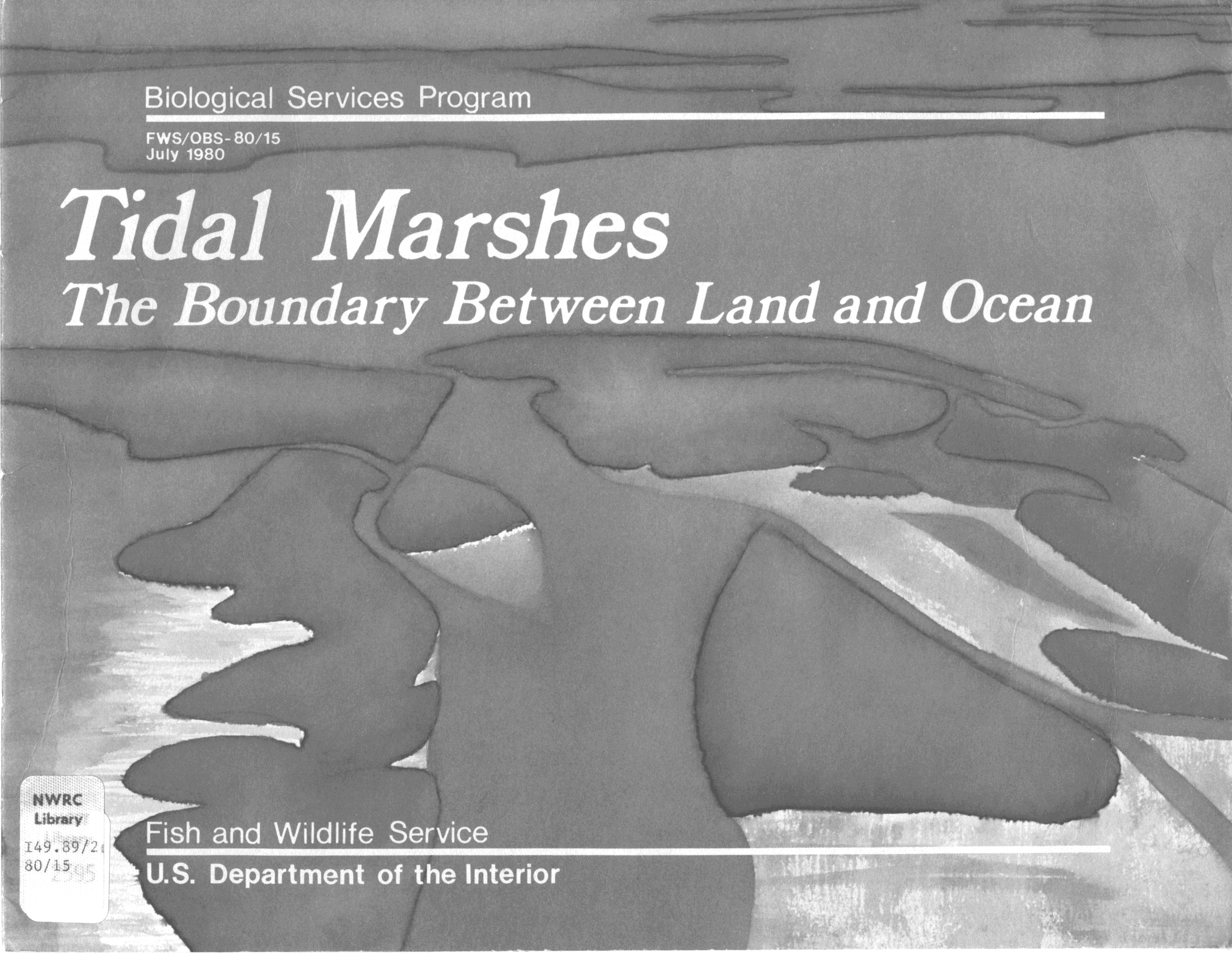


Biological Services Program

FWS/OBS-80/15
July 1980

Tidal Marshes
The Boundary Between Land and Ocean

Fish and Wildlife Service

U.S. Department of the Interior

FWS/OBS-80/15
JULY 1980

The Biological Services Program was established within the U.S. Fish and Wildlife Service to supply scientific information and methodologies on key environmental issues that impact fish and wildlife resources and their supporting ecosystems. The mission of the program is as follows:

- To strengthen the Fish and Wildlife Service in its role as a primary source of information on national fish and wildlife resources, particularly in respect to environmental impact assessment.
- To gather, analyze, and present information that will aid decisionmakers in the identification and resolution of problems associated with major changes in land and water use.
- To provide better ecological information and evaluation for Department of the Interior development programs, such as those relating to energy development.

Information developed by the Biological Service Program is intended for use in the planning and decisionmaking process to prevent or minimize the impact of development on fish and wildlife. Research activities and technical assistance services are based on an analysis of the issues,a determination of the decisionmakers involved and their information needs, and an evaluation of the state of the art to identify information gaps and to determine priorities. This is a strategy that will ensure that the products produced and disseminated are timely and useful.

Projects have been initiated in the following areas: coal extraction and conversion; power plants; geothermal, mineral and oil shale development; water resource analysis, including stream alterations and western water allocation; coastal ecosystems and Outer Continental Shelf development; and systems inventory, including National Wetland Inventory, habitat classification and analysis, and information transfer.

The Biological Services Program consists of the Office of Biological Services in Washington, D.C., which is responsible for overall planning and management; National Teams, which provide the Program's central scientific and technical expertise and arrange for contracting biological services studies with states, universities, consulting firms, and others; Regional Staff, who provide a link to problems at the operating level; and staff at certain Fish and Wildlife Service research facilities, who conduct inhouse research studies.

Tidal Marshes–The Boundary Between Land and Ocean

By James Gosselink
Center for Wetland Resources
Louisiana State University
Baton Rouge, Louisiana 70803

Illustrations by:
Bobbie Young
Diane Baker
Center for Wetland Resources
Louisiana State University

Project Officer:
Elaine W. Bunce
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service

Published by:
U.S. Fish and Wildlife Service
Biological Services Program

Questions or requests for this publication should be addressed to:
Information Transfer Specialist
National Coastal Ecosystems Team
U.S. Fish and Wildlife Service
NASA-Slidell Computer Complex
1010 Gause Blvd.
Slidell, Louisiana 70458

DEPARTMENT OF THE INTERIOR
U.S. FISH AND WILDLIFE SERVICE

Introduction

Tidal marshes of the United States cover about 13,000 square miles, approximately the combined area of Connecticut and Massachusetts. From a global perspective, marshes form a narrow fringe of intertidal flats along ocean coasts. They are vegetated by a few hardy species, mostly grasses, that have been able to adapt to the unusual stresses of tidal flooding and salt water.[1] Tidal marshes provide feeding and nursery grounds for many commercially important fin- and shellfish. Sport fishermen, as well as hunters, are attracted to these areas by the plentiful supply of fish, waterfowl, and furbearers. The value of tidal marshes has been recognized by the passage of Presidential Executive Order (E.O. 11990) in 1977, prompting State and Federal agencies to minimize impacts or alterations in wetlands. The purpose of this brochure is to provide an overview of the ecology of tidal marshes along the Gulf coast of the United States, factors affecting them, and their value.

