Reef	3. Jetty & Bulkhead	4. Open Beach	5. Dune	6. Barrier Flat	7. Marina	8. *Spartina* Salt Water Marsh	9. Hypersaline	10. Channel	11. Spoil Bank	12. Cyanobacteria Flat	13. Mud Flat	14. *Thalassia* Grass Flat	15. Sand Flat	16. Bay Planktonic	17. Oyster Reef	18. *Juncus* Fresh Water Marsh	19. River Mouth	20. River Floodplain Forest	21. Prarie Grassland	22. Upland Deciduous Forest
1. Liquid Waste Disposal	3	3	4	4	4	5	4	5	5	5	3	4	4	5	4	5	5	5	5	3	0	1
2. Gaseous Waste Disposal	1	1	3	1	4	4	4	0	4	4	0	0	0	3	0	4	1	5	5	0	0	0
3. Solid Waste Disposal	0	0	0	3	3	3	5	5	4	0	3	1	2	2	2	2	4	5	5	5	4	5
4. Offshore Construction	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Coastal Construction	0	0	0	4	5	5	1	4	1	0	0	2	3	1	3	2	1	4	0	2	0	0
6. Inland Construction	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	5	4
7. Land Canals	0	0	0	3	4	4	3	4	0	0	0	0	3	0	3	0	4	0	0	5	4	0
8. Offshore Channels	2	3	3	3	0	0	2	4	2	4	0	2	3	5	4	4	5	4	3	0	0	0
9. Dredging & Spoil Disposal	4	4	5	4	4	4	4	5	5	1	5	3	5	5	4	5	5	5	4	1	0	0
10. Excavation	0	0	0	5	5	5	1	4	1	0	0	2	5	3	2	0	5	3	1	2	2	1
11. Drainage	0	0	0	3	3	5	3	4	2	0	0	2	2	0	1	0	0	5	3	1	3	0
12. Filling	0	0	0	2	4	5	2	5	4	0	0	3	3	4	3	0	4	5	3	1	1	1
13. Draining	0	0	0	0	0	5	0	5	2	0	0	2	4	0	1	0	4	5	3	0	0	0
14. Well Development	0	0	1	0	3	4	0	1	3	1	4	1	1	1	1	1	4	1	1	1	3	1
15. Devegetation	0	0	0	0	5	5	0	5	0	0	4	1	1	2	1	0	0	5	0	5	5	5
16. Traversing with Vehicles	0	0	0	2	5	5	0	1	0	0	4	0	0	0	0	0	0	2	0	0	4	1
17. Use of Fertilizers & Biocides	0	0	2	2	5	5	3	5	4	5	4	3	0	5	1	5	5	5	4	4	4	4

TABLE 2. The impact of human activities on the coastal biotopes (0 = no impact; 5 = severe impact).

be devised. Returning to Table 2, we have attempted to relate 17 activities in the coastal zone to the 22 biotopes described. Some of these have, at the present state of the art, severe environmental implications. Others do not. For example, traversing dunes with vehicles will cause severe upset to that biotope. Inland construction, on the other hand, will have little impact on the coastal Gulf biotope. A more subtle impact would be the discharge of waste gases via water into a channel biotope. As an hypothetical case, one activity might involve construction of dwellings or industrial buildings on unstabilized dunes.

Two questions arise: (1) can the decision makers assure structural integrity and pleasing esthetic quality simultaneously? (2) how much can the biotope be altered without significant loss of productivity? To answer these questions, the decision maker could elect to employ extensive rather than intensive construction. By limiting the number of buildings per unit of siting, stabilizing the dunes with sound construction practices and cultivating the remaining flora, construction that combines form and function as well as maintaining the environment may be achieved.

Some biotopes, *e.g.*, the jetty and bulkhead, can be used intensively. Others, like the oyster reef cannot tolerate intensive pressure from man. Radical changes may sometimes be followed by fairly rapid recovery. For example, grassflats can return to normal, with sometimes enhanced productivity after nearby dredging operations, if proper engineering practices are adhered to during operations. Conversely, pollutants incorporated in the sediments of the bay planktonic biotope might require decades or even centuries to return to normal background levels. One environmental perturbation rarely appears in a only a single biotope because of interdependence of the biotopes. A flood borne slug of fresh water into the river estuary (a natural perturbation) or excessive impoundment during seasons of low rainfall (a human perturbation) will both be felt by the sensitive biotopes downstream.

Green (1968) reported on important species and their roles in estuarine systems. Life cycles, distributions, seasonal regimes, food habits, predators, and responses to various factors need to be more completely understood. The organismic approach is an honored tradition. But, the management of the ecosystems requires an understanding of the behavior of combinations of organisms. It is on the direct experimental study of the coastal ecosystem that this paper hopes to focus attention.

Biological and economic approaches need to be united. Odum *et al.* (1969) found in their survey that documents from the two disciplines appeared to have no relationship, while dealing with the same estuarine resources. The practical engineering associated with waste loading factors cannot be adequately implemented until the coastal ecosystem is more quantitatively understood.

From Table 2, it can be inferred that some biotopes are in critical danger in terms of current levels of man's activity. It is suggested that three biotopes, the salt marsh, grassflat, and dune are the most prone to irreversible damage. This is no way implies that the other biotopes are not endangered. On the contrary, one must proceed with great caution. It is only reasonable to call for close cooperation and forthright action from private and public sectors to assure productive use of these resources. As humans draw from the coastal resources, alteration will be inevitable. In accepting this view, one should seek ways to optimize the alterations rather than minimizing their impact. For example, dredging and the associated spoiling alter the adjacent biotopes. Yet spoil islands can be enhanced with small losses in productivity, by planting, and made esthetically pleasing with landscaping.

There are certain disturbances to coastal biotopes that are harmful as currently practiced. These are listed below. It is hoped that science and management can devise alternatives for better protecting the coastal environment.

