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TEXAS COASTAL ZONE BIOTOPES: AN ECOGRAPHY

Interim Report

for

The Bay and Estuary Management Program (CRMP)

by

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November 1972

ACKNOWLEDGEMENTS

The Biotope development was the result of a team approach in combination with several other ecological studies of the Texas Bay systems. The major portion of the artists' renditions were drawn by Marsha Kier with the assistance of David Walters. Biological and literature editorial assistance was given by John Holland, Dorothy Paul, Nancy Maciolek, Julie Gillespie, and Dinah Bowman. Thomas Isensee offered valuable assistance during the final drafting of the report.

Supported in Part
By
Coastal Resources Management Program
Office of the Governor
IAC (72-73)-806
and
The National Science Foundation RANN
Grant GI-34870X

TEXAS COASTAL ZONE BIOTOPES: AN ECOGRAPHY

Today's concern about the state of our coastal environment is primarily related to esthetics, recreation, or sport and commercial fisheries. Therefore we tend to associate any change created by man's industry with the above parameters. As man's interest in the coastal zone continues, it is essential that we define the above terms so that natural or artificial changes can be evaluated. An estuary is described schematically in Figure 1 (Phleger, 1969). We must also recognize that our present day bays have been altered by man's many activities, with both beneficial and adverse results. The original shallow bays 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 man has changed this variable condition through increasing control of the bays resulting from construction of dams and ship channels.

Esthetics (Figure 2) is a very difficult concept to evaluate or identify. To some the change of an estuary to a modern well-designed marina is acceptable. Who can deny that a marina (Figure 3), 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 (Figures 4 and 5).

Because esthetics, biological environment and physiography are so interrelated and have changeable meanings in various environments,

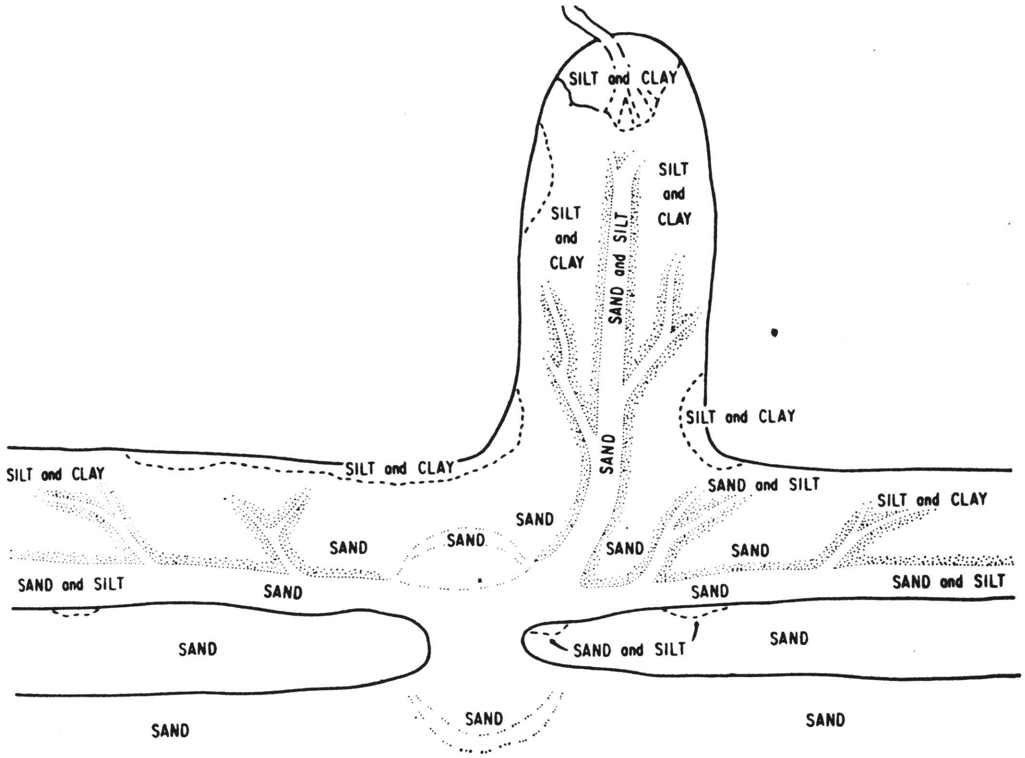


Diagram illustrating generalized distribution of sediment in a lagoon.

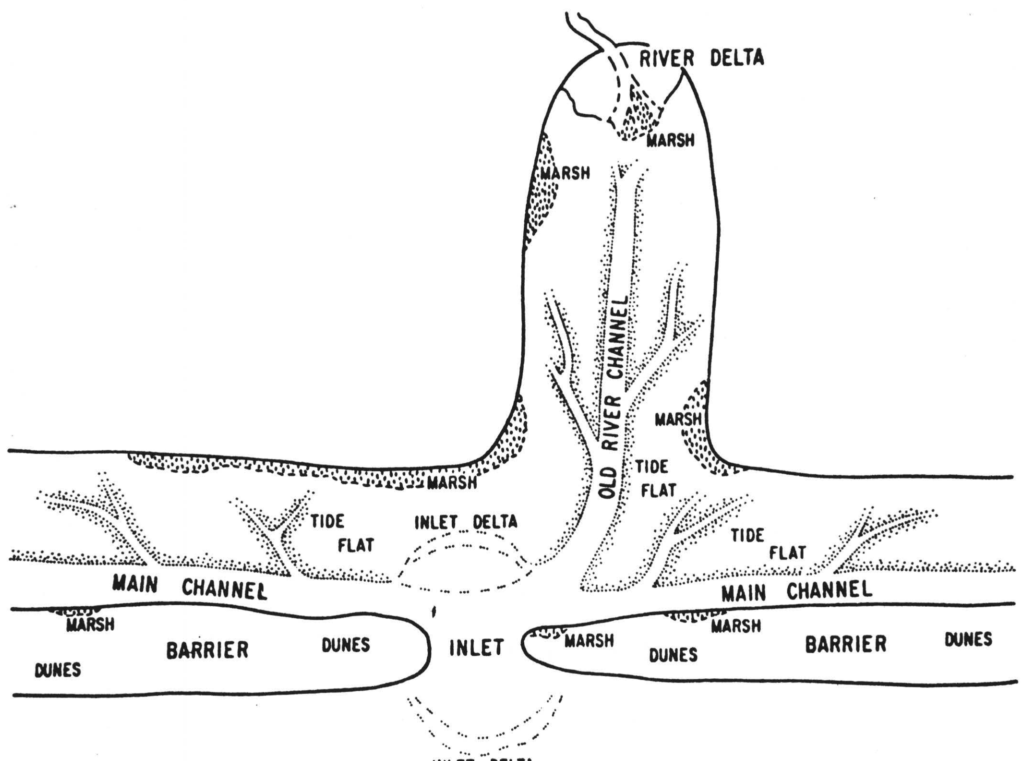


Diagram illustrating many of the geographic features of coastal lagoons.

Figure 1. Typical Estuary Topography

Figure 2. A Hopeful Look at the Surf

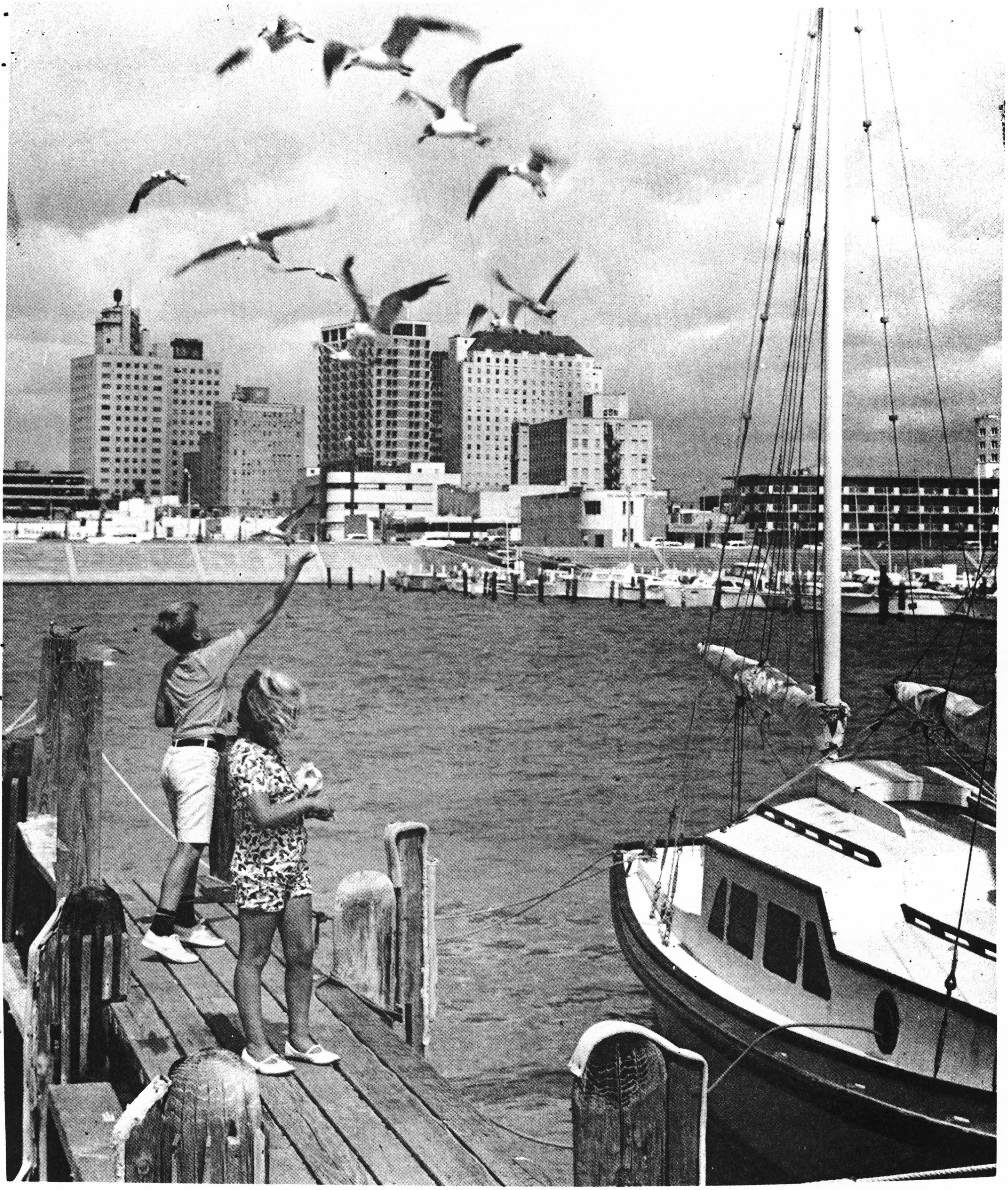


Figure 3. The Marina

Provincetown, Mass., with its windmills and fish-drying tables; from an old woodcut

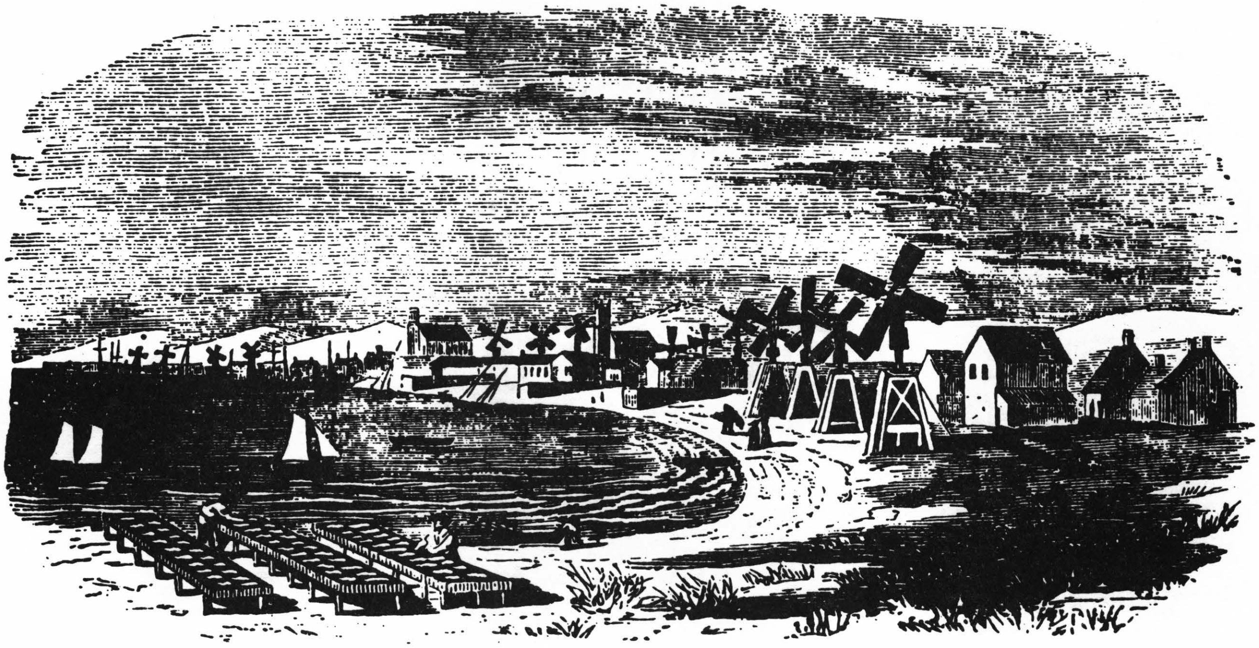


Figure 4. An Early Example of Coastal Zone Use.

Figure 3. *Boca Ciega Bay near St. Petersburg, Florida, showing land development for housing. The upper photograph shows the Bay in 1949. The lower photograph shows the same area in 1965. Ecologists claim that excessive development can destroy the biological productivity of an estuary. (Bureau of Commercial Fisheries photo by Airflite, St. Petersburg)*

Figure 5. Land Development is a Dominant Feature of Coastal Zone Development.

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. To do this we have chosen an old concept and adapted it to identify the relationships among biological communities that may be changed when man 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 layman as either diverse or uniform and 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 eighteen examples listed in Table 1. Thirteen of them plus an overview are illustrated.

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 are long lists of scientific names.

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 6 illustrates the effect of tidal movement in a lagoon as related to current flow and suspended matter, and Figure 7 gives the comparative production rates of carbon or organic matter in transit from the coastal zone. The average rates are in tons of organic carbon per year and show how productive the estuary is. They also suggest the estuary's tremendous role as a food (*i.e.* energy) source for coastal and offshore biota such as those that form the commercial fishery.

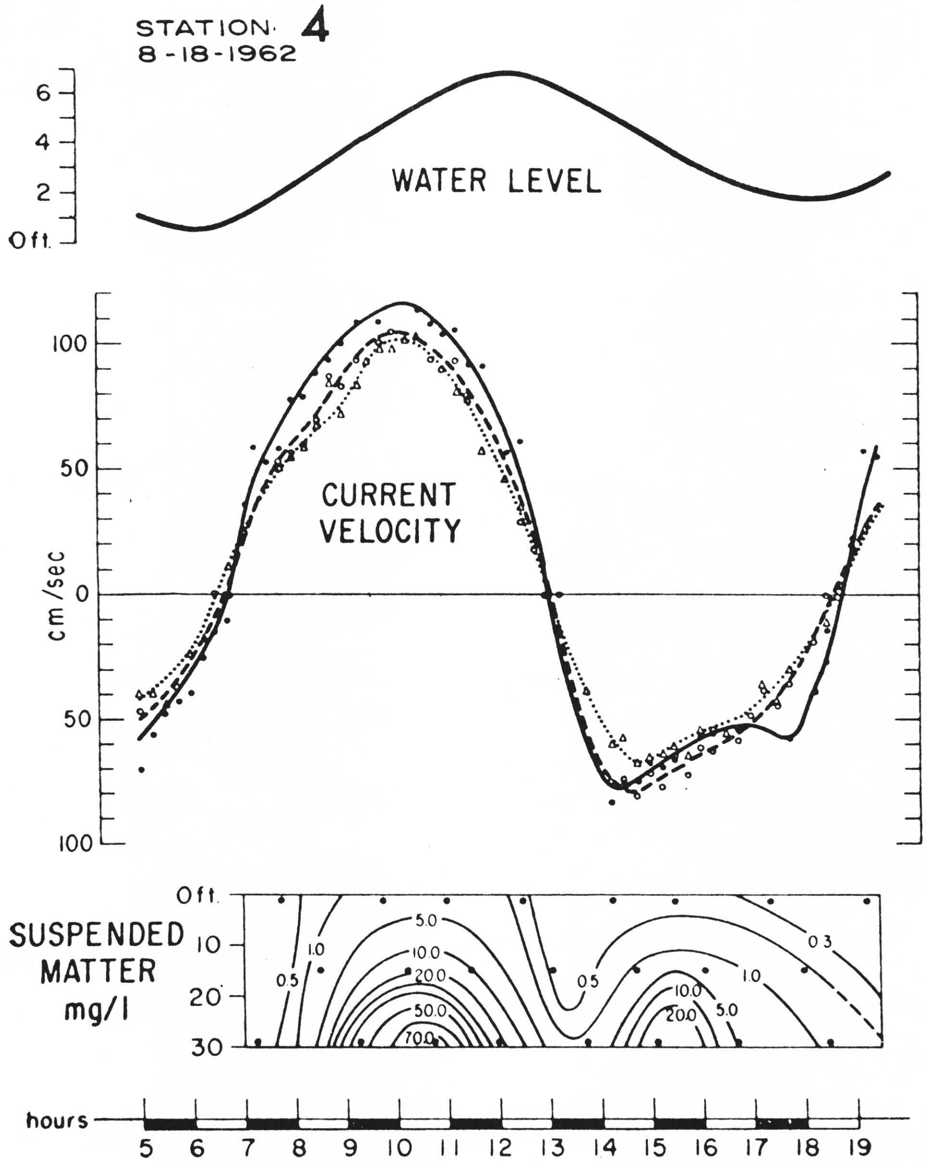
We recognize the impossibility of listing and illustrating all the diverse living organisms, from unicellular forms to large mammals, in any Biotope. However, there are identifying assemblages of organisms that can be used to show the biological balance of any specific Biotope. Because of the migratory 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 eighteen Biotopes in preliminary form. Artists' renditions are included. Modifications will be solicited by environmental scientists and other biologists who are experts on the Gulf of Mexico.