Productivity of tidal marshes is comparable to, or exceeds, that of our most fertile agricultural land (as much as 5 tons per acre annually). This high productivity occurs because tidal marshes are the boundary or "interface" between the ocean and the adjacent land. Interfaces in general are sites of unusual activity and tidal marshes are no exception. They receive fresh water, sediment, and nutrients from the land and are also exposed to salty oceanic waters that add additional nutrients. As a result, grasses grow tall along the boundary between tidal streams and marshes, becoming shorter and sparser as one moves inland. The abundance of food and shelter along this marsh edge results in a concentration of animals, from tiny invertebrates to game fish and fish-eating birds. (See center plate) The stems of individual grass plants, bathed daily by salty water, are coated with a dense layer of microscopic animals, one-celled algae, and bacteria that provide food for small animals. Thus, at all levels the interactions between land and flooding water contribute to the high productivity and value of salt marshes.

Human Impact

In the United States, coastal marshes have been disappearing at a rate of about one-half percent per year. One million acres of coastal marsh have been lost since 1954, as documented by high altitude aerial photography of the coast.[2] By the year 2000, if the present rate of marsh loss continues, an additional one million acres will have disappeared. Public consciousness, combined with legislation at the State and National levels, has begun to reduce the rate of marsh loss from urban, agricultural and industrial development. But other more subtle activities that still occur in coastal wetlands and in areas upstream may, in the long run, produce changes just as important.

The relationship between these activities and wetland alteration is often unexpected. For example, continual sediment deposition is necessary to maintain tidal marshes. Flood control levees on the Mississippi River eliminate most of the sediment flow into adjacent marshes, resulting in a net wetland loss of about 10,000 acres per year. Blockage of normal sediment supplies to the coast by the Toledo Bend Dam on the Sabine River (bordering Louisiana and Texas) has accelerated marsh loss and changed the seasonal freshwater flow enough to reduce shrimp migration into the estuary. Oil-well access channels and pipeline canals, criss-crossing the deep draft navigation waterway in the Calcasieu basin of Louisiana, have linked the Gulf of Mexico to freshwater marshes.

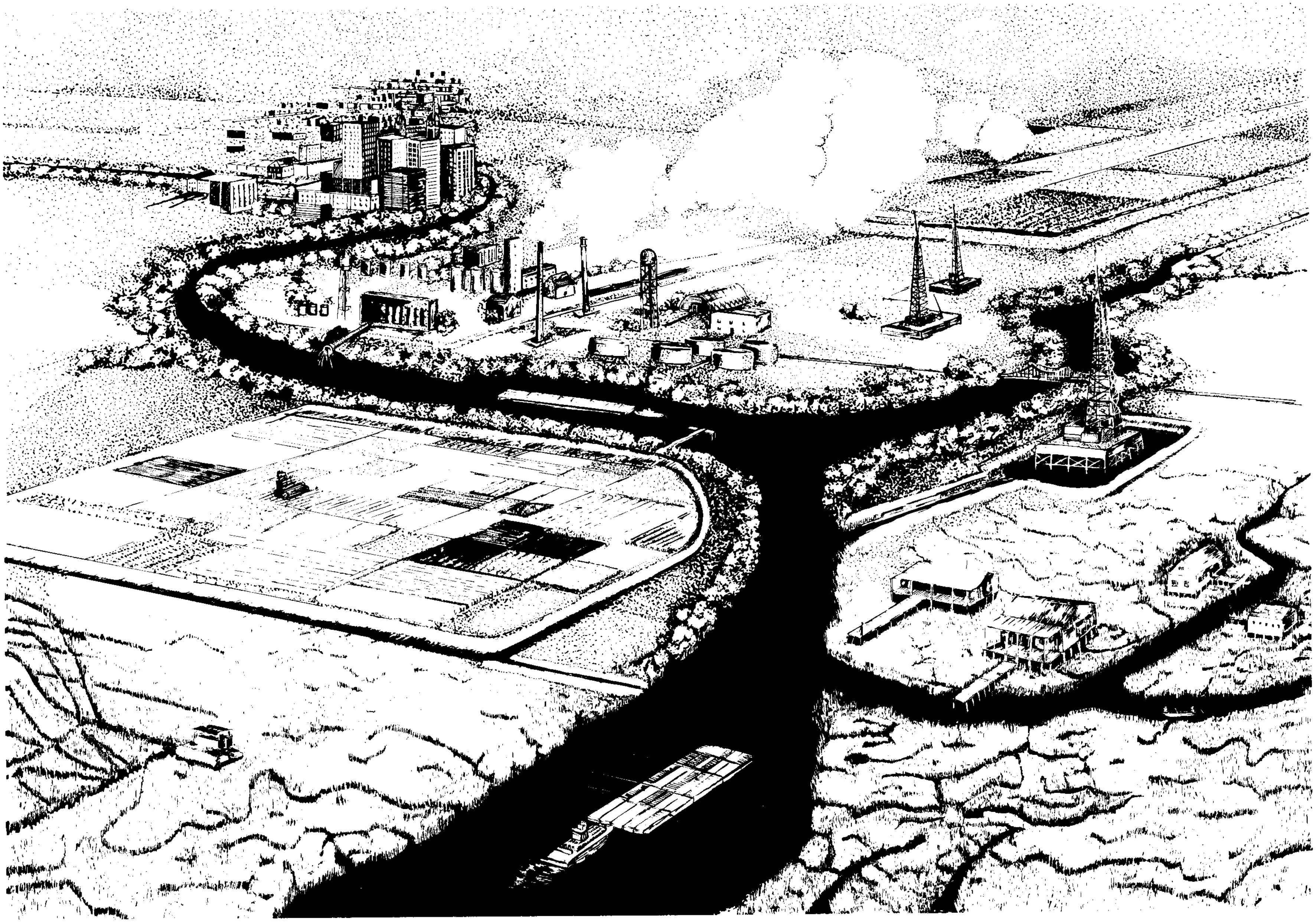


Figure 1. Two-thirds of the human population live on one-third of the world's land area adjacent to ocean coasts. Wetlands are drained for agriculture, housing, and industry. Man alters flooding patterns by constructing road embankments, canals with elevated spoil banks, and levees along streams. Ecological relationships are altered when man pollutes estuarine streams and lakes with sewage, fertilizers, and pesticides.