(1) Impoundments. The construction of dams on coastal streams has limited the distance that migrating forms may traverse upstream for spawning and nursing (Andrew and Green, 1960; Copeland, 1966; French and Wohle, 1966; Saila, 1962; Smith, 1966; Talbot, 1966; and Walburg and Nichols, 1967).

(2) Dredging. The dredging of canals has upset the current and circulation patterns in many coastal systems, which alters the transport route for larvae of many river and sea-spawned organisms relying on current patterns to arrive in coastal systems (Smith, 1966).

(3) Filling. The practice of bulkheading and filling shallow coastal areas to create real estate has removed significant acres of valuable nursery area utilized by migrating organisms (Smith, 1966), and (Talbot, 1966).

(4) Wastes (solid, liquid, gaseous). Various kinds of pollutants which enter coastal systems have been shown to be either toxic to migrating organisms or in some way alter their metabolism to that they no longer will tolerate the affected area (Odum *et al.*, 1969).

(5) Organic Loading. Large concentrations of organic materials from upstream sources usually exert a high oxygen demand on the system, thus competing with the organisms for available oxygen and restraining the migration of organisms (Bishai, 1962; Waldichuk, 1966).

(6) Pesticides. Pesticides may differentially affect different life-cycle stages of migrating organisms, thus either preventing spawning or killing larvae that come in contact with it. Very small concentrations of insecticides are reported to cause shrimp in the Texas coastal

systems to cease inhabiting these waters (Chin and Allen, 1957). Blue crabs are reportedly rendered sterile and are physiologically upset by small concentrations of DDT (Lowe, 1965).

(7) Drilling. Localized lagooning of brine waters from oil wells along the Texas coast develops dense cyanobacteria (blue-green algal) mats in shallow water (Odum *et al.*, 1963).

(8) Liquid Refining Wastes. The refining of petroleum results in wastes that are not only toxic to most organisms, but also contain organic compounds that are not easily decomposed (Dorris *et al.*, 1961). Seventeen different petrochemical wastes exhibited high concentrations of phenols, sulfides, ammonia, suspended and dissolved solids, oil, and exerted high oxygen demands (Beychok, 1967). It is noted, however, that petrochemical wastes, when subjected to biological processing in ponds or other aqueous systems, decrease in toxicity and oxygen demand with time.

(9) Radionuclides. The only conclusive examples to date of effects of radioactive contamination on aquatic ecosystems are associated with test sites, such as Eniwetok and Bikini (Odum *et al.*, 1969).

(10) Multiple wastes. Whereas some ship channels with multiple wastes are so low in diversity and indices of life that there is no question that stress on ecosystems mainly exceeds the capabilities of living systems, some bays showing more eutrophication than toxicity may be producing more life and yields than before humans began introducing wastes (Odum *et al.*, 1969).

Research Needs

(1) Remote and Contact Sensing. Aerial and satellite imagery show significant patterns of distribution of coastal benthic vegetation and of materials suspended in the water (Conrod *et al.*, 1968; Kelly and Conrod, 1969; Kelly, 1969). The technical feasibility of utilizing aerial imagery to identify floral assemblages has been reported by Kolipinski and Higer (1970). Contact, *e.g.*, *in situ* sensing needs to be coordinated with remote sensing. This way the large time expenditures for field survey could be greatly reduced and lead times required for the older survey techniques could be shortened.

(2) Toxicity. Systematic metabolic stress on various indicator organisms *e.g.*, microorganisms, invertebrates and vertebrates determined by toxicity bioassay could provide valuable data establishing threshold limits for these organisms. Long term quantitative loading limits for different coastal ecosystems might then become more reliable.

(3) Ecography. Detailed ecosystem maps for coastal states need to be developed. From there, time and spatial distributions for entire biotopes might be determined.

(4) Resource Management. There is a growing need for study and resource management by system rather than species.

(5) Economics. A formula should be devised by which services that stimulate coastal zone biotic processes, such as encouraging desirable fish food chains can be recognized. Similarly, programs should be developed to encourage public and private agencies to plan on enhancing areas in which they make changes rather than simply changing and abandoning the areas. It is a taken-for-granted principle in the economy of humans that payment is made for goods and services. If such enhancements can be made part of the price for development in the coastal zone, the flow of this kind of currency will allow each participant to compete for survival. Such programs will insure that the coastal zone becomes part of the economy of man and nature rather than part of an operation in which the zone is reduced in its usefulness in terms of future development.

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BIBLIOGRAPHY

Anonymous. 1972. Stream ecosystem: organic energy budget. *BioScience* 22:33-35.

________. 1971. The long-legged wading birds of the marshes. *Tex. Parks Wildl.* 29:6-11.

________. 1969. A portfolio of coastal birds. *Tex. Parks Wildl.* 27:6-11.

Abbott, W. 1966. Analysis and comparison of an upland deciduous forest and a river floodplain forest. *J. Miss. Acad. Sci.* 12:50-64.

American Fisheries Society. 1991. Common and scientific names of fishes from the United States and Canada, 5th Ed. *Amer. Fish. Soc. Spec. Pub.* 20:1-183.

Anderson, A.A. 1960. Marine resources of the Corpus Christi area. *Res. Monogr., Bur. Business Res.* Univ. Tex., Austin. 21 pp.

Andrew, F.J. and G.H. Green. 1960. Sockeye and pink salmon production in relation to proposed dams in the Fraser River system. *Int. Pac. Salmon Fish. Comm. Bull.* 1. 259 pp.

Audubon, J.J. 1942. *The Birds of America.* MacMillan Co., N.Y.

Baldauf, R.J. 1970a. Life cycle of a frog. *Tex. Parks Wildl.* 28:30-31.

________. 1970b. A study of selected chemical and biological conditions of the lower Trinity River and the upper Trinity Bay. Tech. Rept. No. 26, Water Resour. Inst., Tex. A&M Univ., College Station.

Barrett, J.H. and C.M. Yonge. 1958. *Collins Pocket Guide to the Sea Shore.* Collins, London. 160 pp.

Baxter, D. 1971. Floating Hotel. *Tex. Parks Wildl.* 29:6-11.