Table 1

BIOTOPES OF THE TEXAS COASTAL ZONE

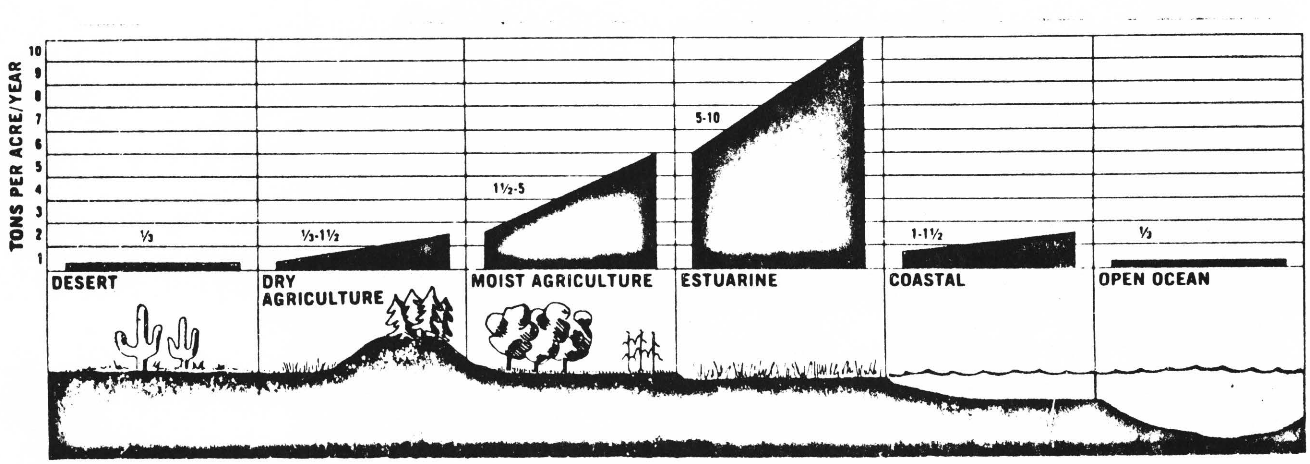
Open Beach and Shelf
Dune and Barrier Flat
Spoil Bank
Jetty and Bulkhead
Oyster Reef
Thalassia (grass flat)
Spartina (salt water marsh)
Juncus (fresh water marsh)
Mud Flat
Sand Flat
Blue-Green Algal Flat
*Hypersaline
*River Mouth
Bay Planktonic
*Channel
*Prairie Grassland
*Upland Deciduous Forest
River Floodplain Forest

*These Biotopes have not been illustrated.



Simultaneous measurements of current velocity, tide level and suspended sediment in Guerrero Negro Lagoon, Baja California, Mexico (After Postma, 1965).

Figure 6



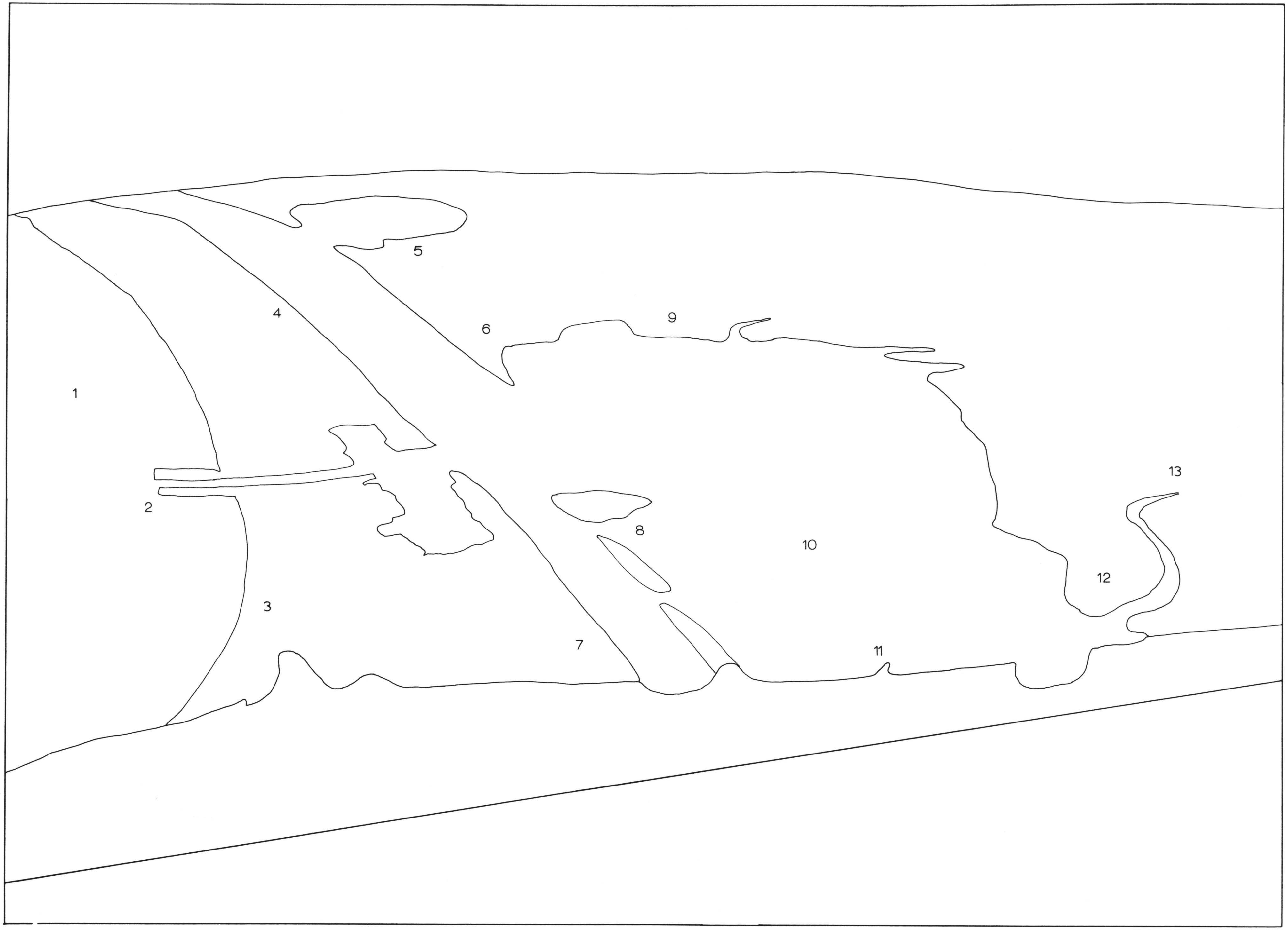
Comparative production rates among terrestrial and aquatic systems. Taken from *Man In The Living Environment.*

Figure 7

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 also the recognition that man's changes may in some instances by 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 8 is a chart that gives examples of the spatial distribution of the Biotopes in Corpus Christi, Nueces, and Aransas Bays. This Figure, like Figure 1, depicts a representative Texas estuarine environment. Two Biotopes, the upland deciduous forest and the river floodplain forest, are not indicated on Table 2 because this chart does not include any upland areas.

The Biotope originals are in water color, 18 x 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 listings 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.



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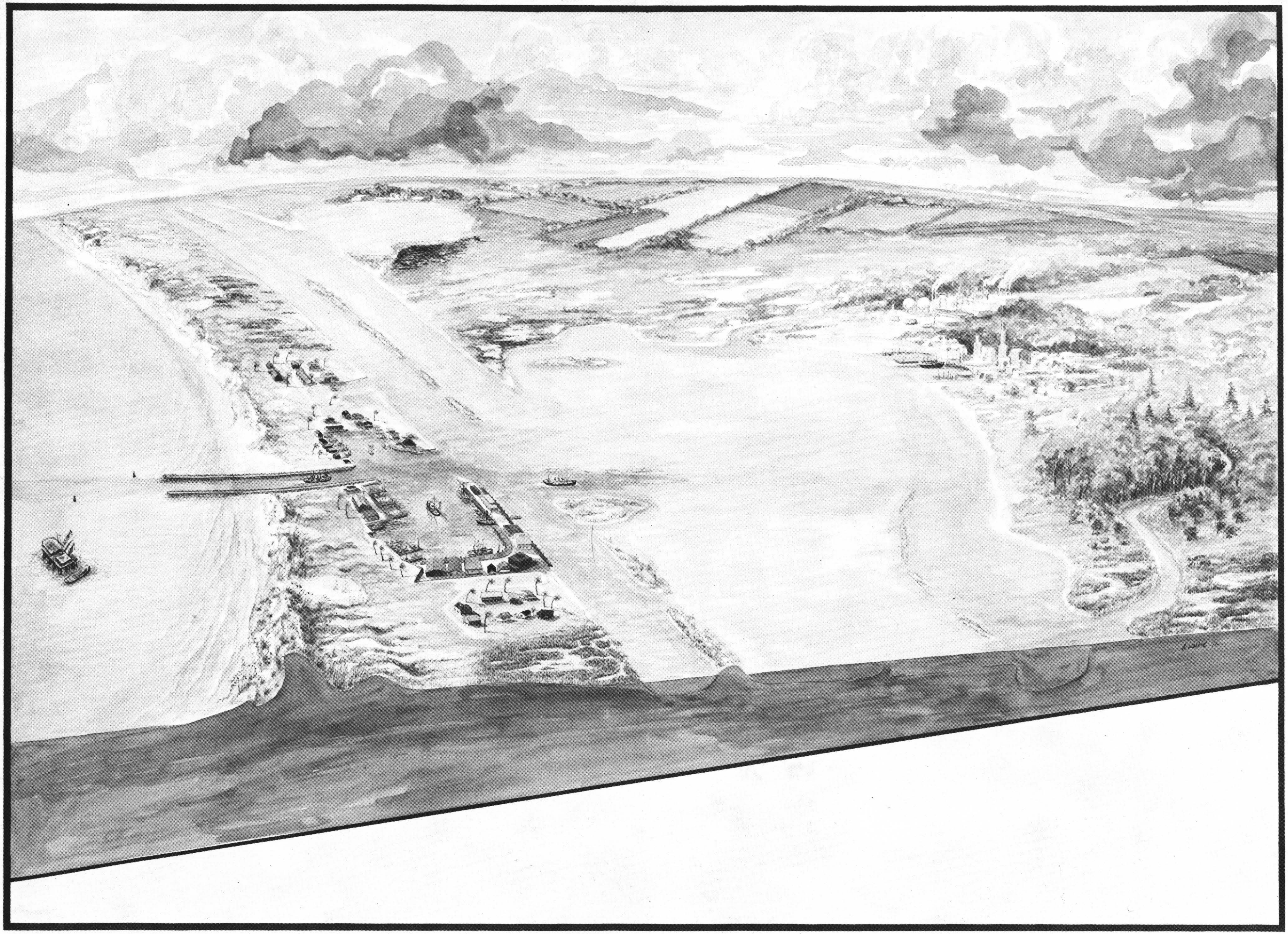


Figure 8. Schematic of Biotopes for Texas Coastal Zone

SYSTEMS OF BIOTOPES

We have attempted to show a hypothetical bay system by the artist's rendition, Figure 8. This illustration contains most of the typical Biotopes presented in the following pages numbered in order from Gulf to land. This illustration 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 less than one acre that while one Biotope may predominate, other Biotopes may be present in discrete patches. 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 actual field situations in the bay systems and estuaries of the Texas Gulf Coast.

1. Open Beach and Shelf
2. Jetty and Bulkhead
3. Dune and Barrier Flat
4. Channel
5. Blue-Green Algal Flat
6. Mud Flat
7. *Spartina* Salt Water Marsh
8. Spoil Bank
9. Sand Flat
10. Bay Planktonic
11. Oyster Reef
12. Fresh Water Marsh
13. River Floodplain Forest

DESCRIPTIONS OF INDIVIDUAL BIOTOPES

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

OPEN BEACH AND SHELF

The open beach Biotope (Fig. 9) 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 longshore currents and a sandy bottom. The water is usually well mixed thermally and well oxygenated. Offshore, the wave action subsides, currents are more stable in direction, and the bottom varies between sand, mud, and shell, with occasional reefs. There may be stratification of temperature and oxygen levels in the deeper areas.

The economic and recreational importance of this area is well known. The commercially important penaeid shrimp spend much of their life cycles in this Biotope. The highly desirable sports fish; tarpon, red snapper, several species of trout, as well as redfish, croaker, flounder, and drum, are found within or moving through the Biotope. Other recreational activities include 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 (19); the ghost shrimp, Callianassa islagrande (20); and the mantis shrimp, Squilla empusa (44). The swimming crabs, Callinectes danae and C. sapidus (27), are often found in the inshore area. Copepods of the genus Calanus (2) are found in the wave wash and interstitially in the sand, as well as elsewhere in the water column. The coquina clam, Donax variabilis (17, 18) and the olive shell, Oliva sayana (24), are found from the upper surf zone into the deeper waters. Also represented from the area of surf action are the sea pansy, Renilla muelleri (37); the sand dollar, Mellita quinquiesperforata (34,35);

and the stingray, Dasyatis americana (33). With the exception of C. danae, all of the above are pictured in Fig. 9.

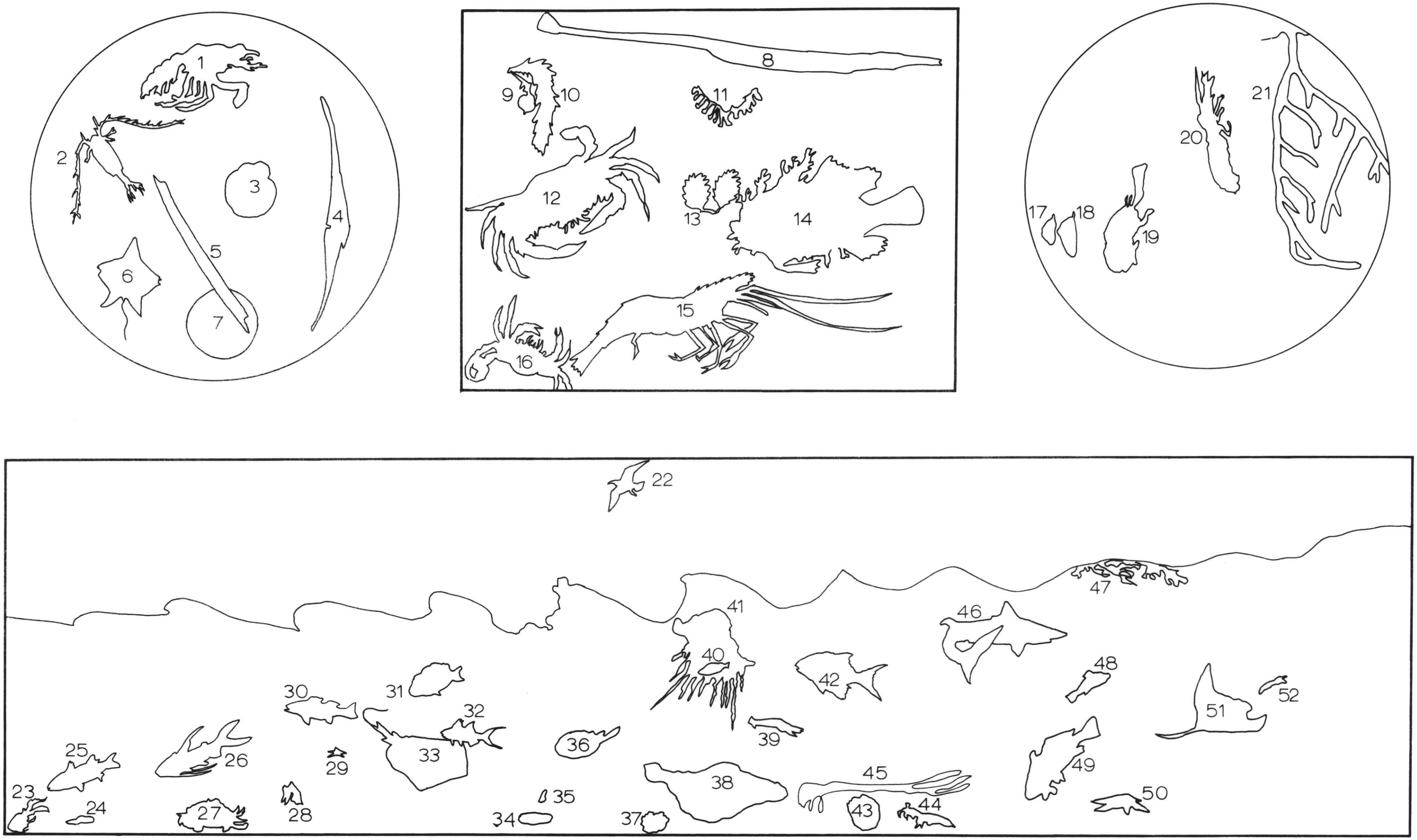
Common offshore bottom dwellers pictured in Fig. 9 include the whip coral, Leptogorgia setacea (45); the pen shell, Atrina serrata (43); starfish of the genus Astropecten (50); the electric ray, Narcine brasiliensis (36); the cow-nosed ray, Rhinoptera bonasus (51); the flounder, Paralichthys lethostigma (38); and the brown shrimp, Penaeus aztecus (52). Not shown are the white shrimp, Penaeus setiferus and the pink shrimp, P. duorarum.

Depicted from the water column are the diatoms Rhizosolenia sp. (5) and Coscinodiscus radiatus (7), the dinoflagellates Ceratium fusus (4) and C. hipos (6) and an example of a typical foraminifera (3). 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. Shown are details and habit of Sargassum sp. (9,10) with some of the specialized residents of these drifting brown algal masses. These animals include the sargassum pipefish, Sygnathus pelagicus (8); the sargassum crab, Portunus gibbesii (12); the sargassum fish, Histrio histrio (14); and the sargassum shrimp, Leander tenuicornis (15). Along with the sargasso weed, another important drifting organism, especially to those who wish to use the beaches for swimming, is the Portuguese Man O'War, Physalia physalia (41).

Finally, there are the actively swimming forms that move within this Biotope and through the inlets into other Biotopes. Those illustrated include the squid, Loligo brevis (39); the striped mullet, Mugil cephalus (25); the gafftopsail catfish, Bagre marinus (26); spotted sea trout, Cynoscion nebulosus (30); sheepshead, Archosargus probatocephalus (31); the eight-fingered threadfin, Polydactylus octonemus (32); golden croaker, Micropogon undulatus (40); pompano, Trachinotus carolinus*(42); spot, Leiostomus xanthurus (48); redfish, Sciaenops ocellata (49); and black-tipped shark, Carcharhinus limbatus*(46). Not shown in Fig. 9, but important and common in the Biotope are sea catfish, Galeichthys felis*; king mackeral, Scomberomorus cavalla; tarpon, Megalops atlanticus; red snapper, Lutjanus campechanus; salt drum, Stellifer lanceolatus*; bumper, Chloroscombrus chrysurus*; white mullet, Mugil curema; moonfish, Vomer setapinnis; bluefish, Pomatomus saltatrix; pigfish, Orthopristis chrysoptera; silver sea trout, Cynoscion nothus; stargazer, Astroscopus y-graecum; pinfish, Lagodon rhomboides; king whiting, Menticirrhus americanus*; menhaden, Brevoortia patronus*; leatherjacket, Oligoplites saurus*; anchovy, Anchoa mitchilli diaphana; silver perch, Bairdiella chrysura; rough silversides, Membras martinica vagrans; sand trout, Cynoscion arenarius; and spadefish, Chaetodipterus faber.