Salt water has moved inland, killing vegetation whose roots prevent soil erosion. Consequently, wetland vegetation has changed and erosion rates have increased. Toxins and nutrients in wastewater from urban and industrial sources have drained into the upland end of these canal complexes. Instead of filtering across wetlands, they now enter directly into coastal lakes, polluting the water and, in extreme cases, causing fish kills.[3]

These impacts have a common origin. The development was undertaken for some worthwhile cause unrelated to wetlands. Individually most were small projects compared to the larger unforeseen consequences on the tidal marshes. Man's activities redirect the enormous powers of nature, as a valve switches a flow of water. A chain of related events often follows. The examples are many. A small dredged channel becomes a major short cut for water flow, with the result that natural meandering channels are abandoned and filled with silt. Dredged materials deposited along canals block water flow to thousands of acres of wetlands, which can no longer function as nursery grounds. Pesticides and herbicides, carried in nearly undetectable concentrations from farm lands in runoff water, are concentrated by birds such as brown pelicans, peregrine falcons, bald eagles, and ospreys, causing sterility or fragile egg shells which break during incubation.

The tidal marsh is threatened by the concentrated development of human society along our coasts (Figure 1). Its future existence depends heavily on widespread understanding of the value to man of this natural ecosystem, and on a broader appreciation of the strong ties between the marsh system and its neighbors, the uplands and the ocean.

Origins of Tidal Marshes

From a geologic perspective, marshes are short-lived features of the coastal landscape. Compared to rocky headlands, such as those found on the north Atlantic and the Pacific coasts, which may be millions of years old, most of the tidal marshes of the United States have a life span measured in thousands of years.

The energy of ocean currents and storms moves marine sediments--sands, muds, and clays--along the coast where they are deposited in shallow water. Gradually, the bottom is elevated, extending the intertidal zone and building sandy barrier islands which parallel the coast to enclose shallow bays. Marsh grasses gradually colonize the fringing mudflats, stabilizing the surface, spreading slowly outward into the bay, and fixing the course of the tidal streams that meander through them.[4] These building processes are typical of marshes of the south Atlantic coast of the U.S. and of the eastern and western Gulf of Mexico.

In contrast, the other tidal marsh systems of the United States are built by rivers carrying sediments into shallow coastal waters. The Mississippi River delta is one of the best examples of this kind of marsh development. This river system has built 40% of our Nation's coastal wetlands.[5] As the Mississippi River flows into the Gulf of Mexico, its waters spread out, currents slow, and much of the sediment load is deposited. The sediments build up until they reach the water surface, at the same time building out into the Gulf in a fan-shaped delta. The periodically exposed mud flats are slowly colonized by freshwater marsh plants because river water keeps the salinity low. The river continues to extend its course into the Gulf until it breaks through its natural levee upstream and finds a shorter route to the sea. As with any shortcut, this breach soon becomes the preferred channel and, over the years, the path of the old river is abandoned. The mouth of the new channel becomes the site of a new delta. As river flow decreases in the old channel, the old marsh enters a destructional phase; salt water invades, salinity levels increase, and salt-tolerant plant species replace the freshwater plants that once occupied the area (Figure 2).

At any time, the elevation of the marsh surface is a balance between land building upward from sediment deposition, and land subsiding from consolidation of marsh sediments and from sinking of the land mass under its own weight. In the initial growth phase deposition predominates. After the river shifts its course, fewer sediments enter the marsh and land subsidence exceeds sediment deposition. Along the Gulf coast, subsidence rates are as much as 1 centimeter per year, and in many areas sediment deposition is much less. As marsh elevation declines, the grasses die and the marsh reverts to a shallow saline lake or bay. Historically, this cycle takes about one thousand years.[6] Since man has occupied the coastal zone, however, the cycle has accelerated. Man-made levees prevent spring floods from carrying silt into the coastal marshes. As a result, nearly all of the marshes built by the Mississippi River along the central coast of the Gulf of Mexico are in a destructional stage.

Plans to divert river water into Louisiana's coastal marshes hold potential for slowing the rate of wetland loss, but the newly forming delta of the Atchafalaya River is the only site of significant wetland growth along the northern Gulf coast.

Marsh Ecosystem

The physical characteristics of a tidal marsh are determined by sediments carried in and deposited by rivers or wind-driven coastal waters, rainfall and the timing of the spring thaw five hundred miles upstream, and severe tropical storms originating thousands of miles away in the Atlantic Ocean. Many outside forces also determine the biological characteristics of a marsh. Considering the variation in these outside forces, it is surprising that there is great similarity in the marsh species found all the way from the Gulf coast to the northern border of the United States. The dominant plants in all of these marshes are two grasses. Saltmarsh cordgrass (Spartina alterniflora) is found in true tidal marshes. In marshes of slightly higher elevation Spartina patens, called salt meadow hay or salt meadow cordgrass, occurs. Also widespread are salt grass (Distichlis spicata) and black rush (Juncus roemerianus). Saltmarsh plants have adapted to two stresses foreign to most land plants--a saturated root zone depleted of oxygen, and a high salt concentration that literally dries out the tissues of most plants. Perhaps the inability of other plants to adapt to these stresses has left the marsh zone free to these salt-