Baxter, K.N. and W.C. Renfro. 1967. Seasonal occurrence and size distribution of postlarval brown and white shrimp near Galveston, Texas, with notes on species identification. *U.S. Fish & Wildl. Serv. Fish. Bull.* 66:149-158.

Bechtel, T.J. 1970. Fish species diversity indices as pollution indicators in Galveston Bay, Texas. M.A. Thesis, Univ. Tex., Austin.

Beychok, M.R. 1967. *Aqueous Wastes From Petrochemical Plants.* Wiley, New York. 370 pp.

Bigelow, H.B. and W.C. Shroeder. 1953. *Fishes of the Western North Atlantic.* Pt. 2. Sears Fdn. for Mar. Res. Mem. #1, Yale Univ. 588 pp.

Birke, L.E. 1968. Development of a blue-green algal assay for vitamin B_{12}: application to an ecological study of the San Antonio estuary. M.A. Thesis, Univ. of Tex., Austin.

Bishai, H.M. 1962. Reactions of larval and young salmonids to water of low oxygen concentration. *J. du Conseil.* 27:167-180.

Borradaile, L.A. and F.A. Potts. 1961. *The Invertebrata.* Cambridge Press, London. 820 pp.

Breder, C.M., Jr. 1948. *Field Book of Marine Fishes of the Atlantic Coast from Labrador to Texas.* Putnam, N.Y. 941 pp.

Breuer, J.P. 1957. An ecological survey of Baffin and Alazan Bays, Texas. *Bull. Inst. Mar. Sci. Univ. Tex.* 4:134-155.

Britton, J.C. and B. Morton. 1989. *Shore Ecology of the Gulf of Mexico.* Univ. Tex. Press, Austin, TX. 387 pp.

Brock, T.D. 1970. *Biology of Microorganisms.* Prentice-Hall, Englewood Cliffs, N.J. 737 pp.

Brown, F.A., Jr. [ed.]. 1950. *Selected Invertebrate Types.* Wiley, N.Y. 597 pp.

Buchsbaum, R. 1938. *Animals Without Backbones.* Univ. Chicago Press, Chicago. 405 pp.

Bullough, W.S. 1951. *Practical Invertebrate Anatomy.* MacMillan, London. 463 pp.

Catlow, J.D., Jr. and C.G. Bookhout. 1959. Larval development of *Callinectes sapidus* Rathburn reared in the laboratory. *Biol. Bull. Mar. Biol. Lab., Woods Hole, MA* 116:373-396.

Chambers, G.V. and A.K. Sparks. 1959. An ecological survey of the Houston ship channel and adjacent bays. *Publ. Inst. Mar. Sci. Univ. Tex.* 6:213-250.

Chapman, V.J. 1960. *Salt marshes and salt deserts of the world.* Plant Monogr. Intersci., N.Y. 392 pp.

________. 1962. *The Algae.* MacMillan, London. 472 pp.

Chestnut, A.F. 1969. pp. 663-695. *In*: Odum, H.T., B.J. Copeland and E.A. McMahan [eds.]. Coastal Ecological Systems of the United States - A Source Book for Estuarine Planning - A Report to the Federal Water Pollution Control Adminis. Vol. 1.

Chin, E. and D.M. Allen. 1957. Toxicity of an insecticide to two species of shrimp, *Penaeus aztecus* and *Penaeus setiferus*. *Tex. J. Sci.* 9:270-278.

________. 1961. A trawl study of an estuarine nursery area in Galveston Bay with particular reference to penaeid shrimp. *Diss. Abst.* 22:1751.

Christmas, J.Y. and G. Gunter. 1960. Distribution of menhaden, genus *Brevoortia*, in the Gulf of Mexico. *Trans. Am. Fish. Soc.* 89:338-343.

________ and P. Musgrave. 1966. Studies of annual abundance of post larval penaeid shrimp in the estuarine waters of Mississippi, as related to subsequent commercial catches. *Gulf Res. Rep.* 2:177-212.

Clark, G.L. 1954. *Elements of Ecology.* Wiley, N.Y. 534 pp.

Conrod, A.C., M.G. Kelly and A. Boersma. 1968. Aerial photography for shallow water studies on the west edge of the Bahama Banks. Exper. Astron. Lab., Mass. Inst. Tech. Pub. RE42.

Conte, F.S. and J.C. Parker. 1971. Ecological aspect of selected crustacea of two marsh embayments of the Texas coast. Tex. A&M Univ. Unpublished.

Cook, H.L. and M.J. Lindner. 1970. Synopsis of biological data on the brown shrimp *Penaeus aztecus.* Fishery taxonomy distribution. *FAO Fish Rep.* 57:1471-1497.

Cooley, N.R. 1970. Estuarine faunal inventory. *U.S. Dept. Fish. Wildlife Serv. Circ.* 335:12-16.

Copeland, B.J. 1966. Effects of decreased river flow on estuarine ecology. *J. Water Poll. Contr. Fed.* 38:1831-1839.

________. 1969. Oligohaline Regime. pp. 789-828. *In* H.T. Odum, B.J. Copeland and Elizabeth McMahan, *Op cit.* Vol.. 2.

________. 1970. Estuarine classification and responses to disturbances. *Trans. Amer. Fish. Soc.* 99:826-835.

________, J.H. Thompson, Jr., and W.B. Ogletree. 1968. Effects of wind on water levels in the Texas Laguna Madre. *Tex. J. Sci.* 20:196-197.

________ and T.J. Bechtel. 1971. Some environmental limits of six important Galveston Bay species. Contr. 20, Pamlico Mar. Lab., N.C. State Univ., Aurora, N.C. 108 pp.

________ and E.G. Fruh. 1970. Ecological studies of Galveston Bay: 1969. Final Report to the Texas Water Quality Board, Austin. 482 pp.

________ and M.V. Truitt. 1966. Fauna of the Aransas Pass Inlet, Texas. II. Penaeid shrimp postlarvae. *Tex. J. Sci.* 28:65-74.