*Asterisk indicates dominant species.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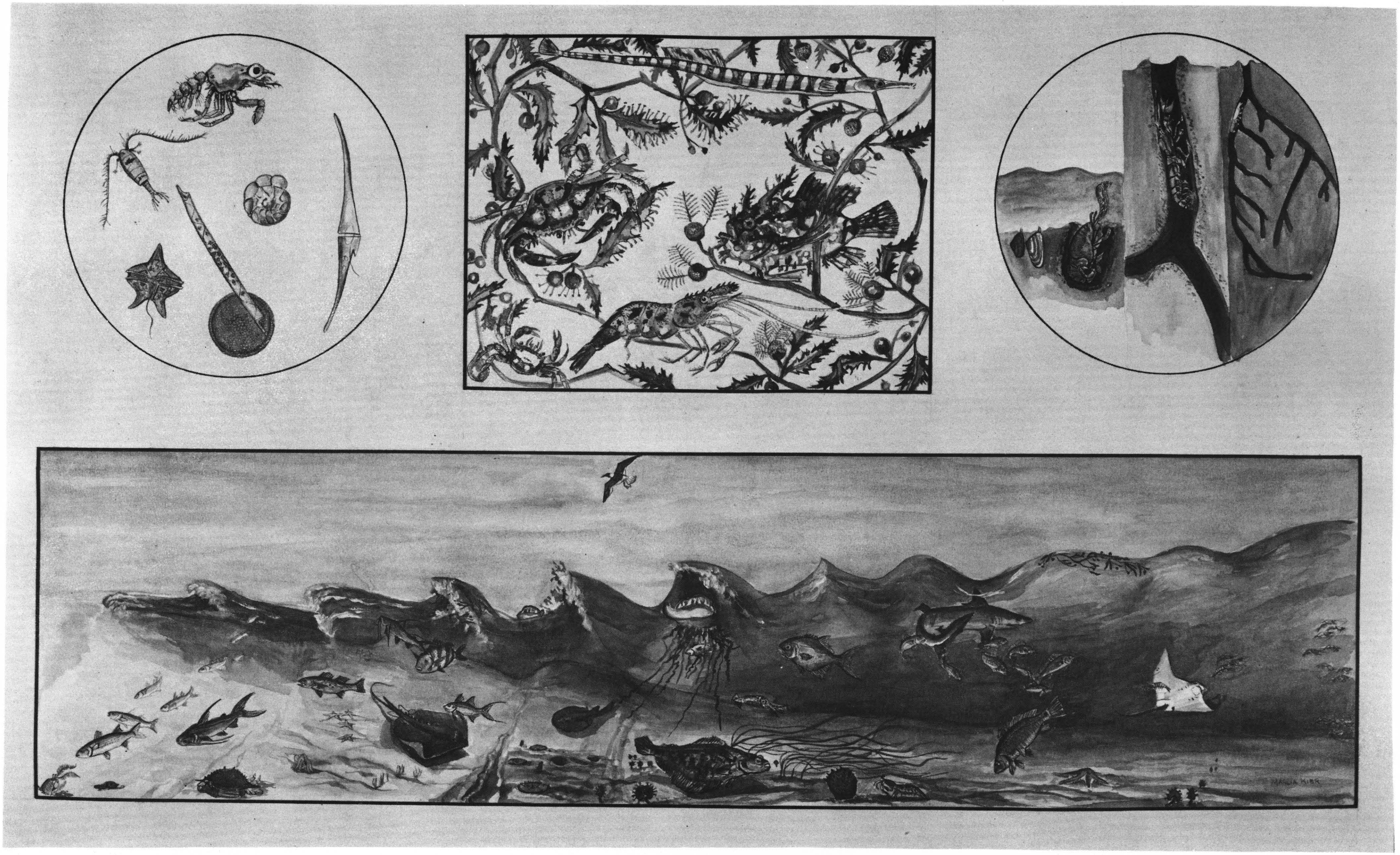

Figure 9. Open Beach and Shelf

OPEN BEACH AND SHELF

1. Megalops larva of Callinectes sapidus - Blue crab
2. Calanus sp. - Copepod
3. Foraminifera
4. Ceratium fusus - Dinoflagellate
5. Rhizosolenia sp. - Diatom
6. Ceratium hipos - Dinoflagellate
7. Coscinodiscus radiatus - Diatom
8. Sygnathus pelagicus - Sargassum pipefish
9. Sargassum float
10. Sargassum leaf
11. Epizoic bryozoan
12. Portunus gibbesii - Sargassum crab
13. Epizoic bryozoan
14. Histrio histrio - Sargassum fish
15. Leander tenuicornis - Sargassum shrimp
16. Portunus gibbesii (imm.) - Sargassum crab
17. Donax variabilis - Coquina
18. Donax variabilis - Coquina
19. Emerita talpoida - Mole crab
20. Callianassa islagrande - Ghost shrimp
21. C. islagrande burrow
22. Larus atricilla - Laughing gull
23. Emerita talpoida - Mole crab
24. Oliva sayana - Olive shell
25. Mugil cephalus - Striped mullet
26. Bagre marinus - Gafftopsail catfish
27. Callinectes sapidus - Blue crab
28. Astropecten sp. - Starfish
29. Astropecten sp. - Starfish
30. Cynoscion nebulosus - Spotted seatrout
31. Archosargus probatocephalus - Sheepshead
32. Polydactylus octonemus - Threadfin
33. Dasyatis americana - Stingray
34. Mellita quinquiesperforata - Dead sand dollar
35. Mellita quinquiesperforata - Live sand dollar
36. Narcine brasiliensis - Electric ray
37. Renilla muelleri - Sea pansy
38. Paralichthys lethostigma - Flounder
39. Loligo brevis - Squid
40. Micropogon undulatus - Golden croaker
41. Physalia physalia - Portuguese Man O'War
42. Trachinotus carolinus - Pompano
43. Atrina serrata - Pen shell
44. Squilla empusa - Mantis shrimp
45. Leptogorgia setacea - Whip coral
46. Carcharhinus limbatus - Black-tipped shark
47. Sargassum sp. - Sargasso weed
48. Leiostomus xanthurus - Spot
49. Sciaenops ocellata - Redfish
50. Astropecten sp. - Starfish
51. Rhinoptera bonasus - Cownosed ray
52. Penaeus aztecus - Shrimp

DUNE AND BARRIER FLAT

The barrier islands of the Texas coast are the result of depositional and aeolian 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 punctuated by swales and freshwater potholes. Finally, along the lagoon edge, there is 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.

The number of species of plants found on the seaward face of the dunes is small compared to the variety found on the flats. The major sand trapping plant is the sea oat, 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-caprae (9) and I. stolonifera (16); and beach tea, Croton punctatus (8); as shown in Fig. 10. Other species trapping sand in the foredune area are seashore dropseed, Sporobolus virginicus; sea-purslane, Sesuvium portulacastrum; and beach groundcherry, Physalis viscosa. Occasionally found on the dunes and 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.

The grassy areas of the barrier flat support seacoast bluestem, Andropogon scoparius littoralis (4); beach tea, Croton punctatus (8); and sunflowers, Helianthus annuus (17), as shown in Fig. 10, as well as the grasses, Spartina patens, Paspalum monostachyum, and Sporobolus virginicus, which are not pictured. Shoregrass, Monanthochloe littoralis (not shown), is the dominant grass bordering mudflat areas. Seasonal dominants are the evening primrose, Oenothera drummondii, and whitestem wild indigo, Baptisia laevicaulis, in the spring; and western ragweed, Ambrosia psilostachya; camphorweed, Heterotheca subaxillaris; groundsel, Senecio spartioides; and an indigo, Indigofera miniata, in the fall.

Variations in vertical elevation influence the vegetation of the barrier flat. Hummocks have relict stands of Uniola paniculata (3), the sea oat, while swales and potholes may contain marshhay cordgrass, Spartina patens; cattails, genus Typha; and Drummond rattlebox, Sesbania 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.

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); blue-tailed skink, Eumeces fasciatus (25); keeled earless lizard, Holbrookia propinqua (10); and Texas horned lizard, Phyrnosoma cornutum (14). The ghost crab, Ocypode quadrata (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 alba (13), are commonly found. The dragonflies, genus Anax (15); the small black ant, Monomorium minimum (21); the grasshopper, Schistocerea americana (22); and centipedes, genus Scolopendra (11,23), are representative of the terrestrial arthropods.


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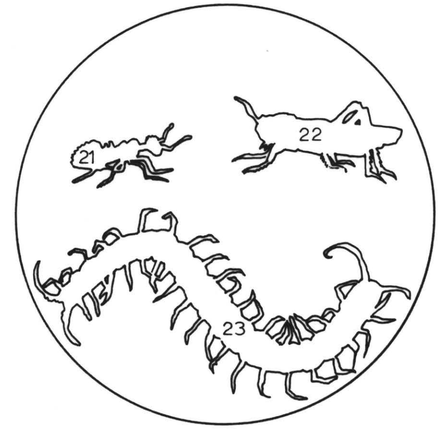
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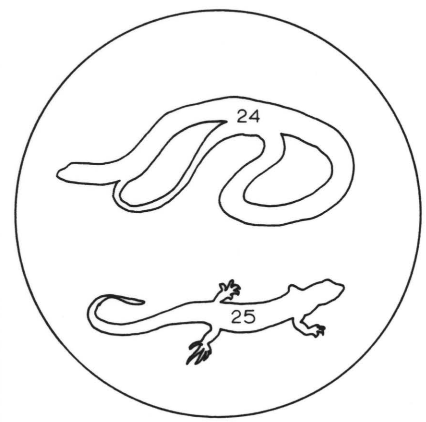
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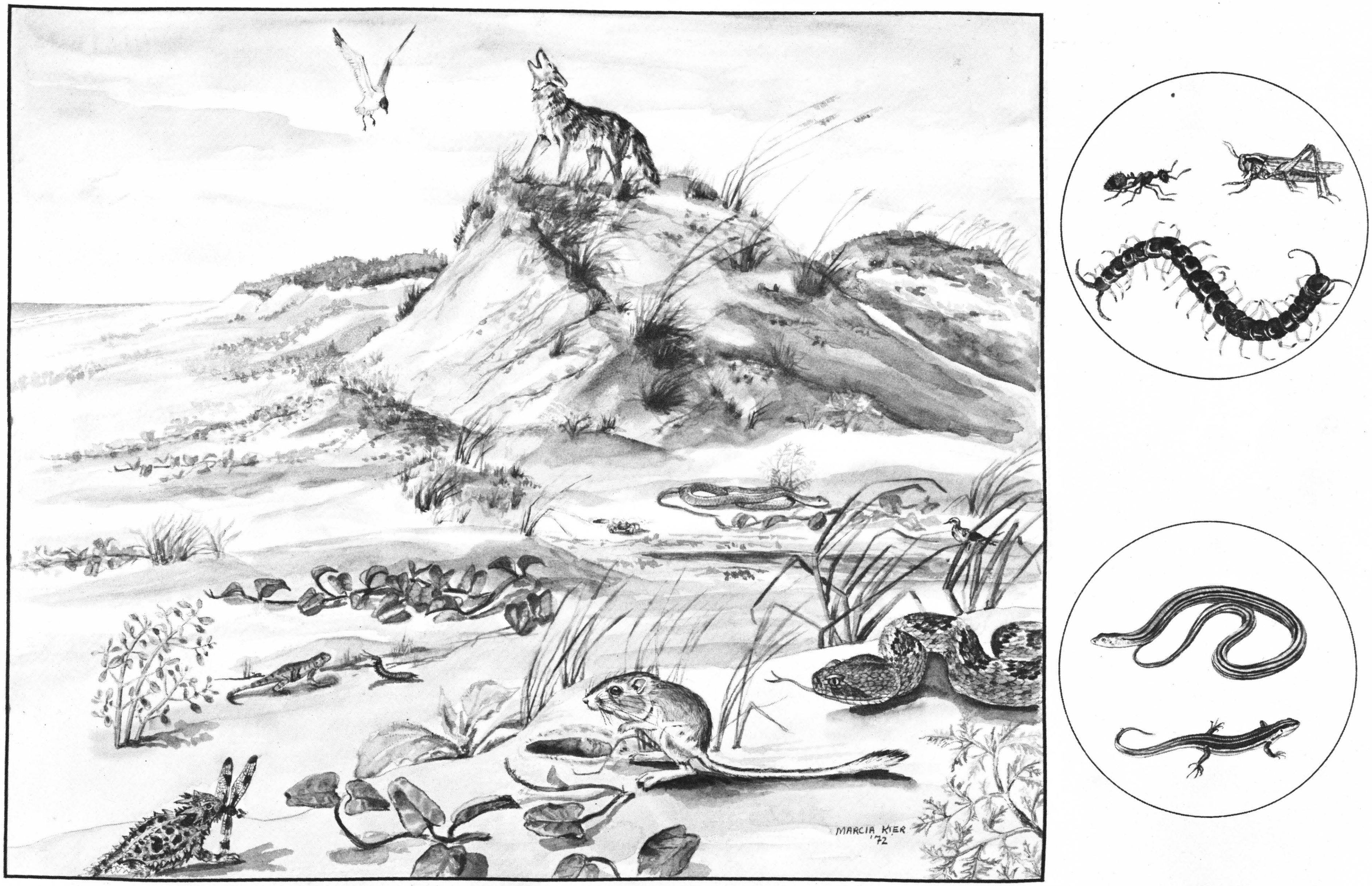


Figure 10. Dune and Barrier Flat

DUNE AND BARRIER FLAT

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

SPOIL BANK

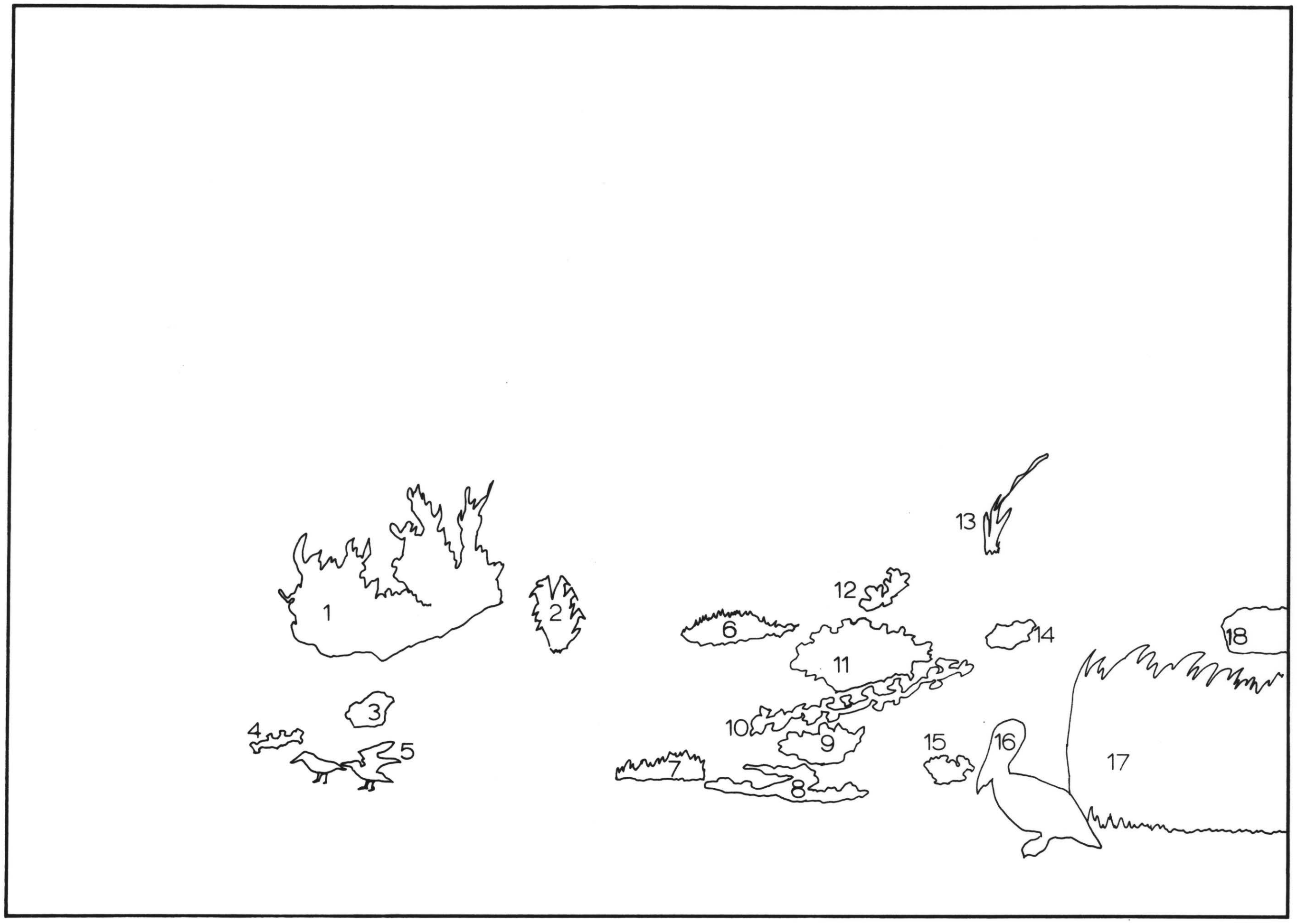
Spoil banks are composed of mud, sand, and shell dredged from several layers of sediments and deposited in mounds extending above the water surface, often parallel to the channels created. These islands vary in shape from circular to elongated with vertical elevations of up to twenty feet. Eventually, these areas are colonized by the organisms shown in Fig. 11.

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); seacoast bluestem, Andropogon scoparius littoralis (2); Gulf cordgrass, Spartina spartinae (31); sea oats, Uniola paniculata (13); and goatfoot morning glory, Ipomoea pes-caprae (10); as shown in Fig. 11. In the intermediate areas, those reached only by the highest tides, are found sea purslane, Sesuvium portulacastrum (8), and marshhay 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); a shoal grass, Diplanthera wrightii (21); as shown in Fig. 11, 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 Clibanarius vittatus (20) and Pagurus pollicaris. The hermit crabs are also found in the adjacent waters, along with blue crabs, Callinectes sapidus (29); brown shrimp, Penaeus aztecus (27); oysters, Crassostrea virginicus (30); as shown; and the clams Rangia cuneata and Mercenaria mercenaria. The fish depicted include sand trout, Cynoscion arenarius (23); golden croaker, Micropogon undulatus (24); black drum, Pogonias cromis (26); flounder, Paralichthys lethostigma (28); and 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 nigra (5), and the white pelican, Pelecanus erythrorhynchus (16).