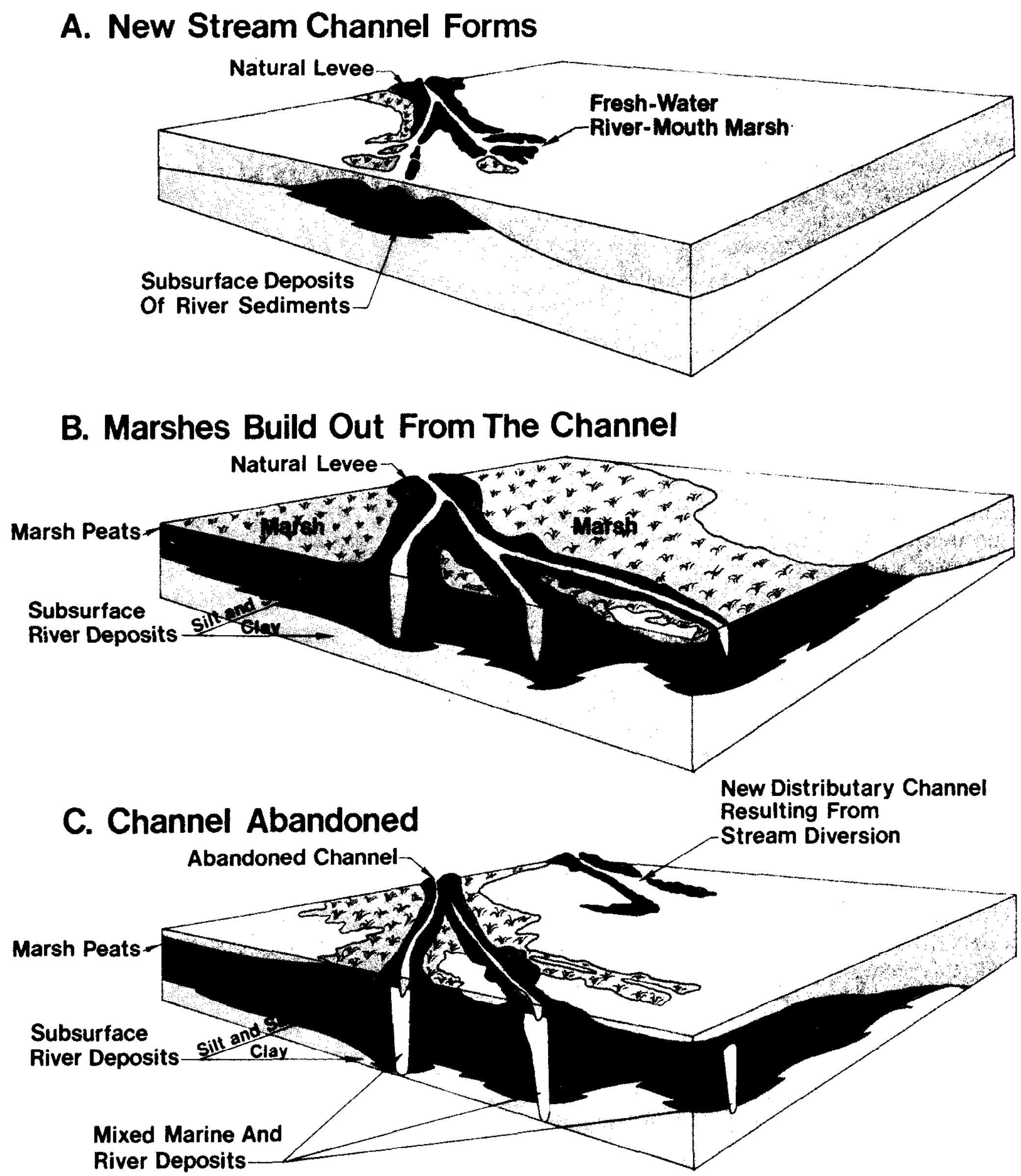


Figure 2. On the Gulf coast of the United States marshes formed by river sediments typically have a 1000-year cycle of growth and decay. (A) New freshwater marshes form where a river channel empties into a shallow sea, depositing sediments and forming mud flats. (B) These flats spread, and are colonized by marsh plants. (C) When the river abandons that channel, ocean forces begin to dominate. The marshes become salty and salt-adapted plants invade. Slowly the marsh sinks as sediments compact. The area reverts to a shallow open sea.

tolerant species. Within a marsh, subtle differences in the degree of adaptation by plants often result in well-defined boundaries between plant communities. These boundaries are defined by slightly different combinations of elevation, soil characteristics, salt concentration and inundation frequency.

Marshes and adjacent tidal creeks along the Atlantic and Gulf coasts are also inhabited by similar species of animals. Fiddler crabs, periwinkle snails, grass shrimp, silverside and mud minnows, clapper rails and red-winged blackbirds are common residents of all tidal marshes. Even the migrating members of the community--shrimp, menhaden, flounder, anchovies, mullet, wading birds and waterfowl--are the same or closely related species from north to south. Climatic differences, for example, rainfall, temperature extremes, and sunlight, seem to take a back seat to flooding and salt stress, determining not so much the kinds of plants and animals that inhabit the marsh, as the length of the growing season and therefore its productivity.

Perhaps the most interesting forces that shape a marsh are the two cyclic ones, the annual cycle of the seasons determined by the orientation of the earth to the sun, and the tidal cycles controlled by the orbit of the moon around the earth. On the Gulf coast, tides flood and ebb once every 24 hours 50 minutes, while on the Atlantic and Pacific coasts tides occur twice during that period. This regular pulse is like breathing for an animal. Falling waters expose marsh soils to air, replenishing the oxygen needed by nearly all living organisms. Rising tides carry in sediments and nutrients necessary for plant growth, and flush from the sediments accumulated metabolic wastes. Receding waters carry these wastes from the marsh along with dead plant litter and the dissolved organic material that gives the water its dark coloring. The activities of marsh animals are adjusted to this cycle. Fiddler crabs are active at low tide and inactive at high tide. Oysters in the intertidal zone open their valves widest to feed during high tides.

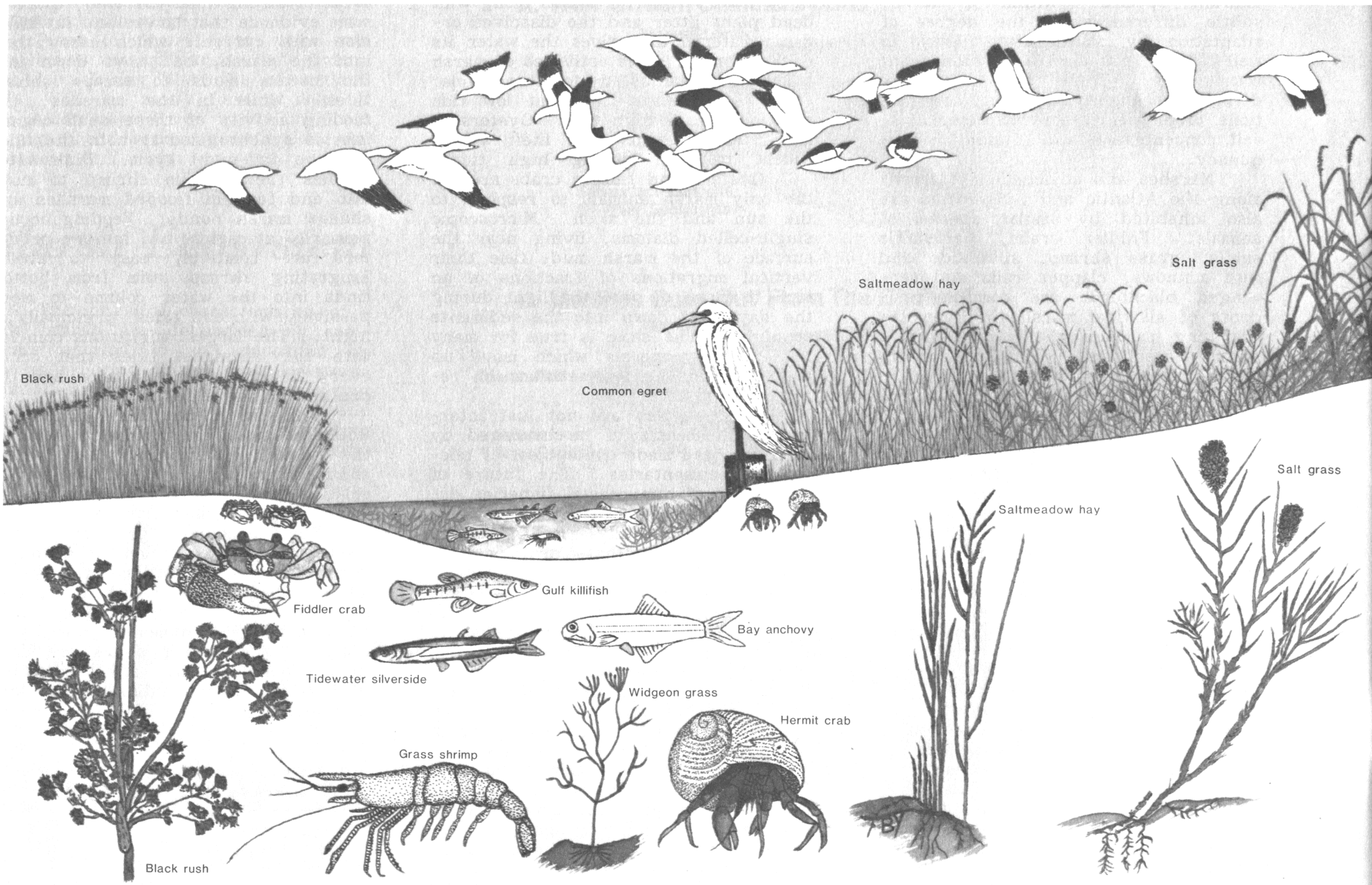
Oysters and fiddler crabs are not the only marsh animals to respond to the sun and the moon. Microscopic single-celled diatoms, living near the surface of the marsh mud, time their vertical migrations of fractions of an inch to move up into the light during the day, and down into the sediments at night. The same is true for many tiny aquatic animals which move up and down in the water column in response to light.