Corliss, J. O. 1961. *The Ciliated Protozoa: Characterization, Classification and Guide to the Literature.* Pergamon Press, N.Y. 310 pp.

Costello, D.F. 1969. *The Prairie World, Plants and Animals of the Prairie Sea.* Crowell, N.Y. 242 pp.

Costello, T.J. and D.M. Allen. 1970. Synopsis of biological data on the pink shrimp *Penaeus durorarum. FAO Fish Rep.* 57:1499-1537.

Costlow, J.D., Jr. 1967. The effect of salinity and temperature on survival and metamorphosis of megalops of the blue crab, *Callinectes sapidus. Helgolander Wiss. Meereunters.* 15:84-97.

Cupp, E.E. 1943. Marine diatoms of the west coast. *Bull. Scripps Inst. of Oceanogr.* 5:1-237.

Curl, H., Jr. 1959. The phytoplankton of Apalachee Bay and the N.E. Gulf of Mexico. *Publ. Inst. Mar. Sci. Univ. Tex.* 6:277-320.

Curtis, H. 1968. *The Marvelous Animals: An Introduction to the Protozoa.* Nat. Hist. Press, Garden City, N.Y. 189 pp.

David, E.M. 1971. Report to Texas Water Development Board on development of methodology for evaluation and prediction of the limnological aspects of Matagorda and San Antonio Bays. Contract IAC (70-71)-467. State of Tex. Water Develop. Bd.

Davis, H.C. and A. Calabrese. 1964. Combined effects of temperature and salinity on development of eggs and growth of larvae of *M. mercenaria* and *C. virginica. U.S. Fish Wildl. Ser. Fish. Bull.* 63:643-655.

Davis, I.L. 1972. *A Field Guide to the Birds of Mexico and Central America.* Univ. Tex. Press, Austin. 282 pp.

Davis, W.B. 1974. The mammals of Texas. *Tex. Parks Wildl. Bull.* 41:1-294.

Dawson, C.E. 1957. *Balanus* fouling of shrimp. Science 126:1068.

Dexter, A. 1971. Sphagnum moss. *Tex. Parks Wildl.* 29:20-22.

Dorris, T.C., B.J. Copeland and D. Peterson. 1961. The case for holding ponds. Oil and Gas J. 59:161-165.

Duncan, W.H. and M.B. Duncan. 1987. *The Smithsonian Guide to Seaside Plants of the Gulf and Atlantic Coasts from Louisiana to Massachusetts, Exclusive of Lower Pensular Florida.* Smithsonian Inst. Press, Washington, D.C. 409 pp.

Edwards, P. 1970. Illustrated guide to the sea weeds and sea grasses in the vicinity of Port Aransas, Texas. *Contr. Mar. Sci. Univ. Tex., Supp.* Vol. 15. 128 pp.

Filece, F.P. 1954. Study of some factors affecting the bottom fauna portion of the San Francisco Bay estuary. *Wasmann J. Biol.* 12:257-292.

Fitch, J.E. and R.J. Lavenberg. 1971. *Marine Food and Game Fishes of California.* Univ. Calif. Press, Berkeley. 179 pp.

Freese, L.R. 1952. Marine diatoms of the Rockport Texas Bay area. *Tex. J. Sci.* 3:331-384.

French, R.R. and R.J. Wohle. 1966. Study of loss and delay of salmon passing Rock Island Dam, Columbia River, 1954-56. *U.S. Fish Wildlife Ser. Spec. Sci. Rep.* No. 32. 93 pp.

Fritsch, F.E. 1952. *The Structure and Reproduction of the Algae.* Cambridge Univ. Press. 939 pp.

Frolander, H.F. 1964. Biological and chemical features of tidal estuaries. *J. Water Poll. Contr. Fed.* 36:1037-1038.

Galtsoff, P.S. 1931. Survey of oyster bottoms in Texas. *U.S. Bur. Fish. Inv. Rept.*, 6:1-30.

________. 1964. The American oyster, *Crassostrea virginica* Gmelin. *U.S. Fish Wildl. Serv. Fish. Bull.* 64:1-480.

Goodrun, P.D. 1972. Modern tree farming threatens an important wildlife food. Acorns for wildlife. *Tex. Parks Wildl.* 30:13.

Gould, F.W. 1962. Moderately permeable sands and impermeable muds (prairie grasslands) in Texas plants - A checklist and ecological summary. *Tex. Agr. Expt. St. Misc. Publ.* MP-585. 112 pp.

_______ and T.W. Box. 1965. Grasses of the Texas coastal bend. *Tex. A&M Univ. Agr. Exp. St.* College Station, Tex. 187 pp.

Green, J. 1968. *The Biology of Estuarine Animals.* Univ. Wash. Press, Seattle. 401 pp.

Gunter, G. 1950. Seasonal population changes and distributions as related to salinity, of certain invertebrates of the Texas coast, including the commercial shrimp. *Publ. Mar. Sci. Inst. Univ. Tex.* 1:7-51.

________. 1961. Habitat of juvenile shrimp (family Penaeidae). *Ecology* 42:598-600.

________. 1967. Some relationships of estuaries to the fisheries of the Gulf of Mexico, pp. 621-638. *In* G.H. Lauff [ed.]. *Estuaries.* Amer. Assoc. Adv. Sci. Pub. No. 83, Horn-Shafer Co., Baltimore, MD.

________ and H.H. Hildebrand. 1951. Destruction of fishes and other organisms on the South Texas coast by the cold wave of January 28-February 3, 1951. *Ecology* 32:731-736.

Hairston, N.G. 1959. Species abundance and community organization. *Ecology* 40:404-416.

Hardy, A. 1956. *The Open Sea,* Pt. I. The World of Plankton. Collins, London. 335 pp.

Hay, J. and P. Fards. 1966. *The Atlantic Shore.* Harper and Row, N.Y. 246 pp.

Hedgpeth, J.W. [ed.]. 1963 (reprinted). *Treatise on Marine Ecology and Paleoecology,* Vol. 1, Ecology. Geol. Soc. of Amer. Mem. 67. 1296 pp.