While this Biotope is a relatively low producer, it has an as yet unexploited value to society as a retreat for fishermen, boaters, picnickers, and campers.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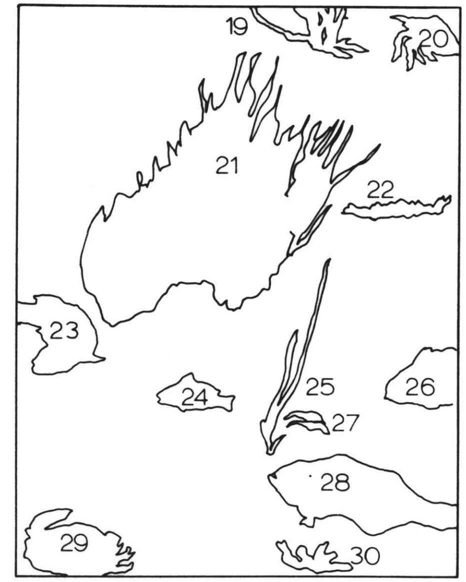
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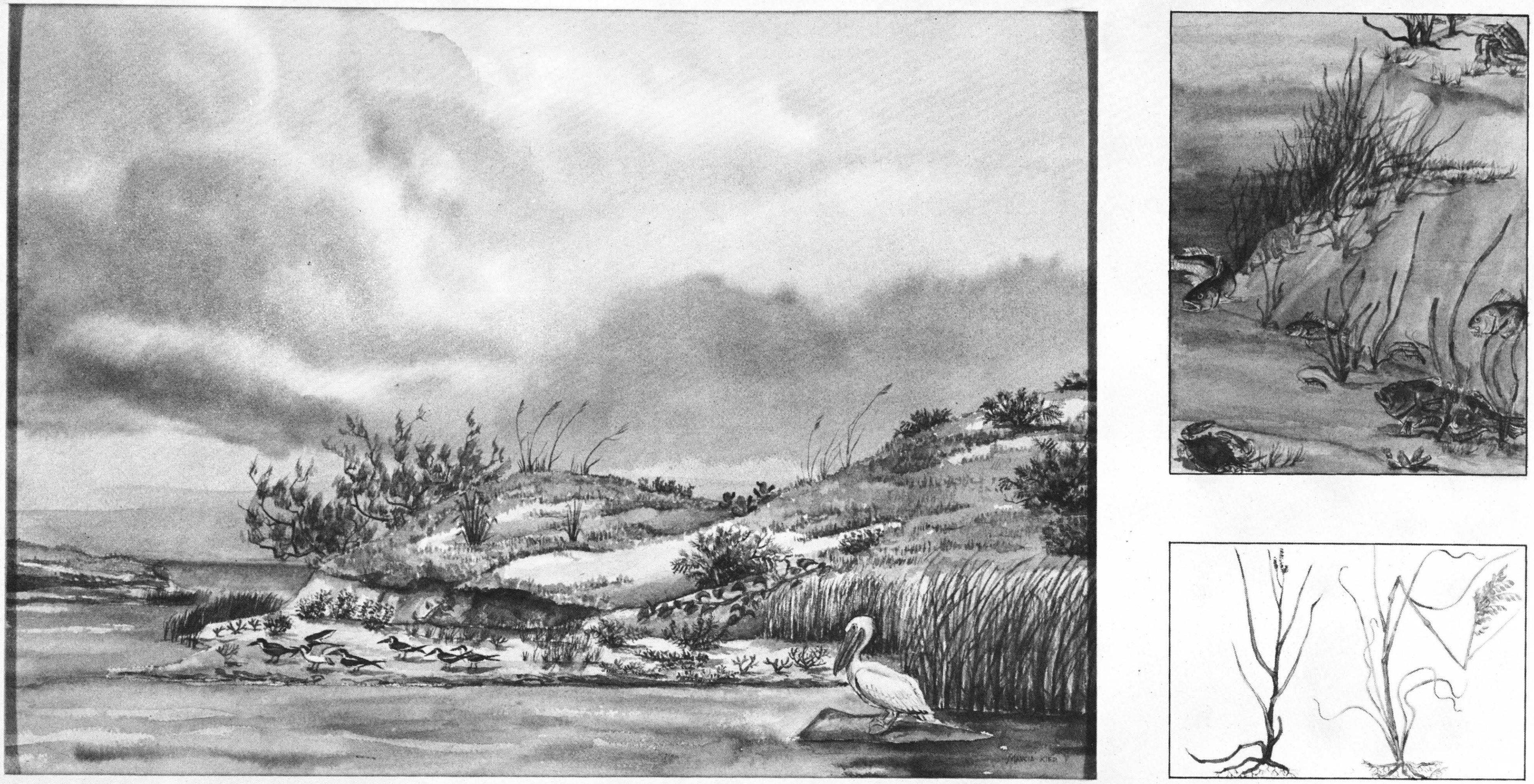


Figure 11. Spoil Bank

SPOIL BANK

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

JETTY AND BULKHEAD

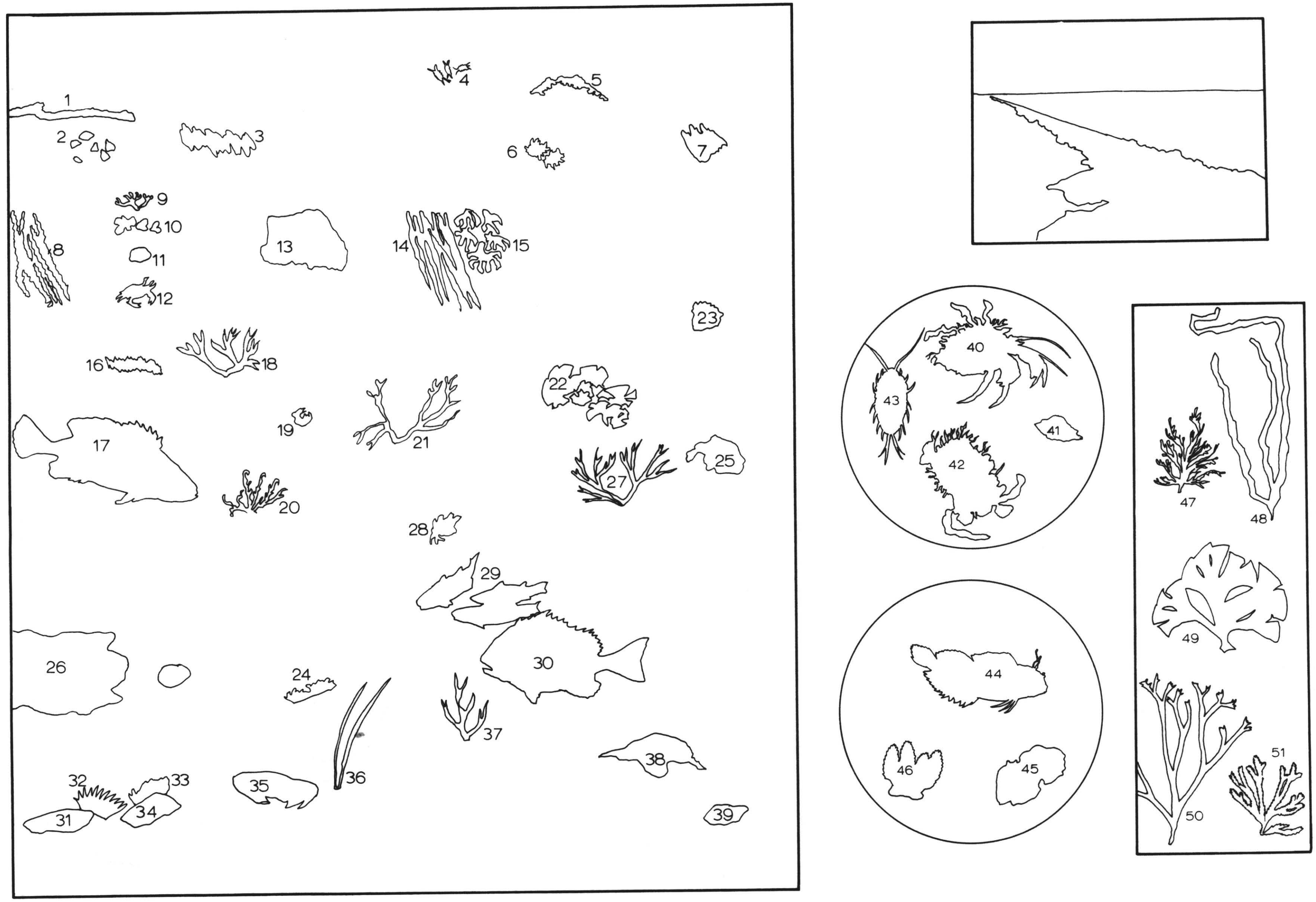
Jetties and bulkheads are man-made structures of rock, shell, concrete, wood and steel, placed to restrict sedimentation in channels or to provide docking areas. As a result, these structures are in areas where there is variable current energy and offer a surface and protection to a wide variety of organisms.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

The dominant green algae pictured in Fig. 12 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 sponges 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, Modiolus 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) and Littorina irrorata (5); the stone crab, Menippe mercenaria (35); hermit crab, Clibanarius vittatus (28); the sea urchin, Arbacia punctulata (32); and the isopod wharf roach, Lygia 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); sheepshead, Archosargus probatocephalus (30); striped mullet, Mugil cephalus (29); blue crab, Callinectes sapidus (12); and another portunid crab, Ovalipes ocellatus (19).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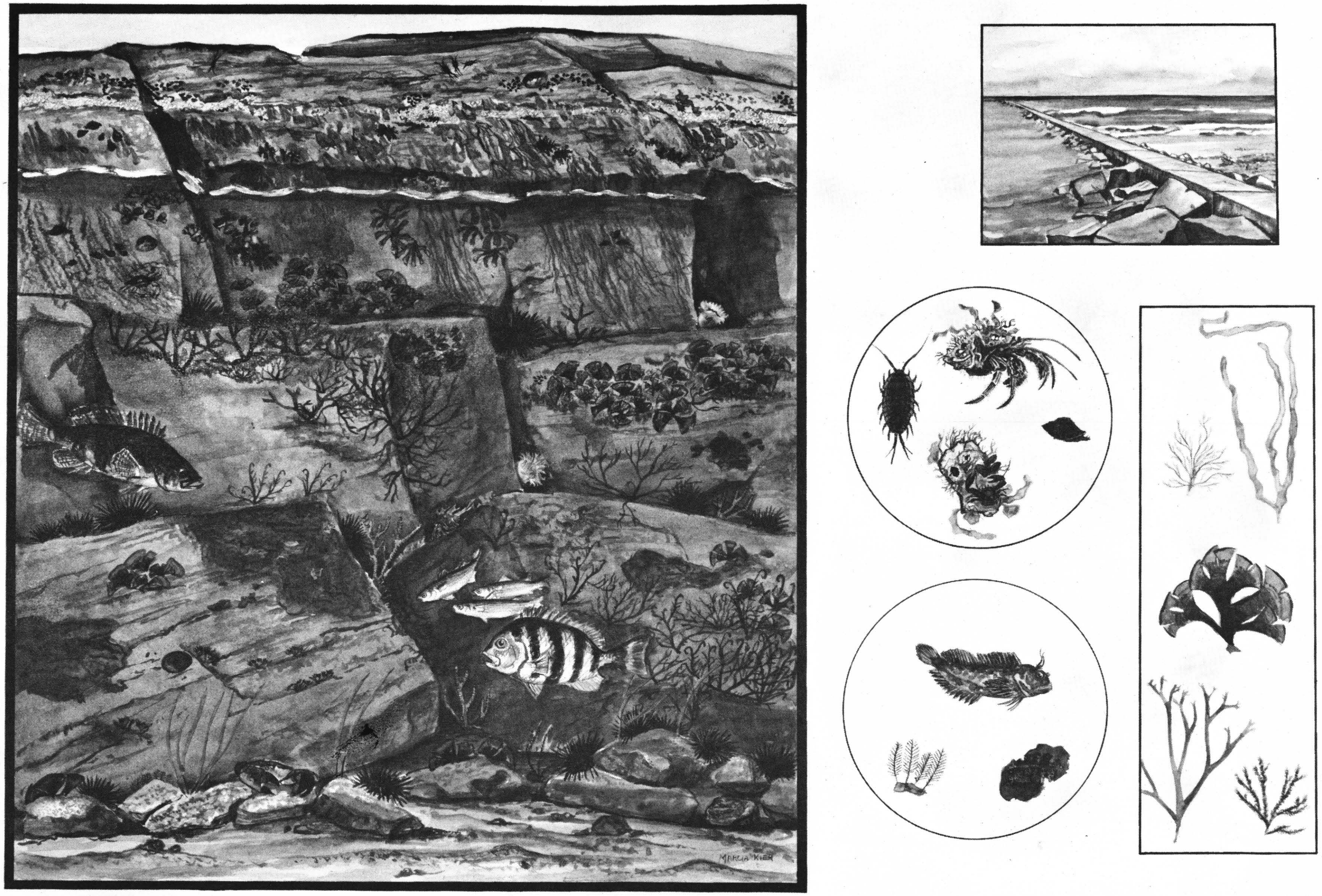


Figure 12. Jetty and Bulkhead

JETTY AND BULKHEAD

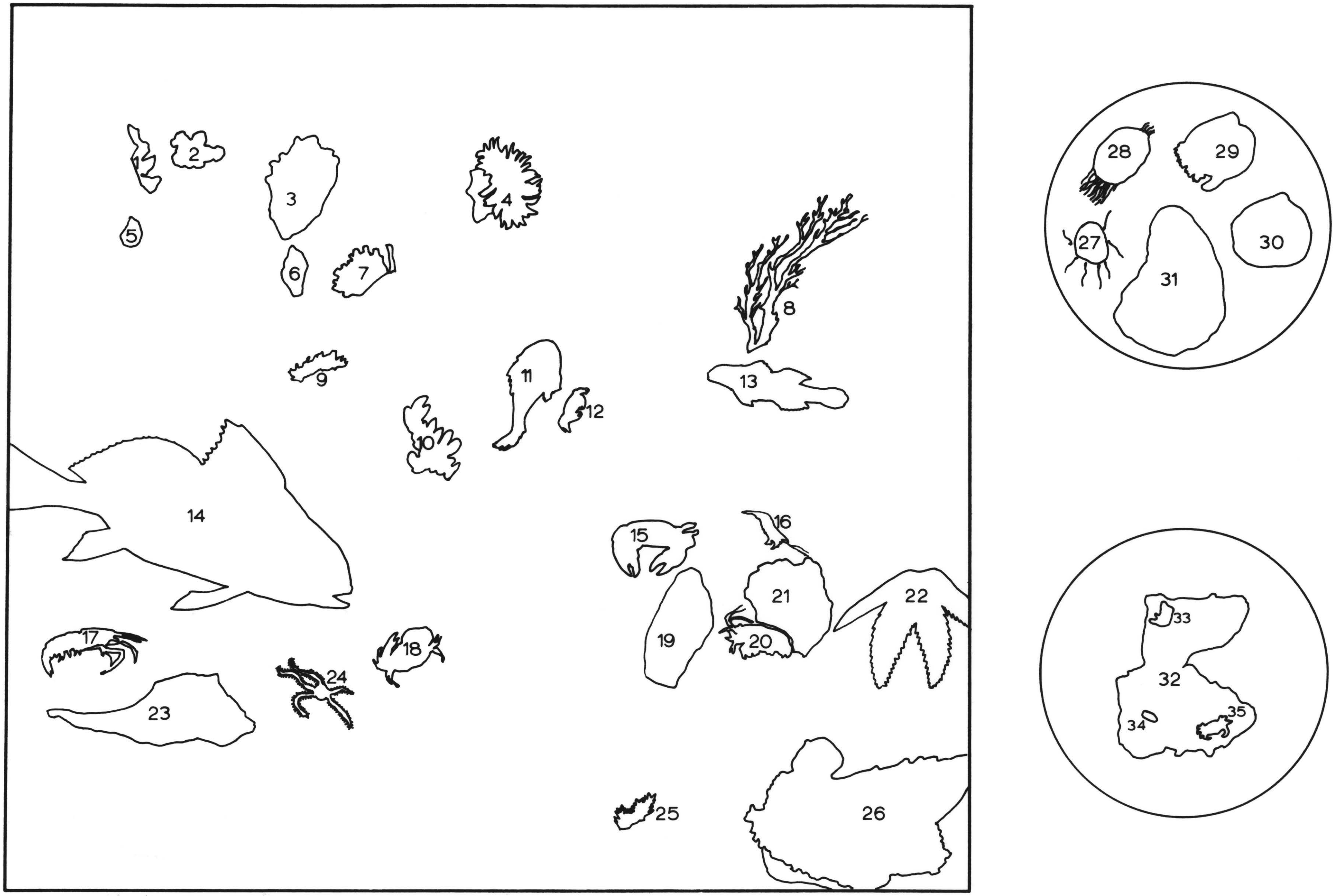
1. Balanus sp. - Barnacle
2. Thais haemostoma - Florida rock shell
3. Enteromorpha flexosa - Green alga
4. Lygia exotica - Wharf roach
5. Littorina irrorata - Periwinkle
6. Bryocladia cuspidata - Red alga
7. Ulva lactuca - Green alga
8. Chaetomorpha sp. - Green alga
9. Gelidium sp. - Red alga
10. Crassostrea virginica - American oyster
11. Hypleurochilus geminatus - Crested blenny
12. Callinectes sapidus - Blue crab
13. Cladophora vagabunda - Green alga
14. Ulva fasciolata - Green alga
15. Enteromorpha lingulata - Green alga
16. Giffordia sp. - Red alga
17. Promicrops itaiara - Spotted jewfish
18. Dictyota dichotoma - Brown alga
19. Ovalipes ocellatus - Swimming crab
20. Hypnea musiciformis - Red alga
21. Agardhiella tenera - Red alga
22. Padina vickersiae - Brown alga
23. Bunodosoma cavernata - Anemone
24. Rhodymenia palmata - Red alga
25. Microciona sp. - Sponge
26. Microciona sp. - Sponge
27. Gracilaria prolifera - Red alga
28. Clibanarius vittatus - Hermit crab
29. Mugil cephalus - Striped mullet
30. Archosargus probatocephalus - Sheepshead
31. White sponge
32. Arbacia punctulata - Urchin
33. Hydroid
34. Yellow sponge
35. Menippe mercenaria - Stone crab
36. Leptogorgia setacea - Sea whip (octocoral)
37. Oculina sp. - Hard coral
38. Haliciona sp. - Pink sponge
39. Microciona sp. - Sponge
40. Clibanarius vittatus - Hermit crab
41. Thais haemostoma - Florida rock shell
42. Modiolus sp. - Mussel and attachments
43. Lygia exotica - Wharf roach
44. Blennius cristatus - Molly miller
45. Microciona sp. - Orange sponge
46. Hydroid
47. Cladophora vagabunda - Green alga
48. Ulva flexosa - Green alga
49. Padina vickersiae - Brown alga
50. Dictyota dichotoma - Brown alga
51. Bryocladia cuspidata - Red alga

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. 13). 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, 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 (1); the red alga Hypnea musciformis (9); and the green algal genus Cladophora (8), as shown in Fig. 13. Other sessile animals shown in the reef setting are barnacles, genus Balanus (2); anemones, Bunodosoma cavernata (4); various hydroids (25); mussels, Modiolus americana (10); and serpulid worms, genus Hydroides (21). Organisms dependent on the shellfish for food include the Florida rock shell, Thais haemostoma (6), a type of oyster drill; and stone crabs, Menippe mercenaria (15); starfish, Luidia clathatare (22); and oyster crabs, Pinnotheres ostreum (35). Burrowing forms include snapping shrimp, Alpheus heterochaelis (20); boring sponge, genus Cliona (19); mud crab, Panopeus herbstii (18); flat mud crab, Eurypanopeus depressus (12); polychaete worms of the genus Polydora sp. (33); and the boring clam, Diplothyra smithii (34). The chiton, Ischnochiton papillosus (5); grass shrimp, genus Palaemonetes (16); brittle star, genus Ophiothrix (24); and the whelk, Busycon contrarium (23) are the predominant grazers shown for this Biotope. Several small fish are found associated with the reef, among them skillet fish, Gobiesox strumosus (11); crested blenny, Hypleurochilus geminatus (13); and gulf toadfish, Opsanus beta (26). The black drum, Pogonias cromis (14), is known to feed on oysters and other shellfish.