These cycles are not just interesting phenomena to be cataloged by scientists and made the subject of television documentaries. The future of nearly all of our coastal fisheries depends on our appreciation of complex interactions of daily, monthly, and seasonal cycles that program the movements of virtually every major coastal fishery species. The details and timing vary from species to species, but the pattern is similar to that of the brown shrimp (Figure 3).[7] Generally these species spawn offshore in the ocean. The floating larvae, too small to swim far under their own power, are carried passively by ocean currents through tidal passes into coastal estuaries. They move into fringing tidal marsh-pond complexes where the shelter of the marsh and the abundant food supply provide a secure nursery ground. As juvenile shrimp approach maturity, they return to the ocean to complete their life cycle. Scientists have only begun to understand the cues that enable an animal to follow this complex route. Once into areas of strong tidal currents, there is some evidence that larvae and juveniles ride with currents which carry them into the marsh, but move down into the bottom muds to escape ebbing tides. While in the marshes, the feeding activity of these small organisms is synchronized to both the tides and the day-night cycle. High water enables the juvenile shrimp to move into and feed in flooded marshes and shallow marsh ponds. Feeding occurs primarily at night when hungry predators are relatively easy to avoid. Emigrating shrimp swim from bottom muds into the water column to move passively with ebb tides, principally at night. The largest migrations coincide with the strongest tides that occur every 28 days when the moon and the sun are in line with the earth.

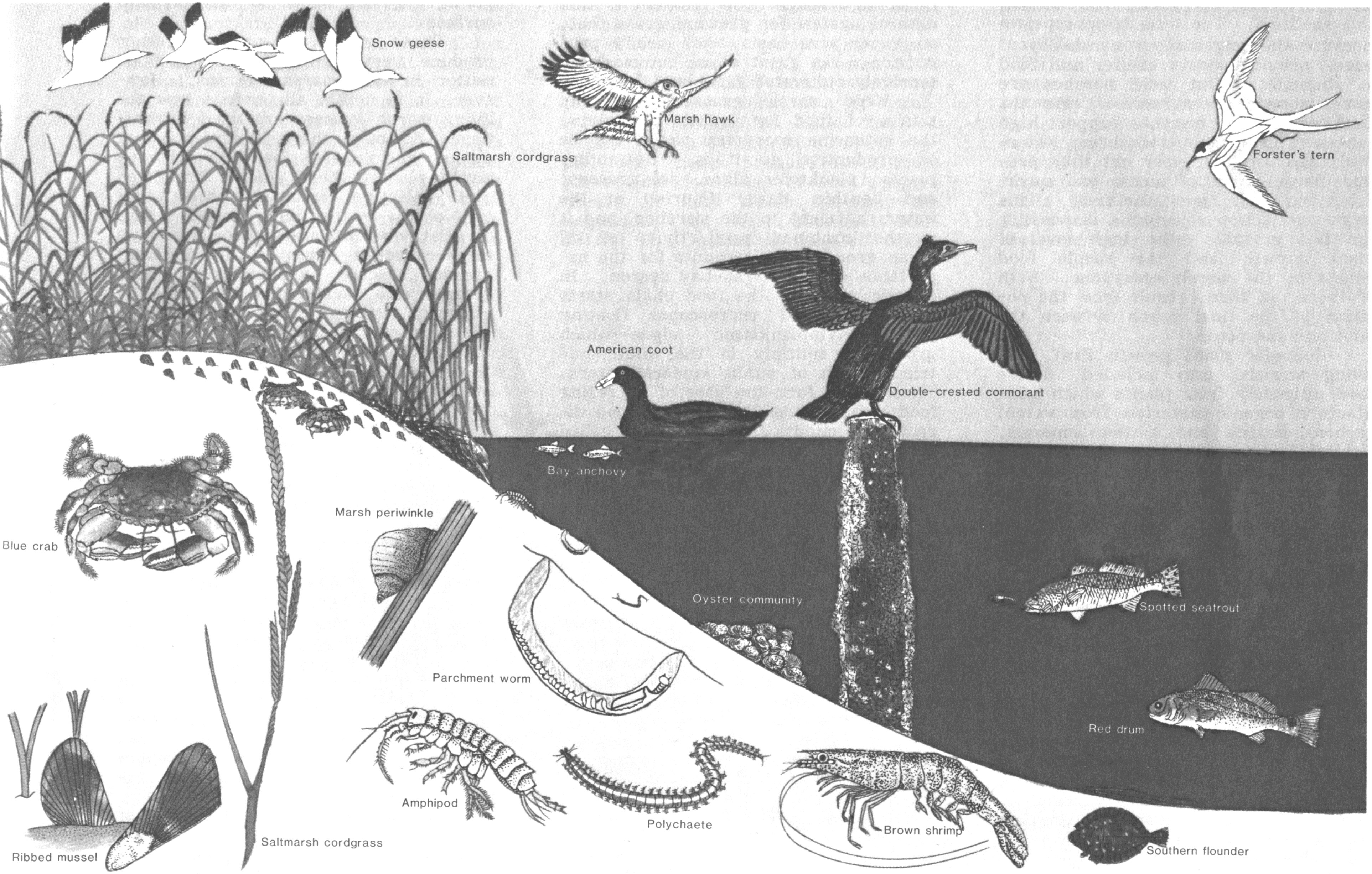
This part of the tidal marsh story would be incomplete without mention of the ducks, coots, and geese, whose annual migrations are regulated by the relative lengths of the day and night. They move annually from Alaskan and Canadian breeding grounds across thousands of miles of land to winter in marshes along the Gulf coast. Generally, these groups of birds prefer freshwater marshes, but the lesser snow goose and numerous species of dabbling and diving ducks are commonly found in tidal marshes, especially in low salinity brackish marshes.[3]