Herke, W.H. 1971. Use of natural, and semi-impounded, Louisiana tidal marshes as nurseries for fishes and crustaceans. Diss., LA St. Univ.

Hildebrand, H.H. 1954. A study of the fauna of the brown shrimp (*P. aztecus* Ives) grounds in the western Gulf of Mexico. *Publ. Inst. Mar. Sci. Univ. Tex.* 3:231-266.

________. 1955. A study of the fauna of the pink shrimp (*Penaeus duorarum* Burkenroad) grounds in the Gulf of Campeche. *Publ. Inst. Mar. Sci. Univ. Tex.* 4:168-232.

________. 1958. Estudios biologicos preliminares sobre La Laguna Madre de Tamaulipas. *Ciencia, Mex.,* 17:151-173.

Hildebrand, S.F. and L.E. Cable. 1930. Development and life history of fourteen teleostean fishes at Beaufort, N.C. *U.S. Dept. Comm., Bur. Fish., Fish. Doc.* #1093. 488 pp.

________. 1938. Further notes on the development and life history of some teleosts. U.S. Dept. Comm., *Bur. Fish. Bull.* No. 24. 642 pp.

Hoese, H.D. and R.S. Jones. 1963. Seasonality of larger animals - a Texas turtle grass community. *Publ. Inst. Mar. Sci. Univ. Tex.* 9:37-47.

Hofstetter, R.P. 1959. The Texas Oyster Fishery. *Tex. Parks Wildl. Bull.* #40. 39 pp.

Hopkins, A.E. 1931. Factors influencing the spawning and setting of oysters in Galveston Bay, Texas. *U.S. Fish Wildl. Serv. Fish. Bull.* 47:57-83.

Hulings, N.C. 1961. The barnacle and decapod fauna from the nearshore area of Panama City, Florida. *Quart. J. Fla. Acad. Sci.* 24:215-222.

Hurlbert, S.H. 1971. The nonconcept of species diversity: a critique and alternative parameters. *Ecology* 52:577-586.

Inglis, A. 1960. Brown shrimp movements, pp. 66-69. *In* Fishery Research, *Galveston Biol. Lab. Circ.* 92, Washington, D.C.

Institute of Ecology. 1971. Man in the living environment. *Report of the Workshop on Global Ecological Problems.* 267 pp.

Jordan, D.S. and B.W. Evermann. 1900. The fishes of North and Middle America. Pt. IV, pp. 3137-3313. *Bull. U.S. Nat. Hist. Mus.* #47.

Kelly, M.G. 1969. Applications of remote photography to the study of coastal ecology in Biscayne Bay, Florida. Contract Report, *U.S. Naval Oceano. Off. Contr.* N-62306. 69-C-0032. 52 pp.

Kelly, M.G. and A.C. Conrod. 1969. Aerial photographic studies of shallow water benthic ecology, pp. 173-183. *In* P. Johnson [ed.] *Remote Sensing in Ecology*, Univ. GA.

King, B.D. 1971. Study of migratory patterns of fish and shellfish through a natural pass. Tech. Series #9. *Tex. Parks Wildl.*, Austin, Texas.

Knapp, F.T. 1949. A partial analysis of the Texas menhaden problem with notes on the food of the more important fishes of the Texas Gulf Coast. (Mimeo) The report of the Marine Lab. *Tex. Game, Fish Oyster Comm.* Fiscal year 1947-48. 42 pp.

Kolipinski, M.C. and S.L. Higer. 1970. Detection and identification of benthic communities and shoreline features in Biscayne Bay using multiband imagery. Se. 47. *In* NASA-MSC-03742 *Third Annual Earth Resources Program Review* Vol. III.

Kotthaus, A. 1965. The breeding and larval distribution of redfish in relation to water temperature. *Intern. Comm. Northwest Atl. Fish,* Spec. Publ. No. 6:417-423.

Kure, H. and K. Wagner. 1957. Tidal marshes of the Gulf and Atlantic coasts of northern Florida and Charleston, South Carolina. *Fla. St. Univ. Studies* No. 24. 168 pp.

Kutkuhn, J.H., H.L. Cook and K.N. Baxter. 1969. Distribution and density of prejuvenile *Penaeus* shrimp in Galveston entrance and the nearby Gulf of Mexico, Texas. *FAO Fish Rep.* 3:1075-1099.

Ladd, H.S. 1951. Brackish-water and marine assemblages of the Texas coast, with special reference to molluscs. *Publ. Inst. Mar. Sci. Univ. Tex.* 2:125-164.

La Monte, F. 1952. *Marine Game Fishes of the World.* Doubleday & Co. Inc. 190 pp.

Lamanna, C. and H.F. Mallette. 1965. *Basic Bacteriology.* Williams & Wilkins Co., Baltimore. 1001 pp.

Leary, S.P. 1961. The Crabs of Texas. *Tex. Parks Wildl. Bull.* 43. 57 pp.

Lawrence, H. 1969. Prowling Marsupials. *Tex. Parks Wildl.* 27:20-23.

Lay, D.W. 1972. Snow Flowers. *Tex. Parks Wildl.* 9:20.

Lindner, M.J. and W.W. Anderson. 1956. Growth, migrations, spawning and size distribution of shrimp *Penaeus setiferus. U.S. Fish Wildl. Serv., Fish. Bull.* 56:555-645.

________ and H.L. Cook. 1970. Synopsis of biological data on the white shrimp *Penaeus setiferus.* Fishery taxonomy distribution. *FAO Fish Rep.* 57:1439-1469.

Lewis, R.M. and W.F. Hettler, Jr. 1968. Effects of temperature and salinity on the survival of young Atlantic menhaden, *Brevoortia tyrannus. Trans. Am. Fish. Soc.* 97:344-349.

Louisiana Wildlife and Fisheries Commission. 1971. Cooperative Gulf of Mexico estuarine inventory and study, Louisiana; Phase I, Area description and Phase IV, Biology. *La. Wildl. Fish. Comm.* 175 pp.