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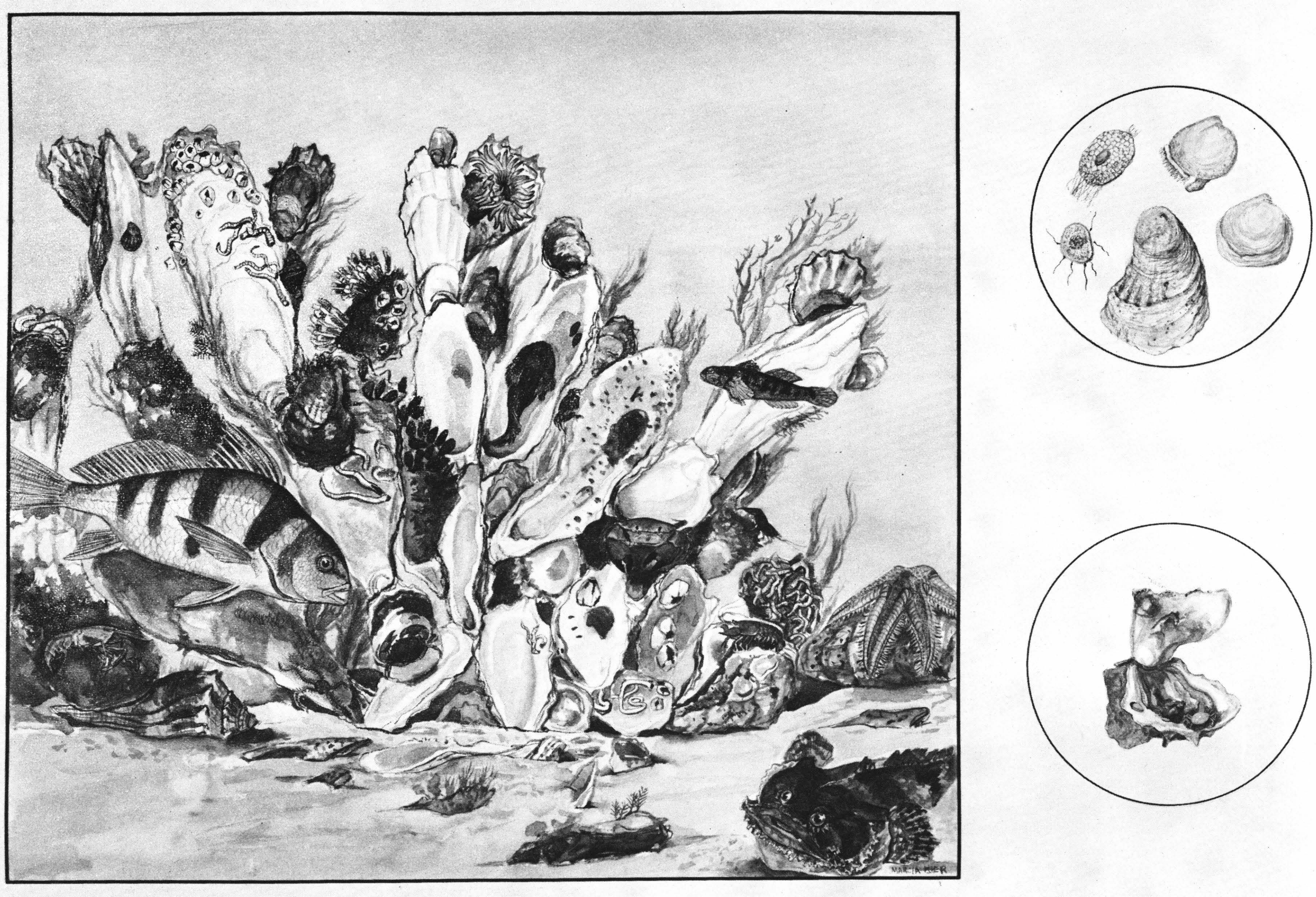

Figure 13. Oyster Reef

OYSTER REEF

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
7. *T. haemostoma* eggs
8. *Cladophora* sp. - Green alga
9. *Hypnea musciformis* - Red alga
10. *Modiolus americana* - 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. *Palaemontes* sp. - Grass shrimp
17. *Alpheus heterochaelis* - Snapping shrimp
18. *Panopeus herbstii* - Mud crab
19. *Cliona* sp. - Boring sponge
20. *Alpheus heterochaelis* - Snapping shrimp
21. *Hydroides* sp. - Serpulid worms
22. *Luidia clathatare* - Starfish
23. *Busycon contrarium* - Whelk
24. *Ophiothrix* sp. - Brittle star
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
31. Adult *Crassostrea virginica*
32. *Crassostrea virginica* - American oyster
33. *Polydora* sp. - Polychaete
34. *Diplothyra smithii* - Boring clam
35. *Pinnotheres ostreum* - Oyster crab

(27–31: Stages in the development of *Crassostrea virginica*)

THALASSIA GRASSFLAT

This extensive and productive Biotope is characteristically composed of moderate to dense growths of turtle grass, *Thalassia testudinum* (22); shoal grass, *Halodule wrightii* (20); *Halophila engelmanii* (19); and widgeon grass, *Ruppia maritima*, as shown in Fig. 14 (*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 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 *Cocconeis* 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 pliculosa* (8); olive nerite, *Neritina reclivata* (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, Palaemonetes vulgaris (7); hermit crab, Clibanarius vittatus (16); mud crab, Neopanope texana (17); blue crab, Callinectes sapidus (18); a crab known as ~~Rhitropanopeus~~ Rhithropanopeus harrisii (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, Minidia beryllina (11); redfish, Sciaenops ocellata (12); as well as golden croaker, Micropogon undulatus; mullets, Mugil cephalus and M. curema; and menhaden, Brevoortia patronus.

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) and Cymbella (31); the dinoflagellate, Ceratium (29); the euglenoid Dunaliella (33); the blue-green Oscillatoria (32); and the colonial green alga, Microcystis (34, 35).

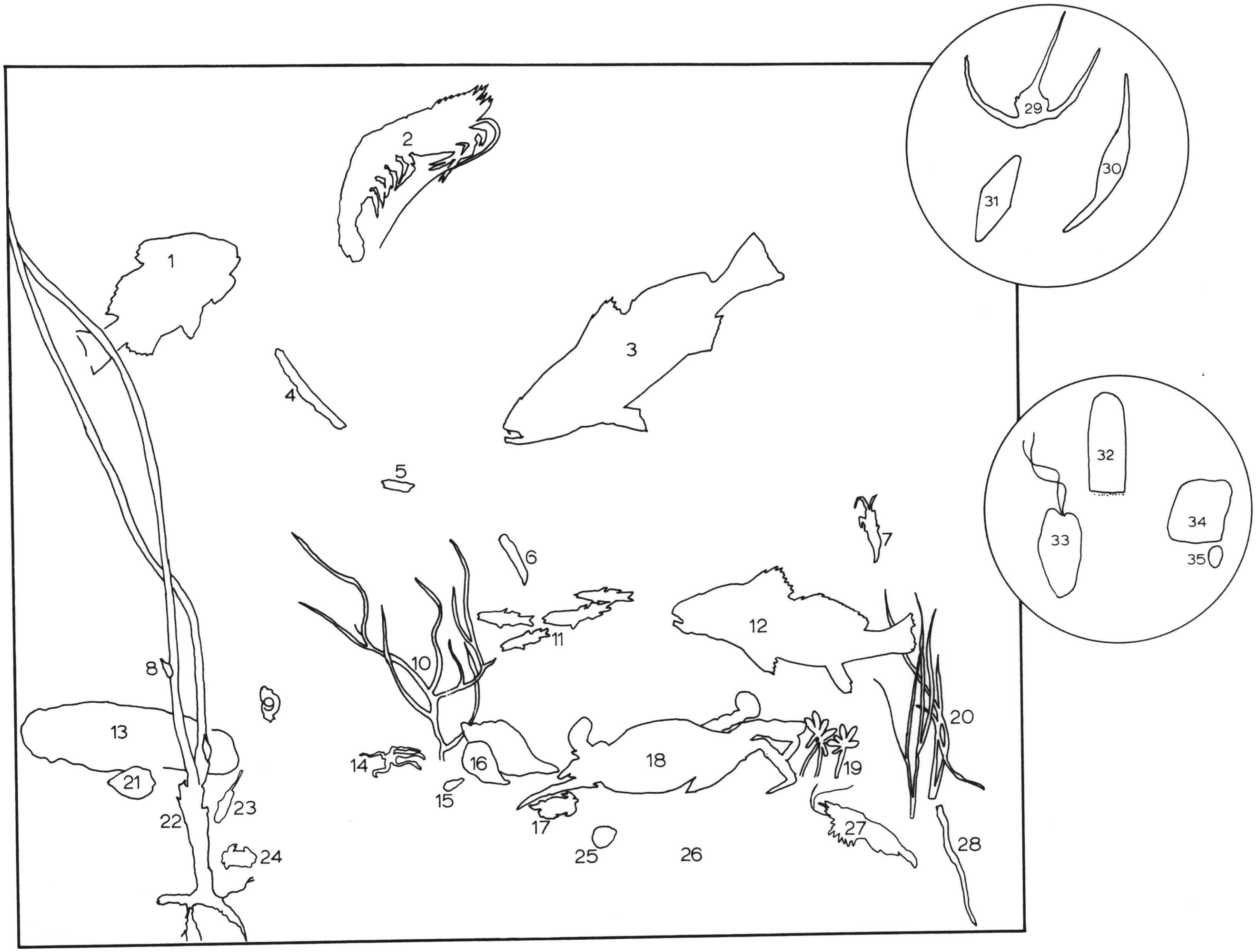
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Figure 14. Thalassia (grass flat)

THALASSIA GRASSFLAT

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

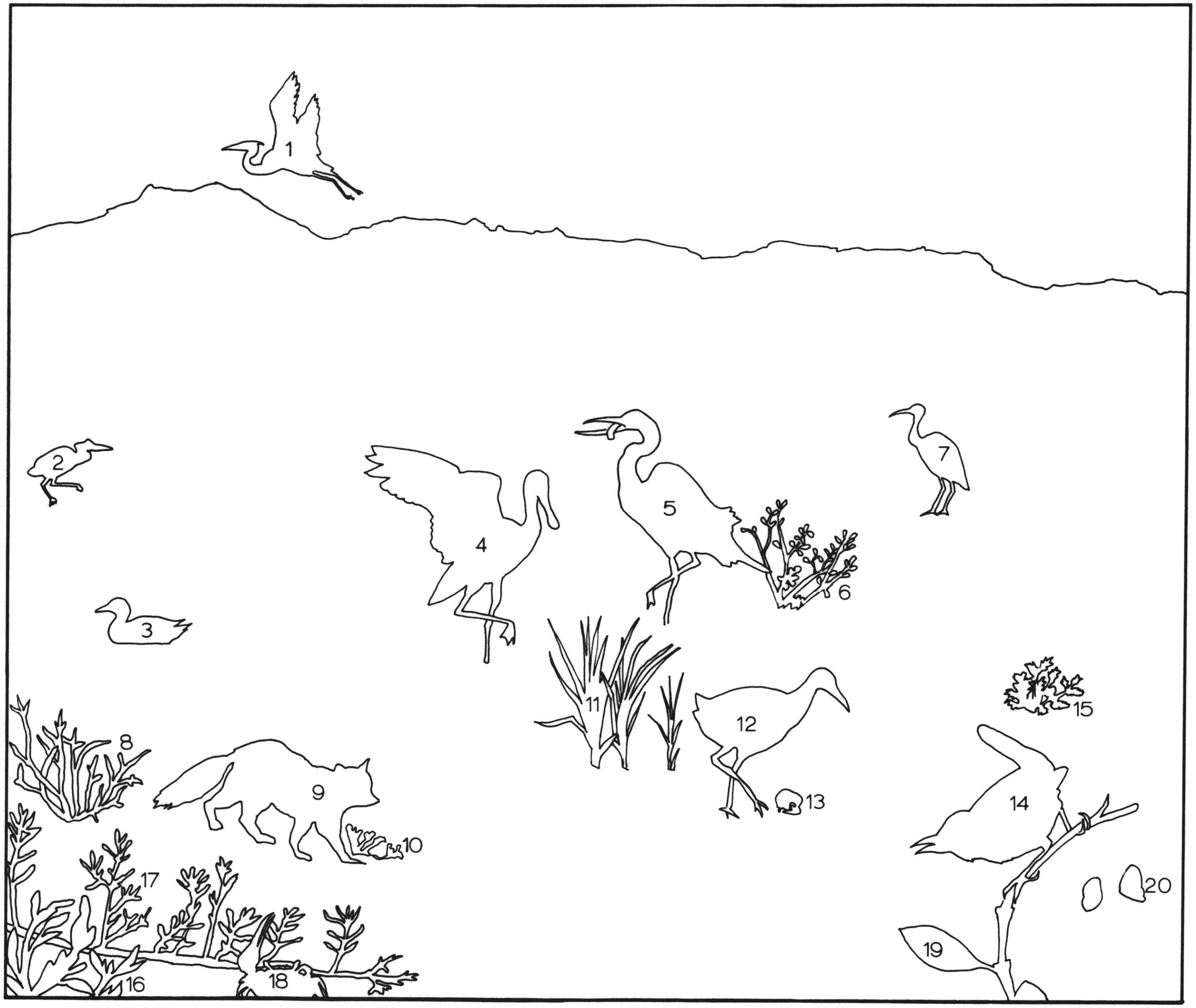
SPARTINA (SALT WATER MARSH)

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

Other common plants shown in Fig. 15 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 purslane, 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); 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 pulustris (14).

Grazing and scavenging are accomplished by a variety of animals. Those shown include the hermit crabs, Pagurus (13); the fiddler crab, Uca ~~pugnax~~ virens (18); 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.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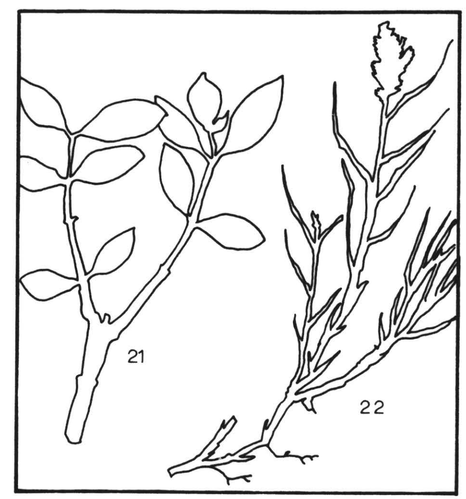
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Figure 15. Spartina (salt water marsh)

SPARTINA (SALT WATER MARSH)

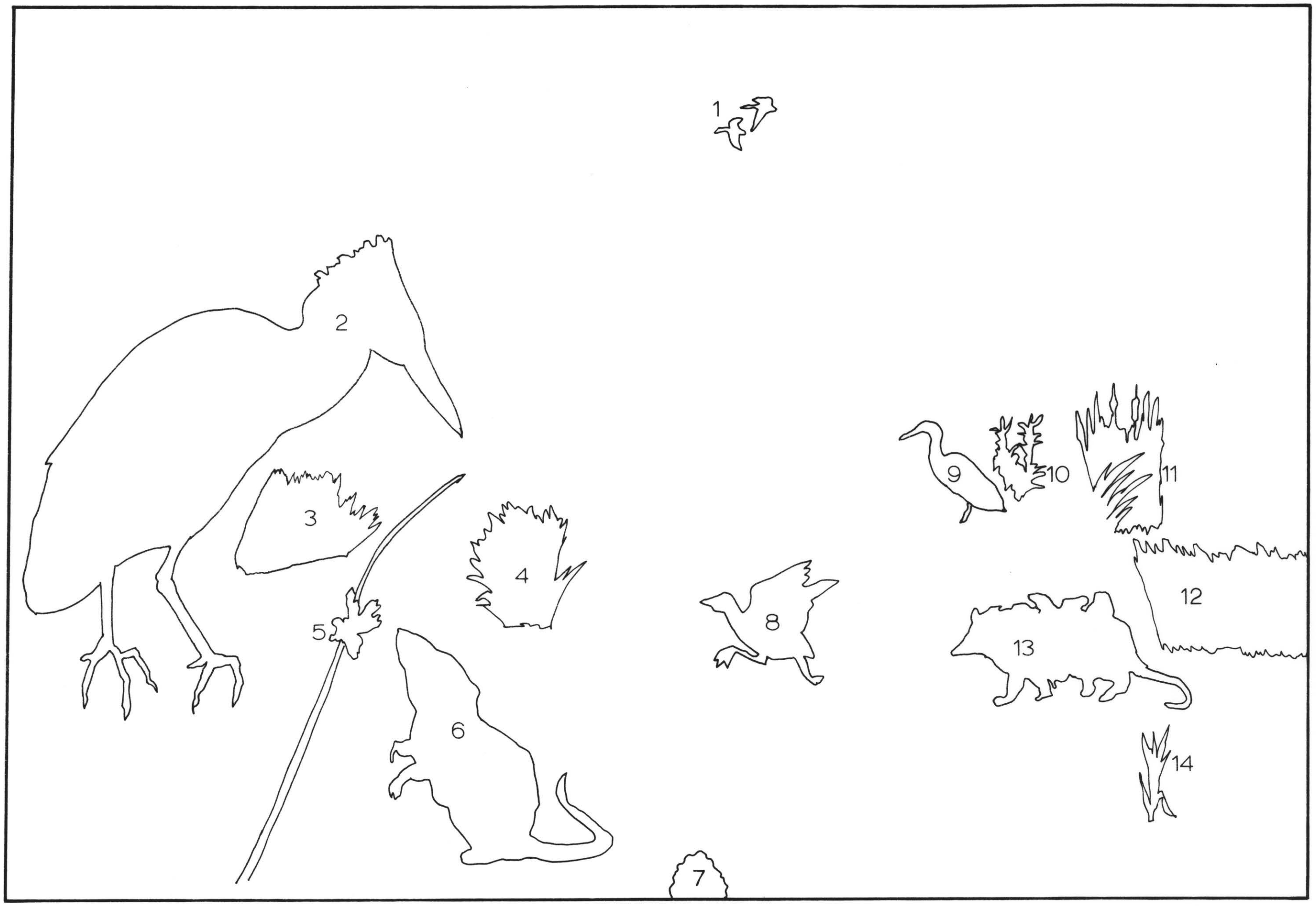
1. Ardea herodias - Great blue heron
2. Butorides virescens - Green heron
3. Anas discors - Blue-winged teal
4. Ajaia ajaja - Roseate spoonbill
5. Casmerodius albus - Common egret
6. Avicennia germinans - Black mangrove
7. Eudocimus albus - White ibis
8. Salicornia bigelovii - Glasswort
9. Procyon lotor - Raccoon
10. Distichlis spicata - Saltgrass
11. Spartina alterniflora - Smooth cordgrass
12. Rallus longirostris - Clapper rail
13. Pagurus sp. - Hermit crab
14. Telmatodytes pulustris - Longbilled marsh wren
15. Croton punctatus - Beach tea
16. Sesuvium portulacastrum - Sea purslane
17. Batis maritima - Salt wort
18. Uca ~~pugnax~~ - Fiddler crab   Uca ~~[illegible]~~ virens ~~([illegible]~~). (Salmon & Atsaides, 1968).
19. Avicennia germinans - Black mangrove
20. Littorina irrorata - Periwinkle
21. Avicennia germinans - Black mangrove
22. Distichlis spicata - Saltgrass