Marsh Food Chain

Tidal marsh zones have been called nursery grounds because of



**The edge of a tidal marsh is an area of concentrated activity for many organisms. The rich nutrients in the water stimulate plant growth. The resulting food and shelter attract many small
enlarged at varying scales to show details.**



nimals, which in turn draw predators looking for an easy meal. This drawing depicts typical plants and animals in the fall season in marshes along the Gulf coast of the United States,

their invasion by young marine fish and shellfish. The term is appropriate because the long sinuous marsh-bayou† edges provide secure shelter and food is abundant. But tidal marshes are much more than nurseries. On the Gulf coast, these marshes support high concentrations of overwintering waterfowl; year in and year out they produce large yields of nutria and muskrat, and fish and shellfish. This large production of animals is possible for two reasons: the high level of plant growth and the simple food chains of the marsh ecosystem. Both of these, in turn, result from the position of the tidal marsh between the land and the ocean.

Consider plant growth first. All living animals, man included, derive food ultimately from plants which manufacture organic materials from water, carbon dioxide and a few minerals. Sunlight provides the energy for this process, called photosynthesis. Man uses fossil energy sources to boost his food production, that is, to fuel tractors, to manufacture fertilizers, and to process foods. In the same way, the plant production of the marsh system is subsidized by the energy of tides and of rivers which continuously replenish the nutrients marsh plants require for growth. Rainfall far upstream washes fertile soil off the land, especially farm land, into streams where it is eventually carried to the coast. As silt-laden river water traverses an estuary, the rhythmic tidal pulses push the water over adjacent marshes where the dissolved nutrients and the nutrients attached to fine soil particles become available to stimulate the growth of plants. Marshes are such effective nutrient traps that they are being used in some places to purify sewage water. So efficient is this natural system for growing grass that, on a per acre basis, each year's production is as great as on our most intensively cultivated farm land.[8]

†A term used in South Louisiana to mean a tidal stream.

Were marsh grasses the only source of food for aquatic consumers, the estuarine ecosystem would not be as productive as it is. But other plants (planktonic algae, sea grasses, and benthic algae) flourish in the waters adjacent to the marshes, and it is the combined productivity of all these groups that accounts for the importance of the marsh-bay system. In aquatic systems, the food chain starts with one-celled microscopic floating plants--phytoplanktonic algae--which grow and multiply in the dilute nutrient broth of sunlit surface waters. These algae form the base of a grazing food web because they are cropped directly by minute floating animals called zooplankton; by fishes such as the bay anchovy and menhaden; by clams; and by oysters, which strain water through their gills to concentrate the algae before ingesting them. Phytoplankton production is especially high in estuarine systems, because of high nutrient concentrations.

The other aquatic plant group that supplements phytoplankton production is composed of sea grasses and benthic algae that can grow on the bay bottom because sunlight penetrates through the shallow water. The importance of this plant community varies with the type of substrate and the depth and clarity of the water. Where sediments are relatively stable and the water clear, sea grasses may abound as they do along the eastern coast of the Gulf of Mexico. In turbid waters, low light intensity and smothering sediments often prevent sea grass growth. In these situations, bottom-dwelling, single-celled diatoms often flourish, giving a golden sheen to the soft mud surface.

These groups of plants together produce very high levels of organic matter in tidal marsh systems. However, it is not at all obvious how the living marsh grasses are used by animals. Although there is evidence that ducks and geese feed directly on marsh plants, these animals are often quite selective, eating the seed clusters only, or the underground tubers of relatively uncommon species such as three-cornered grass. The dominant grasses escape unscathed. These grasses also escape direct grazing by estuarine fish and shellfish. Thus the role of marsh grass in the food chain was for many years problematic. Since the early 1950s, evidence has accumulated that marsh grass contributes significantly to aquatic productivity after it dies. The decaying marsh grass and resulting dissolved organic material are flushed from the marsh by tides and storms, becoming available to aquatic consumers indirectly.*

It is difficult to quantify the relative importance of each of the sources of organic food, but ecologists in Louisiana have estimated that phytoplankton, bottom-dwelling plants and marsh grass each provide equivalent amounts of organic material to the estuarine food chain (Figure 4)[9] In other marsh-estuarine systems where open water areas are large compared to fringing marshes, phytoplankton productivity predominates, with dead plant material from upstream an important food source only when river inflow is significant.[10]

In addition to the diversity of

*Another, probably minor, pathway of food energy flow from marsh to water is through minnows and small shellfish feeding in the marsh during high tides.

plant producers and their high levels of productivity, the simple estuarine food chains are a second reason for the high yield of commercial species. Animals use energy not only to grow, but also to move about in search of food, to digest what they eat, to avoid predators, and to counteract changes in water temperature and salt concentration. No energy conversion is one hundred percent efficient and some energy is lost as it is transferred up each step in the food chain. As a rule of thumb, 1000 calories of plant organic energy will support only about 100 calories of a grazer (an animal which eats plants), 10 calories of a carnivore (an animal which eats other animals), and 1 calorie of a top carnivore (an animal at the top of the food chain). As a consequence, short simple food chains produce much more harvestable food than do long complex ones. In tidal marsh systems, the menhaden, the most abundant commercial fish species of the Gulf coast, grazes phytoplankton directly, a one step food chain.