Lowe, J.I. 1965. Chronic exposure of blue crabs, *Callinectes sapidus*, to sublethal concentration of DDT. *Ecology* 46:899-900.

Mahood, R.K., M.D. McKenzie, D.P. Middaugh, S.J. Bollar, J.R. Davis and P. Spitsbergen. 1970. Report on the cooperative blue crab study - South Atlantic States. *Georgia Game Fish Comm., Coast. Fish. Div., Contr. Ser.* 19:1-32.

Marshall, N.B. 1971. *Ocean Life.* MacMillan, N.Y. 214 pp.

McAlister, W.H. and M.K. McAlister. 1995. *Aransas: A Naturalist's Guide.* Univ. Tex. Press. Austin, TX. 392 pp.

Meglitsch, P.A. 1967. *Invertebrate Zoology.* Oxford Univ. Press, London. 961 pp.

Menzel, R.W. 1956. Checklist of the marine fauna and flora of the St. George's Sounds area. Contr. 61, Oceanog. Inst., Fl. St. Univ. 134 pp.

________. 1971. Checklist of the marine fauna and flora of the Apalachee Bay and the St. George's Sound area. Dept. Oceanog., Fl. St. Univ. Tallahassee. 126 pp.

Mistakidis, M.N. 1968. Proceedings of the world scientific conference on the biology and culture of shrimp and prawns. Mexico City, Mexico, 12-21 June, 1967. *FAO Fish Rep.* No. 57:1-75.

Mock, C.R. 1967. Natural and altered estuarine habitats of penaeid shrimp. *Proc. Gulf Carib. Fish. Inst., 19th Ann. Session*, pp. 86-98.

Moore, D.R. 1963. Distribution of the sea grass, *Thalassia*, in the United States. *Bull. Mar. Sci. Gulf Carib.* 13:329-42.

More, W.R. 1969. A contribution to the biology of the blue crab (*Callinectes sapidus* Rathbun) in Texas, with a description of the fishery. *Tex. Parks Wildl. Tech. Series.* 1:1-31.

Morris, P.A. 1947. *A Field Guide to the Shells.* Houghton Mifflin, Boston. 236 pp.

Moulton, D.W. and D.M. Dall. 1998. Atlas of national wetlands inventory maps (with resource descriptions) for Nueces County, Texas. *U.S. Fish Wildl. Serv., National Wetlands Inventory, Texas Coastal Series* 1:1-58.

Nash, C.G. 1947. Environmental characteristics of a river estuary. *J. Mar. Res.* 6:147-174.

National Geographic Society. 1987. *Field Guide to the Birds of North America.* National Geogr. Soc., Washington, D.C. 464 pp.

Odum, E.P. 1959. *Fundamentals of Ecology.* Saunders, Philadelphia. 546 pp.

Odum, H.T., B.J. Copeland and E.A. McMahan [eds.]. 1969. Coastal Ecological Systems of the United States - A Source Book for Estuarine Planning - A Report to the Federal Water Pollution Control Adminis. Vol. 1-3.

________, R.P. Cuzon du Rest, R.J. Beyers and C. Allbaugh. 1963. Diurnal metabolism, total phosphorus, Ohle anomaly and zooplankton diversity of abnormal marine ecosystems of Texas. *Publ. Inst. Mar. Sci. Univ. Tex.* 9:404-453.

________ and R.F. Wilson. 1962. Further studies on reduction and metabolism of Texas bays, 1958-1960. *Publ. Inst. Mar. Sci. Univ. Tex.* 8:23-55.

Odum, W.E. 1970. Insidious alteration of the estuarine environment. *Trans. Amer. Fish. Soc.* 99:836-847.

Oetking, P. 1972. Research proposal sponsored by SWRI. Water Quality Baseline Study, Corpus Christi Bay.

Oppenheimer, C.H., N.B. Travis and H.W. Woodfin. 1961. Distribution of coliforms, salinity, pH and turbidity of Espiritu Santo, San Antonio, Mesquite, Aransas and Copano Bays, Texas. *Water and Sewage Works.* pp. 298-307.

Parker, J.C. 1966. A study of the distribution and condition of brown shrimp in the primary nursery areas of the Galveston Bay system, Texas. M.S. Thesis, Tex. A&M Univ.

________. 1970. Distribution of brown shrimp in the Galveston Bay system, Texas, as related to certain hydrographic features and salinity. *Contrib. Mar. Sci. Tex.* 15:1-12.

Parker, R.H. 1955a. Changes in invertebrate fauna, apparently attributable to salinity changes in the bays of central Texas. *J. Paleont.* 29:193-211.

________. 1955b. Changes in the invertebrate fauna, apparently attributable to salinity changes in the bays of Central Texas. *Bull. Amer. Ass. Petrol. Geol.* 43:2100-2166.

Pelczar, M.J. and R.D. Reid. 1965. *Microbiology.* McGraw-Hill, N.Y. 662 pp.

Penfound, W. and E.S. Hathaway. 1938. Plant communities in the marshlands of southeastern Louisiana. *Ecol. Monogr.* 8:811-856.

Peterson, R.T. 1960. *A Field Guide to the Birds of Texas.* Houghton Mifflin Co., Boston.

Phillips, R.C. 1969. Temperate Grass Flats, pp. 737-773. *In* H.T. Odum, B.J. Copeland and Elizabeth McMahan [eds.]. *Op cit.*

Phleger, F.B. 1969. Some general features of coastal lagoons. pp. 5-26. *In* A. Ayala Castañares and F.B. Phleger [eds.] *Coastal lagoons, a symposium.* Univ. Nacional Autonoma Mexico.

Price, W.A. and G. Gunter. 1942. Certain recent geological and biological changes in south Texas with consideration of probable causes. *Proc. Tex. Acad. Sci.* 26:138-156.

Prichard, D.W. 1967. Observations of circulation in coastal plain estuaries, pp. 37-44. *In* G.H. Lauff [ed.] *Estuaries,* AAAS Publ. No. 83. Horn-Shafer Co., Baltimore, MD.