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 bulrush, genus *Scirpus* (5, 12,20) as shown in Fig. 16. Also found here are the cordgrasses, *Spartina alterniflora* and *S. patens* (14), as well as cattails, genus *Typha* (11, 21), and green briars, *Smilax* sp. (10). In areas where there is a 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 (estimated at 20,000 lb. per acre, E. P. Odum, 1959) provide food and nesting areas for many water-fowl. Among these are the Canada goose, *Branta canadensis* (1); green heron, *Butorides virescens* (2); coot, *Fulica americana* (8); and wood stork, *Mycteria americana* (9). The crustaceans are also represented in the fresh water marsh, with crayfish, *Procambarus clarkii* (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 cottonmouth, *Agkistrodon piscivorus* (19); the opossum, *Didelphis marsupialis* (13); 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 inter-face, the fiddler crab, *Uca* ~~*pugnax*~~ virens (16), predominates along the banks, and the clams, *Mercenaria mercenaria* and *Tagelus divisus* (not shown), on the channel bottoms. Also found, but not shown, is the marsh periwinkle, *Littorina irrorata*, which feeds on the grasses.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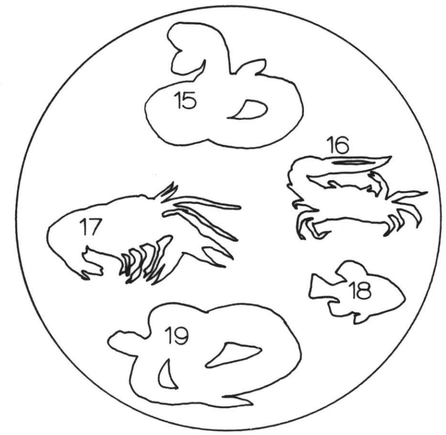
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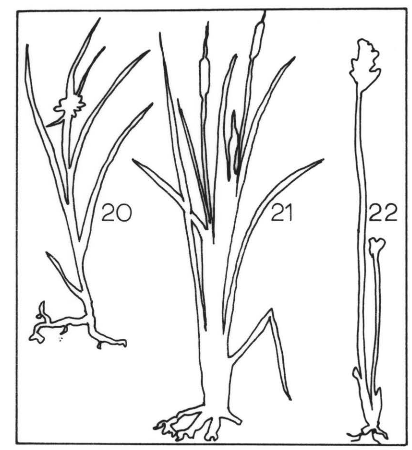
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Figure 16. Juncus (fresh water marsh)

JUNCUS (FRESH WATER MARSH)

1. Branta canadensis - Canadian geese
2. Butorides virescens - Green heron
3. Spartina alterniflora - Smooth cordgrass
4. Juncus sp. - Reed
5. Scirpus sp. - Bulrush
6. Rattus norvegicus - Norway rat
7. Procambarus burrow
8. Fulica americana - Coot
9. Mycteria americana - Wood stork
10. Smilax sp. - Greenbriars
11. Typha domingensis - Cattails
12. Scirpus sp. - Bulrush
13. Didelphis marsupialis - Opossum and young
14. Spartina patens - Marshhay cordgrass
15. Crotalus atrox - Western diamondback rattlesnake
16. Uca ~~pugnax~~ - Fiddler crab Uca virens ~~[illegible]~~ (1968). M. Salmon and ~~[illegible]~~ S.P. Atsaides. Proc. Biol. Soc. Wash. 81: 275-290.
17. Procambarus clarkii - Crayfish
18. Cyprinodon variegatus - Sheepshead minnow
19. Agkistrodon piscivorus - Cottonmouth snake
20. Scirpus sp. - Bulrush
21. Typha domingensis - Cattail
22. Sporobolus virginicus - Seashore dropseed

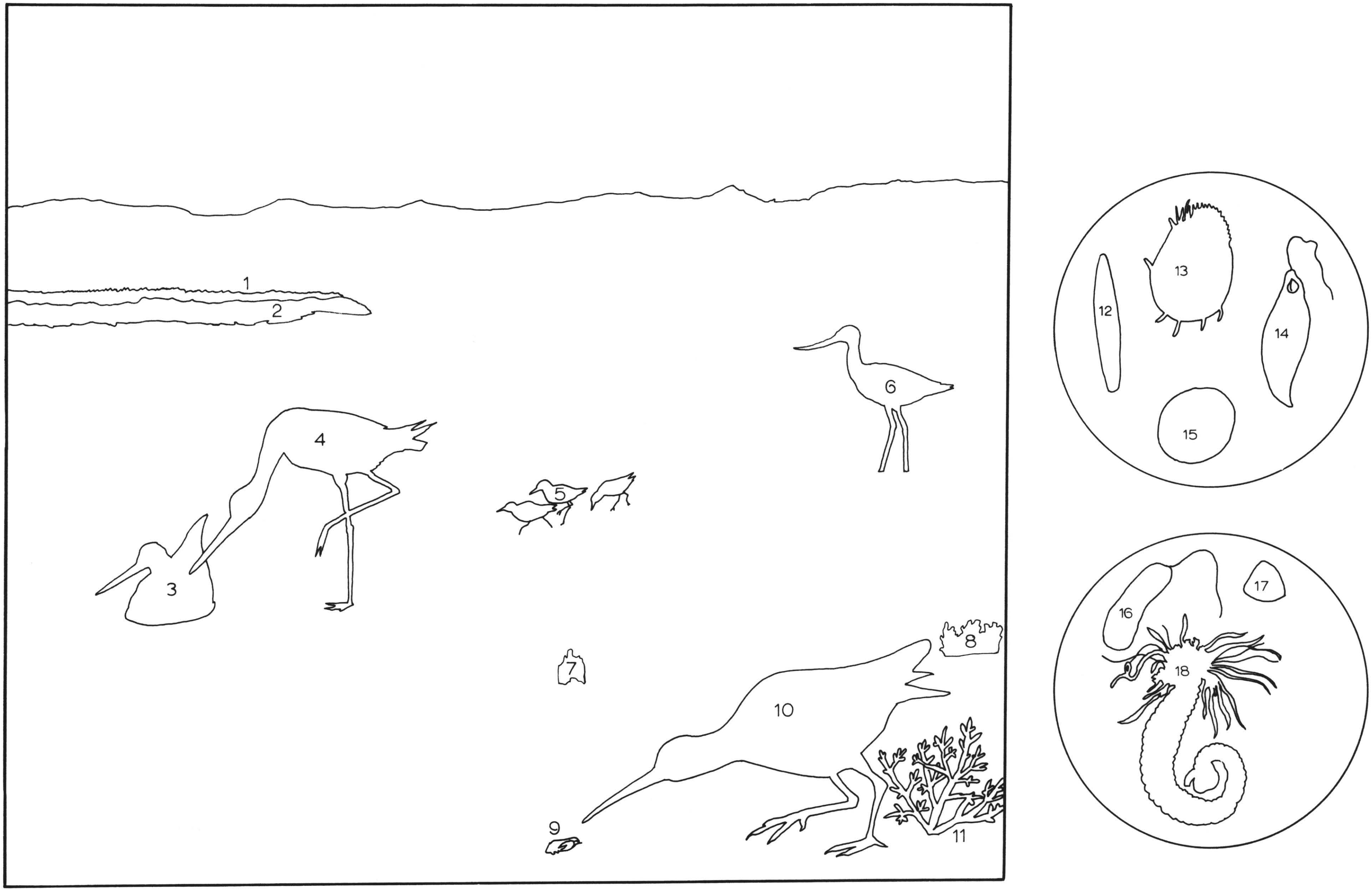
MUD FLAT

Mud flats are extensive regions in the highest backwaters of the estuarine system. They consist of mobile fine silt that is well 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 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. 17.

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), numerous protozoans, such as *Euplotes* (13), and *Euglena* sp. (14); dinoflagellates, nematodes, copepods, amphipods, ostracods, as well as anaerobic bacteria. Other infaunal organisms include the gem clam, *Gemma purpurea* (17), Terebellid worm (18) and the clam *Tagelus* sp. Organisms which may be found living on firmer bank areas are oysters, *Crassostrea virginica* (7) and fiddler crabs, *Uca* ~~*pugnax*~~ virens (9).

Many birds are common visitors. Those shown are the black-necked stilt, *Himantopus mexicanus* (3,4); western sandpiper, *Ereunetes mauri* (5), marbled godwit, *Limosa fedoa* (6); and the long-billed dowitcher, *Limnodromus scolopaceus* (10).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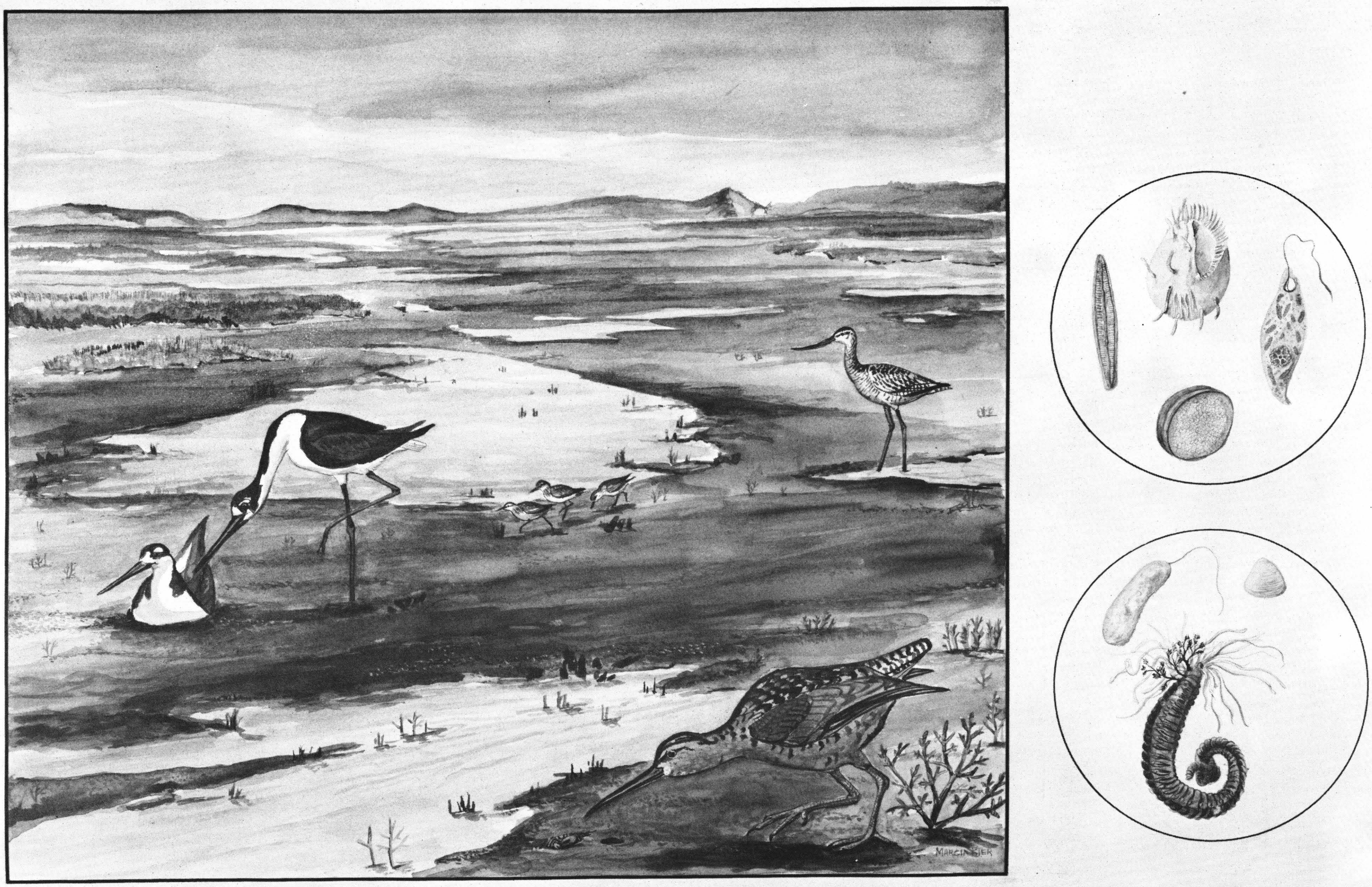

Figure 17. Mud Flat

MUD FLAT

1. *Distichlis spicata* - Saltgrass
2. *Salicornia* sp. - Glasswort
3. *Himantopus mexicanus* (female) - Black-necked stilt
4. *Himantopus mexicanus* (male) - Black-necked stilt
5. *Ereunetes mauri* - Western sandpiper
6. *Limosa fedoa* - Marbled godwit
7. *Crassostrea virginica* - Oyster
8. *Salicornia bigelovii* - Glasswort
9. *Uca* ~~*pugnax*~~ - Fiddler crab *Uca virens*
10. *Limnodromus scolopaceus* - Long-billed dowitcher
11. *Salicornia perennis* - Glasswort
12. *Navicula* sp. - Pennate diatom
13. *Euplotes* sp. - Protozoan
14. *Euglena* sp. - Green algae
15. *Coscinodiscus* sp. - Diatom
16. Aerobic bacterium
17. *Gemma purpurea* - Gem clam
18. Terebellid worm

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 saltgrass, Distichlis spicata (11); and glassworts, Salicornia bigelovii and S. perennis (8,12), as shown in Fig. 18. Also found on the banks are fiddler crabs, Uca ~~pugnax.~~ [redacted] panacea (3,7). 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 blue-green algal genus Chroococcus (20); and various sulfur bacteria such as Desulfovibrio (16) and Beggiatoa (21).

Common birds are the greater yellowlegs, Totanus melanoleucus (1); caspian tern, Hydroprogne caspia (2); sanderling, Crocethia alba (4); avocet, Recurvirostra americana (5); ruddy turnstone, Arenaria interpres (6); semipalmated plover, Charadrius semipalmatus (10); and the oyster-catcher, Haematopus palliatus (14).

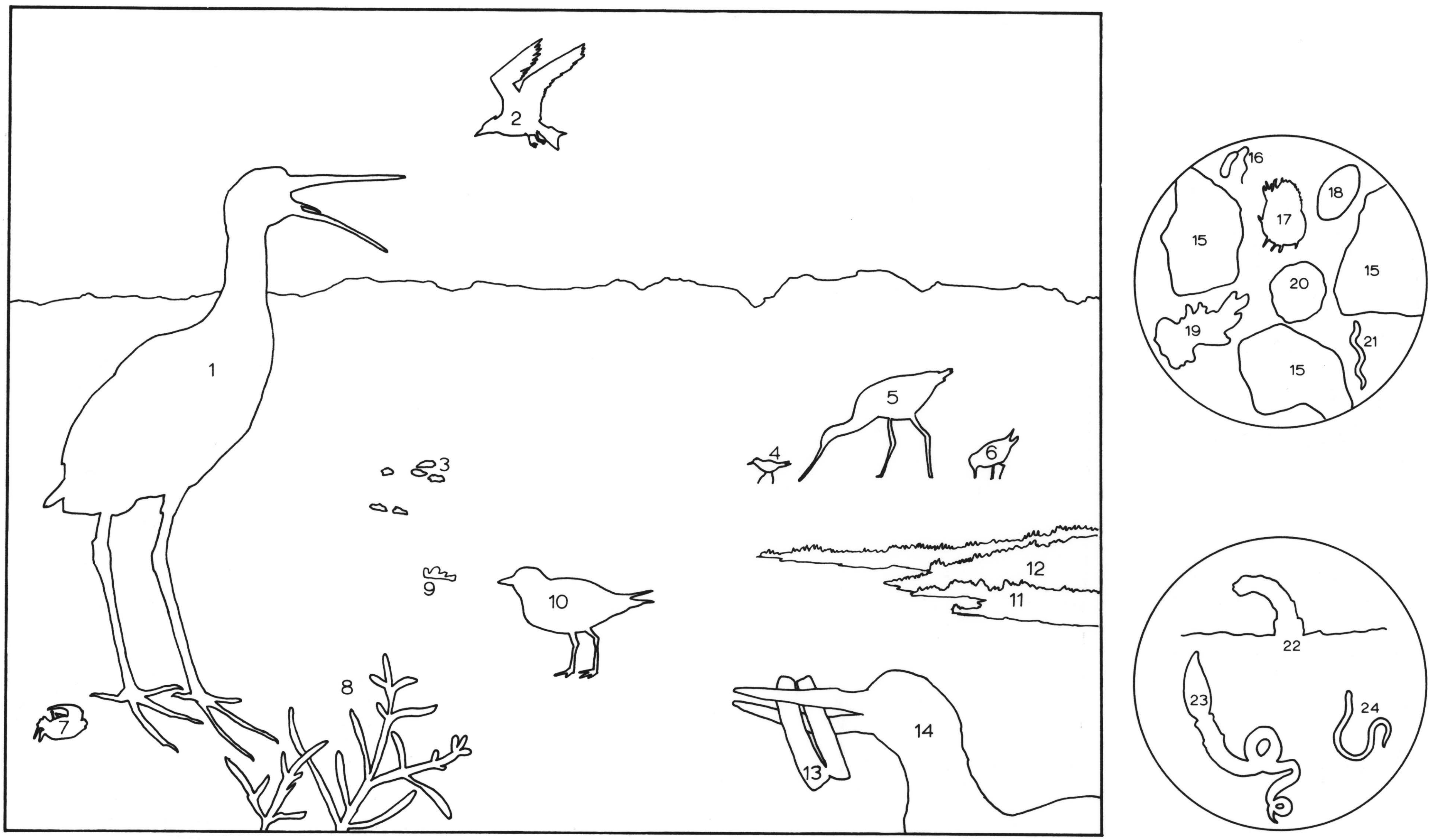
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Figure 18. Sand Flat