Many other animals depend on a "detritus" food chain in which sea grasses and marsh grasses are the raw materials. The term detritus comes from a Latin word meaning "worn down" or "disintegrated." As used by ecologists, it refers to the decaying remains of plants and animals. A detritus food chain is one in which plants are not grazed while alive, but are used after they die. The decom-

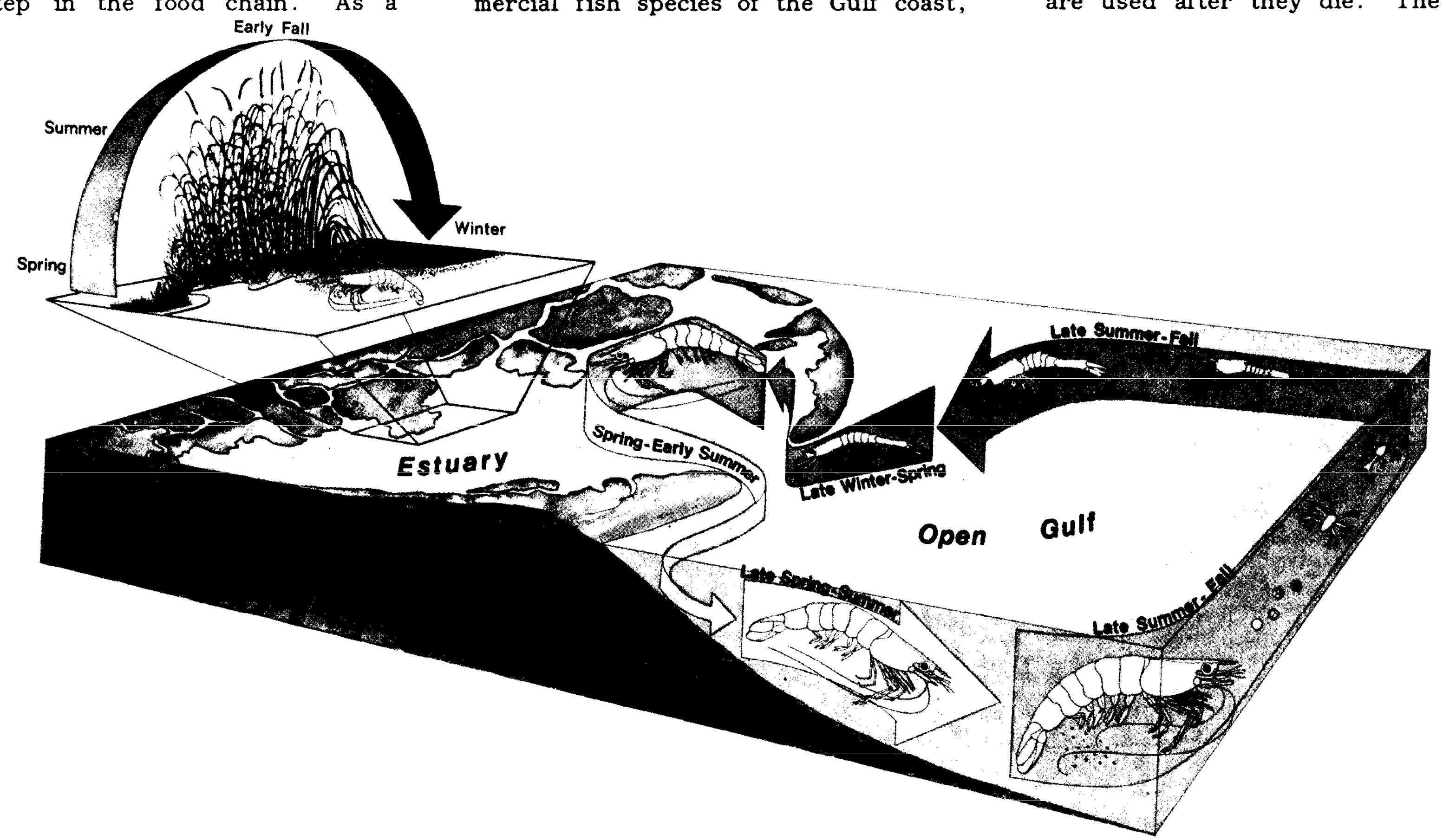


Figure 3. The brown shrimp is typical of many marine animals that spawn offshore, move into the estuary as juveniles, and emigrate to sea again as adults. Their sojourn in the estuary corresponds with the time of peak food production from the adjoining marshes.