Randall, J.E. 1968. *Caribbean Reef Fishes.* T.F.H. Publ. Jersey City, N.J. 318 pp.

Reid, G.K., Jr. 1955a. A summer study of the biology and ecology of East Bay, Texas, I. *Tex. J. Sci.* 7:316-343.

________. 1955b. A summer study of the biology and ecology of East Bay, Texas, II. *Tex. J. Sci.* 7:430-453.

________. 1955c. Ecological investigations of a disturbed Texas coastal estuary. *Tex. J. Sci.* 8:296-327.

________. 1956a. Summer foods of some fish species in East Bay, Texas. *Southwestern Naturalist* 1:100-104.

________. 1956b. Observations on the eulittoral ichthyofauna of the Texas Gulf coast. *Southwestern Naturalist* 1:157-165.

________. 1957. Biologic and hydrographic adjustment in a disturbed Gulf coast estuary. *Limnol. Oceanogr.* 2:198-212.

________. 1958. Size distribution of fishes in a Texas estuary. *Copeia* 3:225-231.

Renfro, W.C. 1964. Life history stages of Gulf of Mexico brown shrimp. Fish. Res. Biol. Lab., Galveston. *Fish Wildl. Serv. Circ.* 183:94-98.

Robbins, C.S. 1966. *Birds of North America.* Golden Press, N.Y. 340 pp.

Saila, S.B. 1962. Proposed hurricane barriers related to winter flounder movements in Narragansett Bay. *Amer. Fish. Soc. Trans.* 91:189-195.

St. Amant, L.S., K.C. Corkeen and J.G. Brown. 1963. Studies on growth dynamics of brown shrimp, *Penaeus aztecus,* in Louisiana waters. *Proc. Gulf Carib. Fish. Inst. 15th Ann. Session.* pp. 14-26.

Shidler, J.K. 1960. Preliminary survey of invertebrate species (Galveston Bay) *Tex. Parks Wildl.. Ann. Rept.* 1959-60. Project No. MO-1-R-2.

Simmons, E.G. 1957. An ecological study of the upper Laguna Madre of Texas. *Publ. Inst. Mar. Sci. Univ. Tex.* 4:156-203.

Simmons, E.G. and J.P. Breuer. 1962. A study of redfish, *Sciaenops ocellata* Linn., and black drum, *Pogonias cromis* Linn. *Publ. Inst. Mar. Sci. Univ. Tex.* 8:184-211.

Simmons, E.G. and W.H. Thomas. 1962. Phytoplankton of the eastern Mississippi Delta. *Contr. Scripps Inst. Mar. Sci.* 32:1295-1324.

Slobodkin, L.B. and H.L. Sanders. 1969. On the contribution of environmental predictability to species diversity. *In* Diversity and Stability in Ecological Systems. *Brookhaven Symp. Biol.* 22:82-95.

Smith, G.M. 1950. *The Freshwater Algae of the U.S.* McGraw-Hill, N.Y. 719 pp.

Smith, G.M. 1955. Cryptogamic Botany, Vol. I. *Algae and Fungi.* McGraw-Hill, N.Y. 546 pp.

Smith, S.H. 1966. Effects of water use activities in Gulf of Mexico and south Atlantic estuarine areas, pp. 93-101. *In* R.F. Smith [ed], A Symposium on Estuarine Fisheries. *Amer. Fish. Soc. Spec. Pub.* #3.

Stewart, K.W. 1971. Aquatic flies. *Tex. Parks Wildl.* 29:24-29.

Tabb, D.C. 1966. V. The estuary as a habitat for spotted seatrout, *C. nebulosus.* Amer. Fish. Pub. No. 3:59-67, Supp. to *Trans. Am. Fish. Soc.* 95(4).

Talbot, G.B. 1966. Estuarine environmental requirements with limiting factors for striped bass, pp. 37-49. *In* R.F. Smith [ed.], A Symposium on Estuarine Fisheries. *Amer. Fish. Soc. Spec. Pub.* #3.

Tagatz, M.E. 1968a. Growth of juvenile blue crabs, *Callinectes sapidus* Rathbun, in the St. Johns River. *Fish. Bull.* 67:281-288.

________. 1968b. Biology of the blue crab, *Callinectes sapidus* Rathbun, in the St. Johns River, Florida. *Fish. Bull.* 67:17-33.

Tempe, R.F. 1965. Vertical distribution of the planktonic stages of penaeid shrimp. *Publ. Inst. Mar. Sci. Univ. Tex.* 10:59-67.

Tharpe, B.C. 1952. *Texas Range Grasses.* Univ. of Tex. Press, Austin. 126 pp.

Thimann, K.V. 1955. *The Life of Bacteria.* McMillan, N.Y. 909 pp.

Train, R.E. 1968. The challenge of the estuary. *Proc. Nat. Shellfish Assoc.* 59:14-17.

Trent, W.L., E.J. Pullen, C.R. Mock, D. Moore. 1968. Ecology of western Gulf estuaries. *Bur. Comm. Fish. Circ.* 325:18-24.

Truesdale, F.M. 1969. Some ecological aspects of commercially important decapod crustaceans in low salinity waters. Ph.D. diss., Tex. A&M Univ. 164 pp.

Turner, W.R. 1969. Life history of menhaden in the eastern Gulf of Mexico. *Trans. Am. Fish.*

Soc. 98:216-224.

U.S. Dept. of the Interior. Fish & Wildlife Service. 1954. Gulf of Mexico – Its origin, waters and marine life. *U.S. Fish Wildl. Serv. Fish. Bull.* 55:1-604.

U.S. Dept. of the Interior, National Park Service. 1955. *Our vanishing shoreline: the shoreline, the survey, the areas.* U.S. Dept. of the Interior, Washington, D.C. 36 pp.

Valiela, I. 1995. *Marine Ecological Processes.* 2nd ed. Springer-Verlag, New York. 686 pp.