SAND FLAT

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

BLUE-GREEN ALGAL FLAT

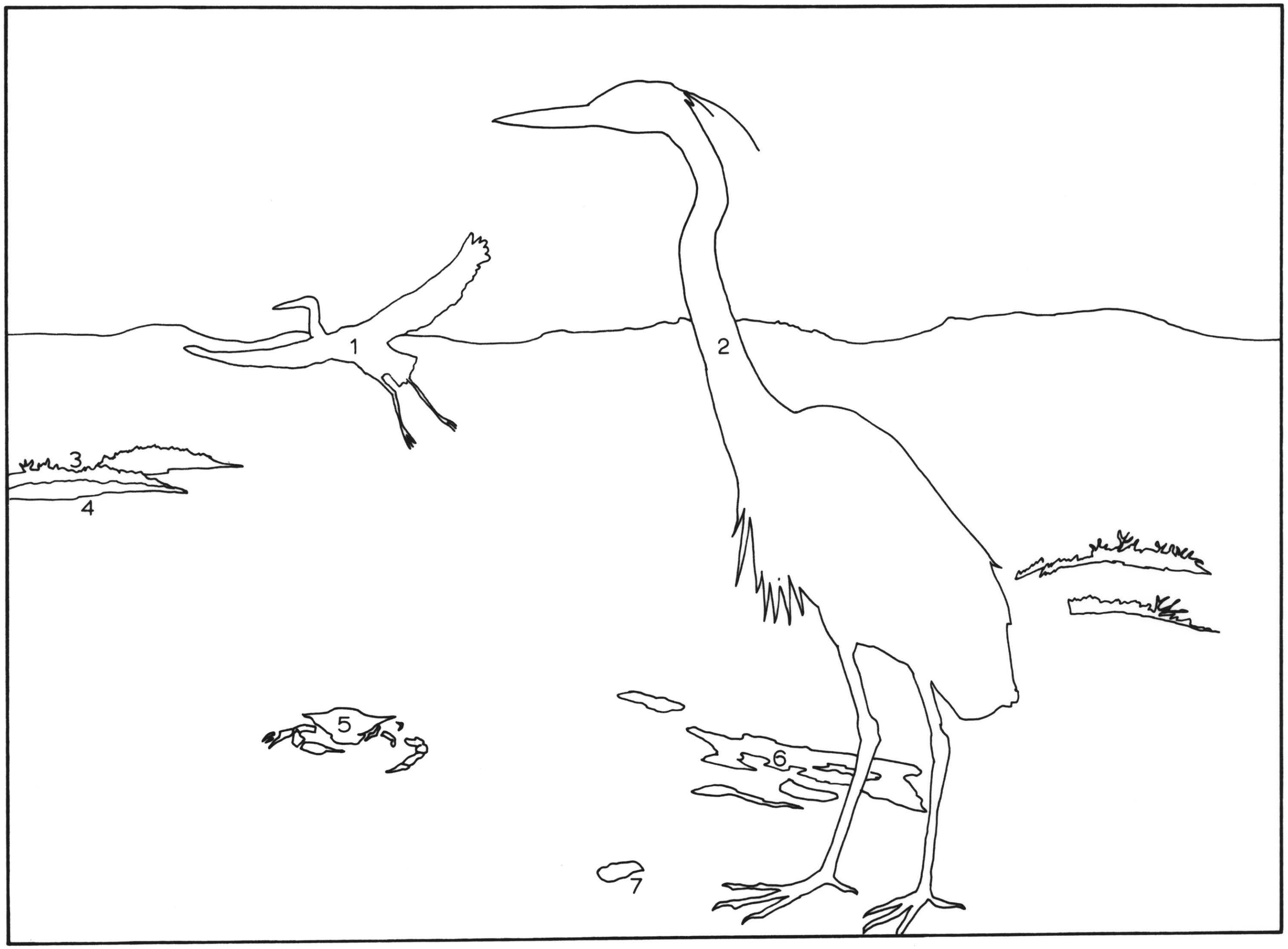
Blue-green algal flats (Fig. 19) are common along the floodplains adjacent to the estuaries and on marsh areas just above the tidal range where they are occasionally inundated with fresh or brackish water. The sediment is normally fine sand or silt on which the filamentous blue-greens infiltrate to form 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 algal mat to float on the water surface. At times of high tide these floating algal mats will wash into adjacent waters. The algal 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 algal surface. This results in incrustations of halite and nutrients. These nutrients act as fertilizer for the algal 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 algal growth. These areas are quite productive, extending into the sediment for several millimeters and actively stabilize the sediments. The algal mats contain a wide variety of microorganisms.

The major constituent of this mat is the blue-green alga *Lyngbya majuscula* (8). Also found are the blue-greens *Holopedia irregularis* (9), *Nodularia sphaerocarpa* (10) and *N. tenuis* (11), *Oscillatoria limosa* (12), the diatoms *Pleurosigma angulatum* (14), *Navicula punctigera* (15) and *N. diversistriata* (16), the green alga *Chlorococcum* (13), the euglenoids *Chlamydomonas snowiae* (17) and *Pyramimonas tetrarhynchus* (18). Bacterial components of the mat are Rhodospirillum fulvum (19), Rhodopseudomonas palustris (20), Rhodomicrobium vannielii (21) and 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 perennis (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, Egretta thula (1) and great blue heron, Ardea herodias (2).

Numerous nematods, diatoms and protozoans grow both in and below the blue-green layer. The anaerobic sediments are rich in various bacteria such as the desulfovibrio and pseudomonads.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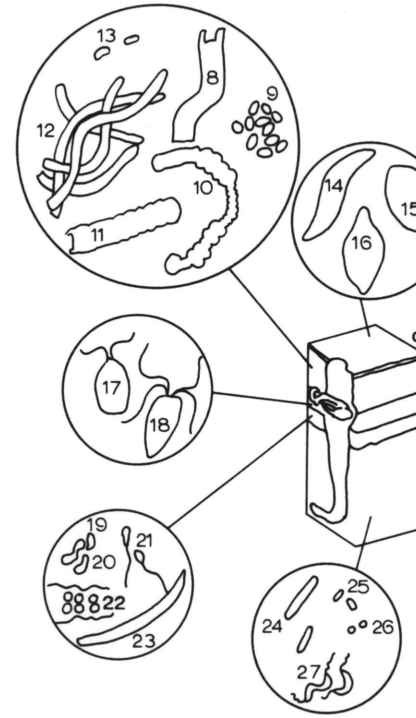
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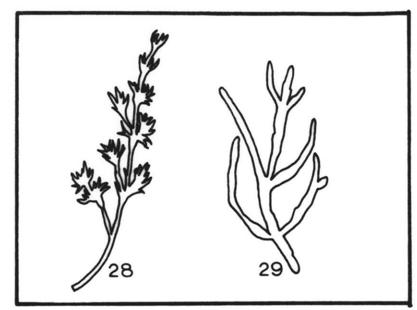
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Figure 19. Blue-Green Algal Flat

BLUE-GREEN ALGAL FLAT

1. Egretta thula - Snowy egret
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 majuscula - Blue-green alga
9. Holopedia irregularis - Blue-green alga
10. Nodularia sphaerocarpa - Blue-green alga
11. Nodularia tenuis - Blue-green alga
12. Oscillatoria limosa - Blue-green alga
13. Chlorococcum sp. - Green alga
14. Pleurosigma angulatum - Diatom
15. Navicula punctigera - Diatom
16. Navicula diversistriata - Diatom
17. Chlamydomonas snowiae - Euglenoid
18. Pyramimonas tetrarhynchus - Euglenoid
19. Rhodospirillum fulvum - Sulfur bacterium
20. Rhodopseudomonas palustris - Sulfur bacterium
21. Rhodomicrobium vannielii - Sulfur bacterium
22. Beggiatoa sp. - Sulfur bacterium
23. Thiocapsa sp. - Sulfur bacterium
24. Rod shaped
25. Short rods — Various bacteria
26. Coccoid
27. Spirilla
28. Distichlis spicata - Saltgrass
29. Salicornia perennis - Glasswort

HYPERSALINE

Where sea water flows into shallow lagoons in climates with more evaporation than runoff, salinities rise and briny conditions develop. 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 o/oo. Examples of this Biotope are Baffin Bay and the Laguna Madre. 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 o/oo difference 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 blue-green algae, diatoms and other alga. In the Laguna Madre the vast underwater beds of 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 beeding on bottom organic matter include mullet, Mugil; croaker, Micropogon; and shrimp, Penaeus. Detritivores feeding on suspended organic material include the barnacle, Balanus; blue crabs, Callinectes; and sea catfish, Galeichthys. Secondary consumers include trout, Cynoscion; croaker, Micropogon; redfish, Sciaenops; flounder, Paralichthys; pinfish, Lagodon; and sea catfish, Galeichthys. Tertiary consumers include flounder, Paralichthys; croaker, Micropogon; 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.

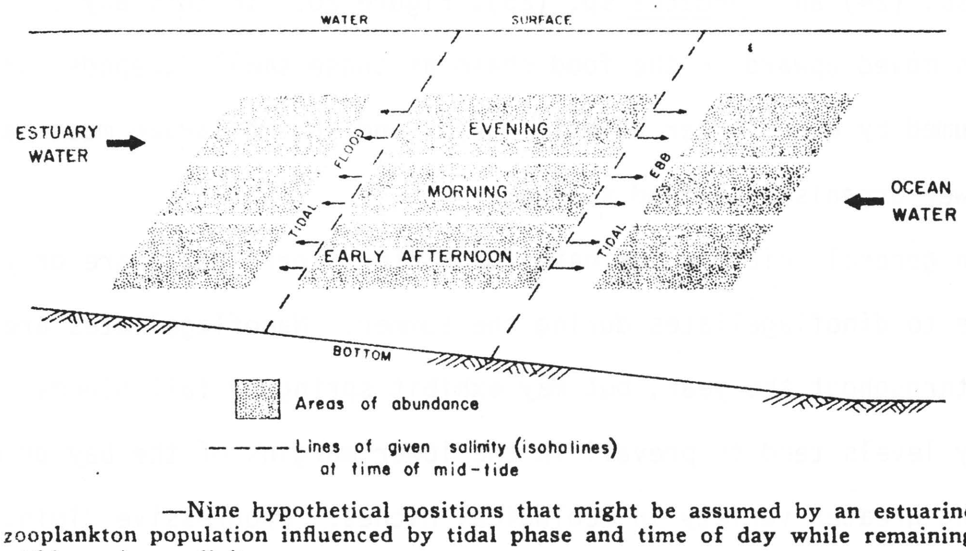
RIVER MOUTH

This is a low salinity area (from 0.5 to 8 $^{o}/oo$) 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 widgeion 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 periwinkle, Littoridina, is common in some localities. Crustaceans include Callinectes and Macrobrachium. The soft, muddy, organic-rich bottoms provide a habitat for abundant ostracods. Foraminifers are not abundant in this Biotope. Ostracoda 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 $^{o}/oo$. 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.

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 to travel within these water masses and are restricted from crossing any physical or chemical boundaries. Frolander (1964) shows nine hypothetical positions that might be assumed by an estuarine zooplankton population influenced by tidal phase and time of day while remaining in a given salinity range. These positions are illustrated in the following diagram.



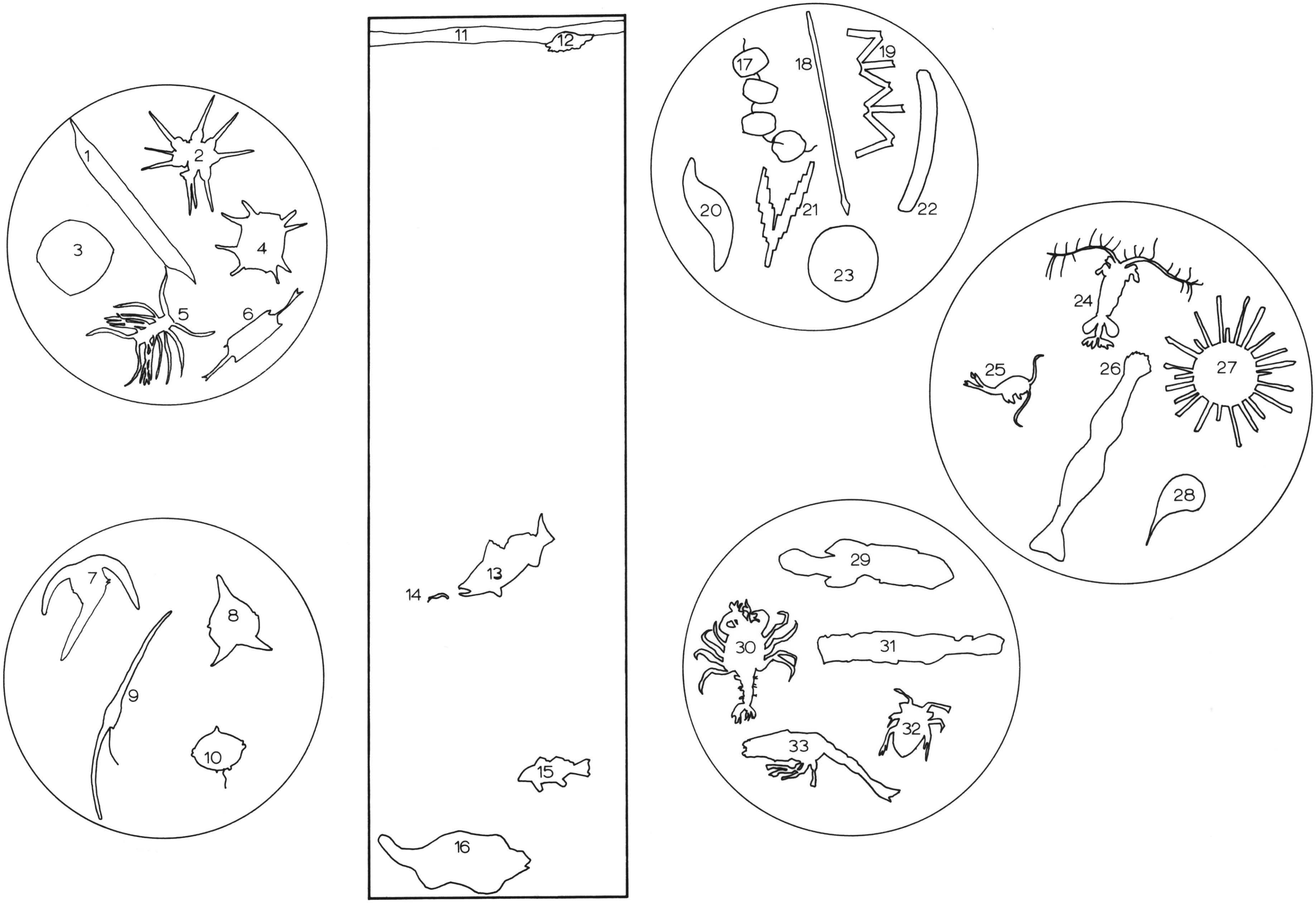
—Nine hypothetical positions that might be assumed by an estuarine zooplankton population influenced by tidal phase and time of day while remaining within a given salinity range.

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 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 (2), Coscinodiscus (3), Biddulphia (4), Thalassiosira (17), Thalassiothrix (18), Thalassionema (19), Gyrostigma (20), Nitzschia (21), Skeletonema (22), and Actinoptychus (23) and dinoflagellates of the genera Ditylum (6), Ceratium (7), and Peridinium (8), (Figure 20) 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, Calanus sp. (24) and Candacea sp. (25), Figure 20. In this way organic carbon is moved upward in the food chain as these small copepods (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 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 the bay indicates a reduced number of niches resulting from gross pollution or other unfavorable 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 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 aztecus (14); mullet, Mugil sp.; spot, Leiostomus xanthurus (15); croaker, Micropogon sp.; trout, Cynoscion arenarius (13); menhaden, Brevoortia sp.; flounder, Paralichthys sp. and Ancylopsetta quadrocellatus (16); and redfish, Sciaenops ocellata are found seasonally in this Biotope feeding on zooplankton such as Paracalanus and "grazing" on the phytoplankton such as the diatom Thalassionema (19) and dinoflagellates such as Skeletonema (22) and Nitzschia (21).



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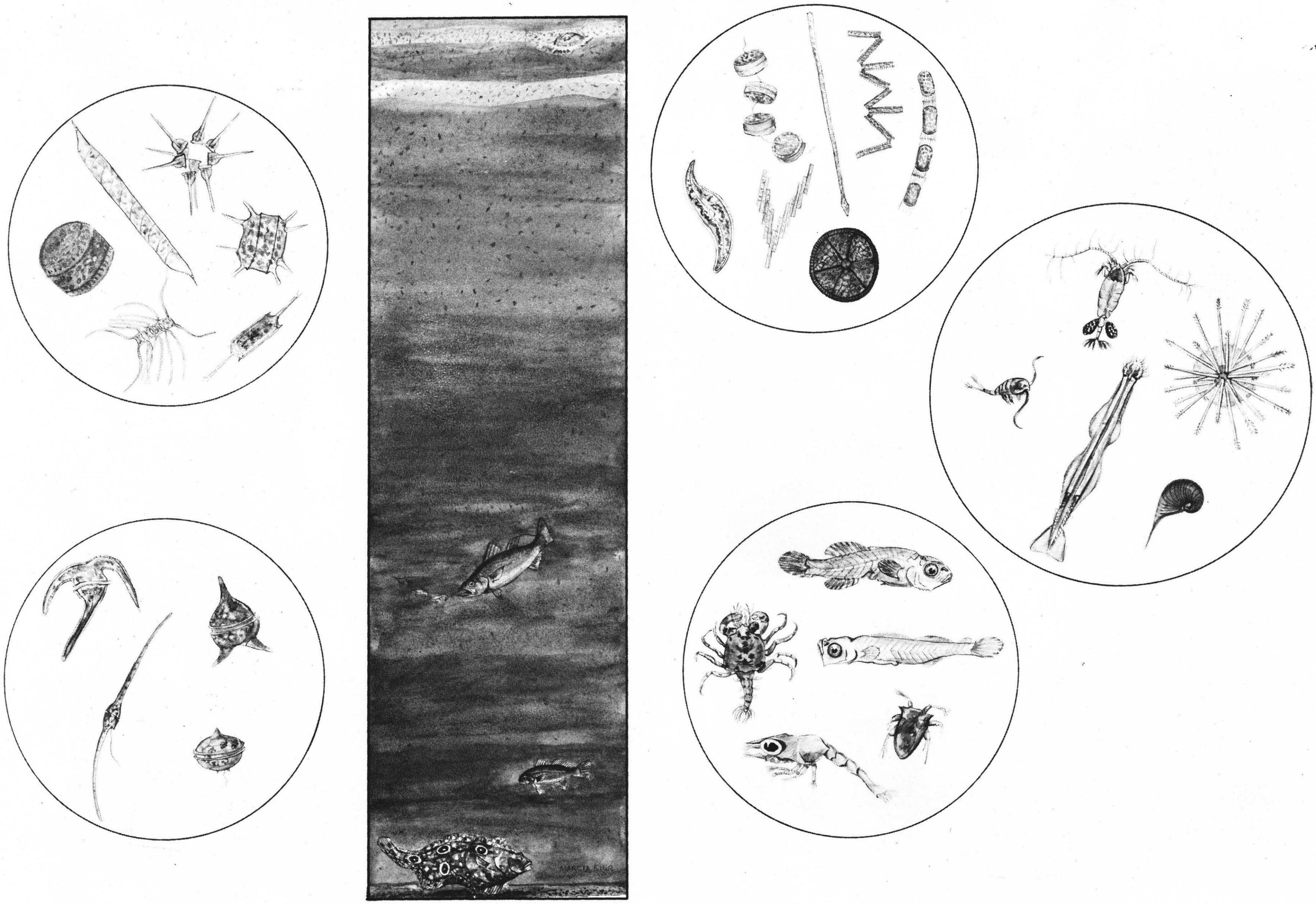


Figure 20. Bay Planktonic

BAY PLANKTONIC

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

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 by man. 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 photosythetic 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 in small numbers 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.