Vines, R.A. 1960. *Trees, Shrubs and Woody Vines of the Texas Southwest.* Univ. Tex. Press, Austin. 1104 pp.

Walburg, C.H. and P.R. Nichols. 1967. Biology and management of the American shad and status of the fisheries, Atlantic coast of the United States, 1960. *U.S. Fish Wildl. Ser. Spec. Sci. Rep. Fish.*, No. 550. 106 pp.

Waldichuck, M. 1966. Effects of sulfite wastes in a partially enclosed marine system in British Columbia. *J. Water Poll. Contr. Fed.* 38:1505.

Wallace, D.H. 1966. Oysters in the estuarine environment, pp. 68-76. *In* R.F. Smith [ed.], A Symposium on Estuarine Fisheries. *Amer. Fish. Soc. Spec. Pub.* #3.

Wass, M.L. and T.D. Wright. 1969. Coastal Wetland of Virginia: Interim Report to the Governor and General Assembly. *Spec. Rep. Appl. Mar. Sci. Ocean Engr.* No. 10, VA. Inst. Mar. Sci., Gloucester Point, VA. 154 pp.

Weber, M., R.T. Townsend and R. Bierce. 1992. *Environmental quality in the Gulf of Mexico: a citizen's guide.* Center for Marine Conservation, Washington, D.C. 132 pp.

Weniger, D. 1971. *Cacti of the Southwest.* Univ. Tex. Press, Austin. 249 pp.

Weymouth, F.W., M.J. Lindner and W.W. Anderson. 1933. Preliminary report on the life history of the common brown shrimp *Penaeus setiferus* (Linn.) *U.S. Bur. Fish. Bull.* 48:1-26.

Wilhm, J.L. 1970. Range of diversity index in benthic macroinvertebrate populations. *J. Water Poll. Control Fed.* 42:R221-4.

Wimpenny, R.S. 1966. *The Plankton of the Sea.* Faber & Faber, London. 426 pp.

Wood, E.J.F. 1963. A study of the diatom flora of fresh sediments of the south Texas bays and adjacent waters. *Pub. Inst. Mar. Sci. Univ. Tex.* 9:237-310.

Zim, H.S. and C. Cottam. 1956. *Insects.* Golden Press, N.Y. 160 pp.

________ and L. Ingle. 1955. *Seashores: A Guide to Animals and Plants Along the Beaches.* A Golden Nature Guide. Simon and Schuster, N.Y. 160 pp.

_______ and H. Shoemaker. 1956. *Fishes - A Guide to Fresh and Salt Water Species.* Golden Press, N.Y. 160 pp.

RUTH GRUNDY (1936 - 1998)

Ruth Grundy came to Port Aransas 28 years ago and soon became affiliated with the University of Texas Marine Sciences Institute. Her name appears as the Technical Editor of the Contributions in Marine Science as early as volume 16 in 1972 and she was associated with its publication ever since. As the Institute grew and expanded, and the reference collection associated with the Contributions grew with it, her role expanded into Librarian as well and she almost single-handedly developed the UTMSI Library into what it is today.

The 1972 issue of the Contributions in Marine Science contains a forward that states "Issues are distributed at a cost of $4.15 per copy (no discounts possible), or on an exchange basis", and "For orders, further information, or exchange agreements, please write to the Librarian, UTMSI at Port Aransas." The price changed as the years went on, but the "exchange agreements" part is what Ruth used to leverage what is now one of the finest and most complete collections of marine science research publications on the Gulf Coast.

Never one to take a narrow view of collecting and exchanging information, Ruth soon found and became a member of a marine science libraries organization that is now best known by its funny-sounding acronym of "IAMSLIC", the International Association of Aquatic and Marine Science Libraries and Information Centers. My personal acquaintance with Ruth dates back to the 1982 meeting in Beaufort, North Carolina. I remember her gracious invitation to attend the next year's conference, which she hosted in Port Aransas. That meeting has been famous in the annals of IAMSLIC, not only for the fine professional exchange of ideas, but also for the after-meeting shopping expedition to Mexico.

Ruth has always been a "try harder, go farther" kind of person. She was the conference convener for IAMSLIC's 1984 meeting in Woods Hole, Massachusetts. That meeting was the first IAMSLIC meeting for which there were published proceedings and sure enough, Ruth not only convened the meeting, she also edited the proceedings; and the same for next year when she was both President and editor.

I was always interested in Ruth's approaches to librarianship and information handling. Her most memorable presentation to IAMSLIC was in 1987 at Halifax, Nova Scotia. It was entitled "How to build your own standalone system using an IBM AT or compatible and existing software." In 1986, us Aggies in Galveston had just moved into a brand new $5 million library building and were grappling with a new automation system that cost $100,000 and was produced by computing specialists. Ruth proceeded to tell us how she built the computer herself, and manipulated database software that cost a fraction as much, to produce a system that worked well for her library. I was only a few steps beyond locating the on/off switch on my personal computer. Ruth modestly asked me "Do you think I talked over their heads?" She was undaunted by technological challenge and assumed the rest of us were as on top of the technology as she was.

Ruth's husband, Doyle Grundy, was almost as much a fixture of IAMSLIC annual meetings as Ruth. Many times they used their annual vacation times to drive across the country to meetings - Woods Hole, Monterey Bay, Key Biscayne, Bethesda. They shared 42 years together and were parents to four children, and grandparents of six. Ruth's final hours were with her family and many of her friends - no visitor was turned away. Her family sang favorite hymns as Ruth passed into the great beyond. IAMSLIC was in session for its annual meeting at that time, and condolences arrived from across the globe. The conference host, Eirikur Einarsson in Reykjavik, Iceland, sent a message that would be true for many of us, about Ruth and IAMSLIC: "This group of librarians has meant a lot to me, living out here in the middle of the Atlantic Ocean, and I will be forever thankful to her for introducing IAMSLIC to me. She will be missed by all of us."

Natalie Wiest
Library Director, Jack K. Williams Library
Texas A&M University at Galveston

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