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 Kennedy 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, *Colaptes cafer*; woodpeckers, *Asyndesmus lewis*; red-tailed hawks, *Buteo jamaicensis*; crows of the genus *Coruus*; grosbeaks, and blackcapped chickadees are prevalent. Other frequent avian inhabitants of praire waters and adjacent vegetated borders are mallard ducks, *Anas platyrhynchos*; kingfishers, genus *Ceryle*; great blue herons, *Ardea herodias*; marsh-wrens, and several species of blackbirds. The long-billed curlew, *Numenius americanus*; killdeer, *Charadruis* vociferus; and nighthawk, Chordeiles minor; meadowlark, Sturnella neglecta; several species of owls, including burrowing owls, Speotyto cunicularia hypugaea, and barn owls, Tyto alba pratincola; and eagles of the generus 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 grasshoper, Melanoplus bivittatus; clear-winged grasshopper, M. femurrubrum; the lubber grasshopper, Brachystola magna; and the spotted bird grasshopper, Schistocerca lineata.

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 tree crickets of the subfamily Oecanthinae. 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 butterfly, Papilio cresphontes. Skippers, the dull-colored 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 pollenators. One common variety is Bombus ternarius.

Reptiles found in the prairie Biotope include the cottonmouth, Agkistrodon piscivorus leucostoma; bullsnake, Pituophis melanoleucus sayi; western diamondback rattlesnake, Crotalus atrox; and the Texas blind snake, Leptotyphlops dulcis dulcis. Other reptiles include the collared lizard, Crotaphytus collaris, and the common snapping turtle, Chelydra serpentina 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 honey mesquite, Prosopis glandulosa; and a variety of oaks, Quercus spp. Grasses, the dominant plants, include little bluestem, Andropogon scoparius; big bluestem, A. gerardi; Indiangrass, Sorghastrum spp.; Gulf muhly grass, Muhlenbergia capillaris var. filipes; eastern gamagrass, Tripsacum dactyloides; broomsedge bluestem, A. virginicus; smutgrass, Sporobolus poiretii; and tumblegrass, Schendonnardus 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 Wang.. 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 Wang.; 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 lanuginosa (Michx.) Pers.; and Texas hercules-club prickly ash, Zanthoxylum clava-herculis L..

Along the lower margin of the upland forest, where this Biotope interfaces with the river floodplain Biotope, the loblolly pine, *Pinus taeda* L., predominates.

Representative animals include the Texas white tail deer, *Odocoileus virginianus texanus*; bobcat, *Lynx rufus*; bluejay, *Cyanocitta cristata*; quail, turkey, squirrels, and grey fox. The western coachwhip, *Masticophis flagellum 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).

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 normally found in this Biotope include the following, listed in tabular form by scientific and common names.

Trees --

Ulmus crassifolia Nutt. - Cedar elm

Ulmus americana L. - American elm

Celtis occidentalis L. - Common hackberry

Celtis laevigata Willd. - Sugar hackberry

Morus rubra L. - Red mulberry

Diospyros virginiana L. - Common persimmon (Fig. 21, No. 9)

Fraxinus pennsylvanica landeolata Sarg. - Green ash

Carya illinoensis (Wang.) K. Koch - Pecan

Carya cordiformis (Wang.) K. Koch - Bitternut hickory

Quercus falcata Michx. - Southern red oak

Quercus lyrata Walt. - Overcup oak

Planera aquatica (Walt.) Gmel. - Water elm

Other trees found in this area are the following, by scientific and common name. Numbers indicate position on Fig. 21.

Quercus stellata - Post oak (1)

Quercus nigra L. - Water oak (2,18)

Ulmus alata Michx. - Winged elm (3)

Salix nigra - Black willow (1)

Salix caroliniana Michx. - Coastal plain willow (12,20)

The predominant shrubs are shown here by scientific name and common name.

Rubus sp. - Dewberry

Crataegus sp. - Hawthorne

Ampelopsis arborea (L.) Koehne - Pepper Vine

Vitis cinerea Engelm. - Sweet winter grape

Ilex decidua Walt. - Possum-haw holly

Symphoricarpos sp. - Snowberry

Bignonia radicans L. - Common trumpet-creeper

Rhus sp. - Sumac

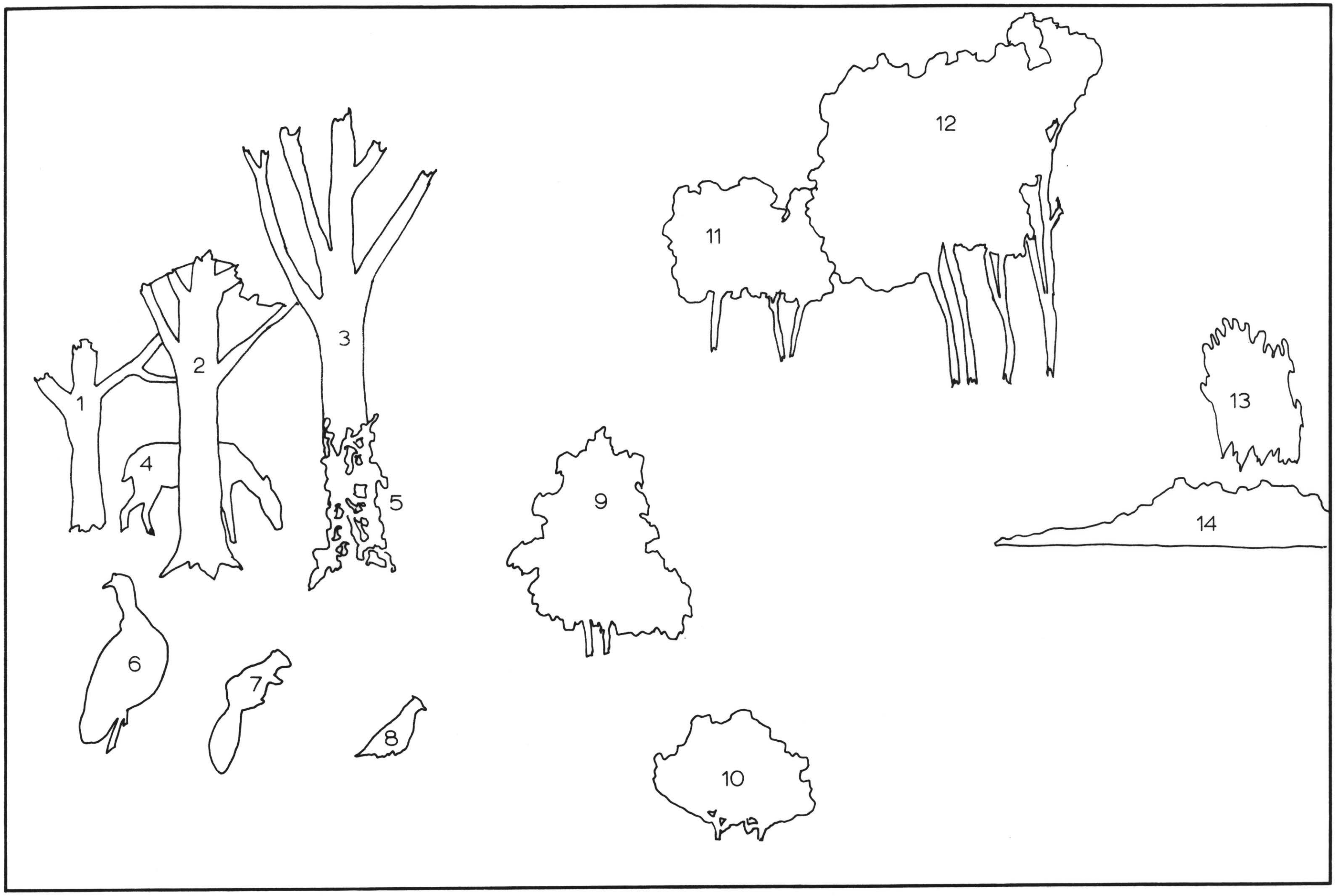
Zanthoxylum clava-herculis L. - Texas hercules-club prickly ash

Also found are briars, Smilax sp. (5) and yaupon, Ilex vomitoria Ait. (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. 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 grasshopper, *Schistocerca americana* (15); nine-spotted lady bug, *Coccinella novemnotata* (17); bluebottle fly, *Calliphora* sp. (22) and mosquitos of genus *Culex* (23). Occasional grazer 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 clarkii* (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 marshhay cordgrass, *Spartina patens*, and black rush, *Juncus roemerianus*.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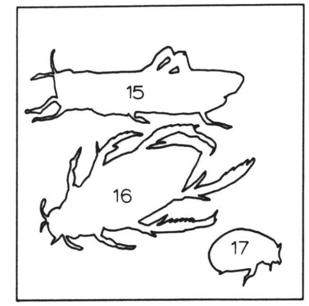
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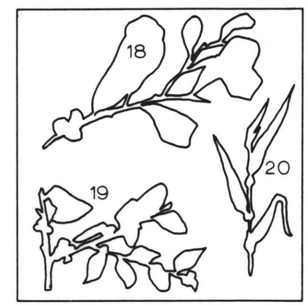
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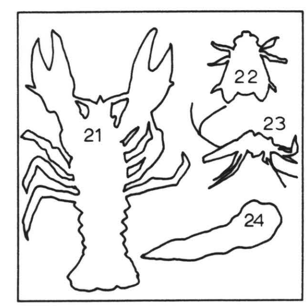
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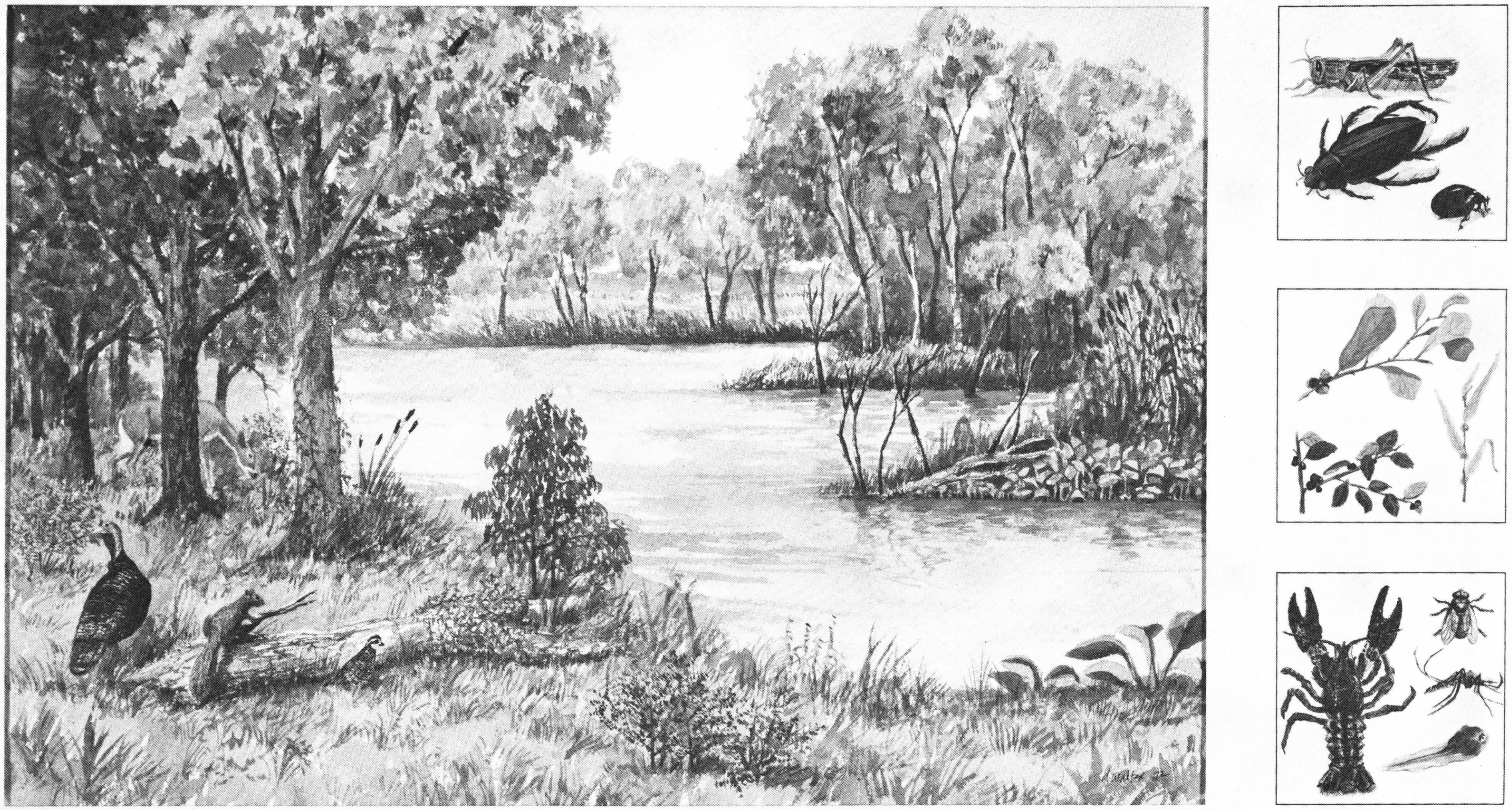

Figure 21. River Floodplain Forest

RIVER FLOODPLAIN FOREST

1. Quercus stellata - Post oak
2. Quercus nigra L. - Water oak
3. Ulmus alata Michx. - 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 L. - Persimmon
10. Ilex vomitoria Ait. - Yaupon
11. Salix nigra - Black willow
12. Salix caroliniana Michx. - Coastal plain willow
13. Typha domingensis - Cattails
14. Eichornia crassipes - Water hyacinth
15. Schistocerca americana - grasshopper
16. Hydrophilus triangularis - Water scavenger
17. Coccinella novemnotata - Spotted lady bug
18. Quercus nigra L.- Water oak
19. Ilex vomitoria Ait. - Yaupon
20. Salix caroliniana Michx. - Coastal plain willow
21. Procambarus clarkii - Crayfish
22. Calliphora sp. - Bluebottle fly
23. Culex sp. - Common mosquito
24. Rana sp. - Tadpole

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 (Westlake, 1963) and, with plankton and land runoff of organic matter and nutrients, accounts for large fish and shellfish population. 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 in Table 2. Such activities are components of a variety of economically important sectors such as agriculture (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 be devised. Returning to Table 2, we have attempted to relate seventeen activities in the coastal zone to the eighteen 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.

Table 2

THE IMPACT OF MAN'S ACTIVITIES ON THE COASTAL BIOTOPES

COASTAL ZONE ACTIVITIES \ BIOTOPES	1. *Open Beach & Shelf*	2. *Dune & Barrier Flat*	3. *Spoil Bank*	4. *Jetty & Bulkhead*	5. *Oyster Reef*	6. *Thalassia (grass flat)*	7. *Spartina (salt water marsh)*	8. *Juncus (fresh water marsh)*	9. *Mud Flat*	10. *Sand Flat*	11. *Blue-Green Algal Flat*	12. *Hypersaline*	13. *River Mouth*	14. *Bay Planktonic*	15. *Channel*	16. *Prairie Grassland*	17. *Upland Deciduous Forest*	18. *River Floodplain Forest*
1. *Liquid Waste Disposal*	4	3	3	4	5	5	5	5	4	4	4	5	5	5	5	0	1	3
2. *Gaseous Waste Disposal*	1	0	0	3	1	3	0	5	0	0	0	4	5	4	4	0	0	0
3. *Solid Waste Disposal*	0	4	3	0	4	2	5	5	2	2	1	4	5	2	0	4	5	5
4. *Offshore Construction*	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. *Coastal Construction*	2	5	0	0	1	1	4	4	3	3	2	1	0	2	0	0	0	2
6. *Inland Construction*	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	4	4
7. *Land Canals*	1	0	0	0	4	0	4	0	3	3	0	0	0	0	0	4	0	5
8. *Offshore Channels*	1	0	0	3	5	5	4	4	3	4	2	2	3	4	4	0	0	0
9. *Dredging & Spoil Disposal*	4	0	5	5	5	5	5	5	5	4	3	5	4	5	1	0	0	1
10. *Excavation*	0	5	0	0	5	3	4	3	5	2	2	1	1	0	0	2	1	2
11. *Drainage*	0	0	0	0	0	0	4	5	2	1	2	2	3	0	0	3	0	1
12. *Filling*	0	0	0	0	4	4	5	5	3	3	3	4	3	0	0	1	1	1
13. *Draining*	0	0	0	0	4	0	5	5	4	1	2	2	3	0	0	0	0	0
14. *Well Development*	2	3	4	1	4	1	1	1	1	1	1	3	1	1	1	3	1	1
15. *Devegetation*	0	5	4	0	0	2	5	5	1	1	1	0	0	0	0	5	5	5
16. *Traversing with Vehicles*	0	5	4	0	0	0	1	2	0	0	0	0	0	0	0	4	1	0
17. *Use of Fertilizers & Biocides*	0	5	4	2	5	5	5	5	0	1	3	4	4	5	5	4	4	4

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, and 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 dysfunction rarely appears in a single Biotope because of interdependence of the Biotopes. A flood-borne slug of fresh water into the river estuary (a natural dysfunction) or excessive impoundment during seasons of low rainfall (a manmade dysfunction) 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 behaviour 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 appraoches need to be united. Odum _et al_. (1969) found in their survey that documents from the two backgrounds 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 in 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 man draws 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; 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 so 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; Herman *et al.*, 1966; 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 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 (Odum and Steed, 1969; Dorris *et al.*, 1961, 1963). In general the seventeen different 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 man began introduing 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; and 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. Systemic metabolic stress on various indicator organisms, *e.g.* microorganisms, invertebrates and vetebrates, determined by toxicity bio-assay could provide valuable data establishing threshold limits for these organisms. Long term quantitative loading limits for different coastal eco-systems 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 man 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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