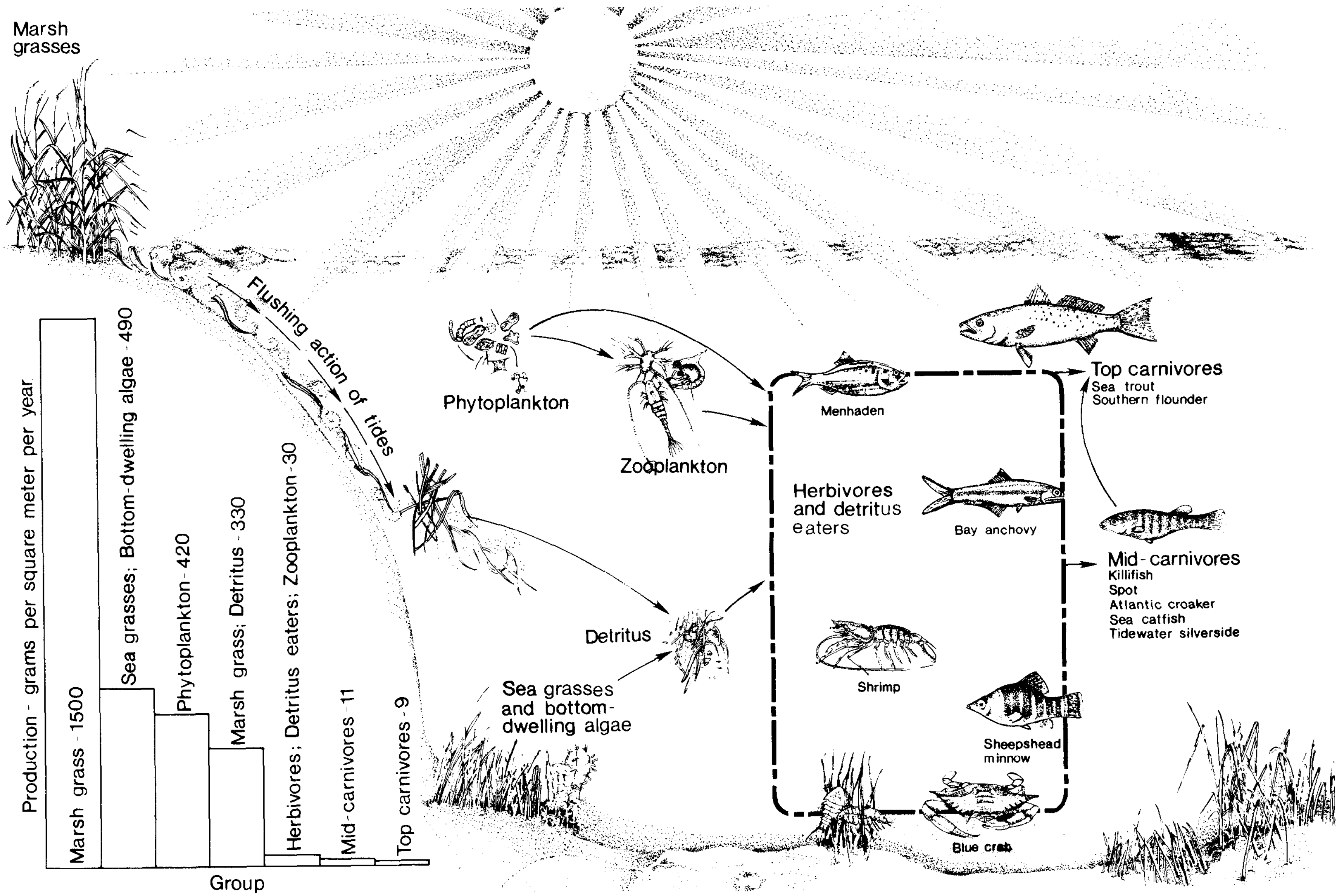


Figure 4. The food that marsh and estuarine animals depend on comes from three sources: floating single celled algae (phytoplankton), sea grasses and benthic algae, and marsh grasses swept into the adjacent water. Certain animals prefer each of these plant food sources, while other carnivorous fish and birds eat only other animals. In this very simplified illustration of marsh-estuary food chains of a Louisiana salt marsh, the bar graph illustrates the annual production of each group of organisms. (Multiplying each number by 10 approximates the production in pounds per acre.) The heights of the bars decrease dramatically as the animals feed further and further from the plant food base.

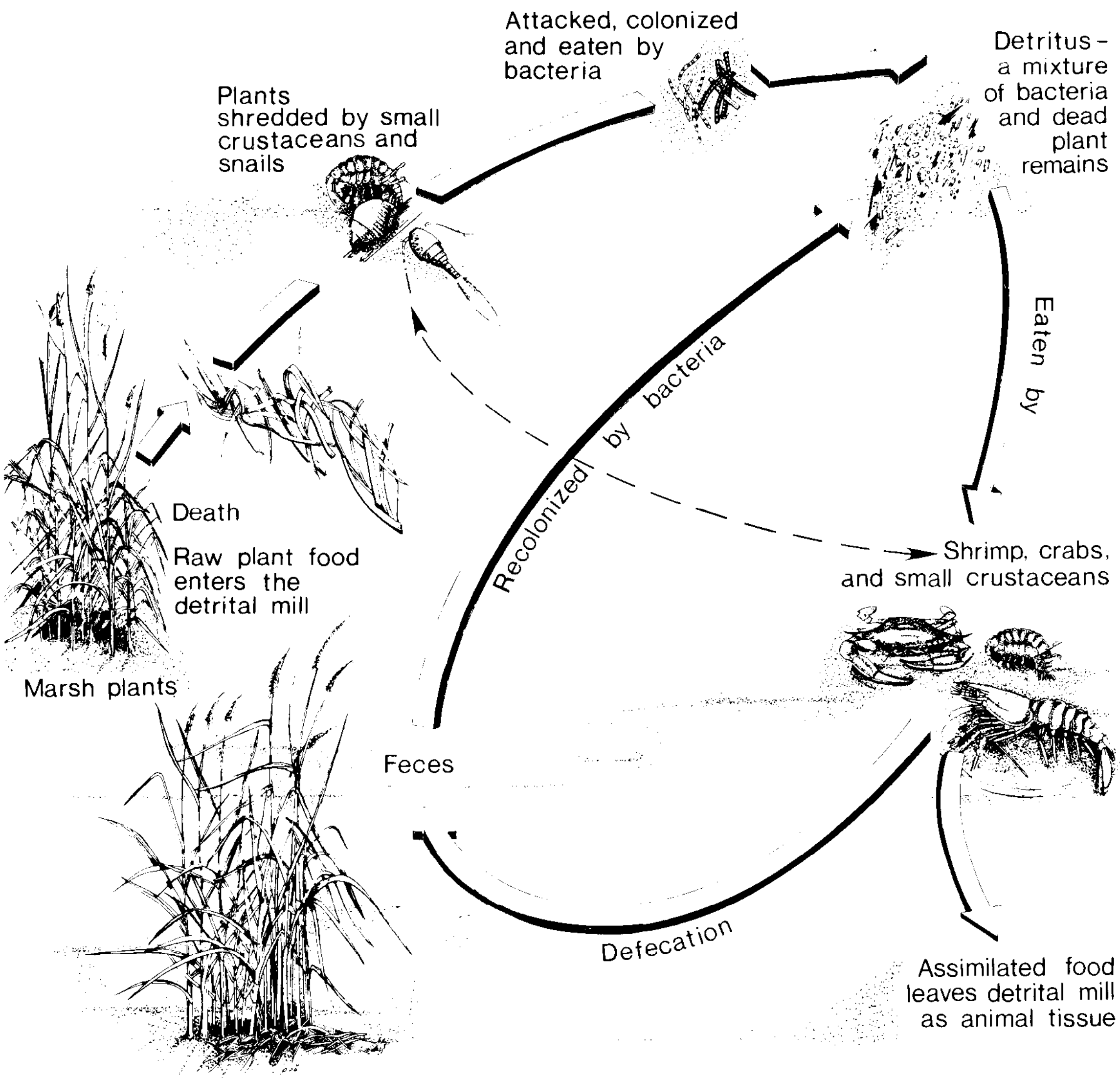


Figure 5. Marsh grasses feed the detrital mill. Small marsh animals physically shred the dead grass, enabling bacteria to invade it and break it down chemically, so that animals can assimilate it and grow. Their waste products are recolonized by bacteria and the cycle is repeated.

posing remains are eaten by scavenging animals, which are in turn eaten by carnivores as in a grazing food chain. Three differences distinguish the "detritus" food chain from the grazing food chain. First, bacteria play an important role, breaking down the cellulose* in grasses, which is indigestible to animals, to a usable chemical form. Without exception, higher animals do not manufacture the necessary enzymes to accomplish this. Even a cow must depend on the bacteria in its rumen (stomach) to break down the grass it eats. The detrital system of the salt marsh performs exactly the same function in the water where broken bits of plant material wash back and forth with the tide. It is a kind of external rumen, and its products support a major marsh-estuarine food chain. Second, because nearly all of this decomposition occurs on or in the bottom sediments, the scavenging animals are predominantly bottom-dwellers (for example, very small wormlike nematodes and crustacean amphipods and isopods) or bottom-feeding fish and shellfish. These animals ingest the decaying plant-bacteria material, strip from it and assimilate the bacteria, and egest the remains in neatly packaged fecal pellets that can be colonized again by bacteria (Figure 5). Finally, tides and storms are important in the estuarine detritus food chain. They aid in breaking up the plants and flushing the detritus out of the marsh into the shallow estuarine waters where it becomes available to aquatic animals.

Like the grazing food chain, the detrital pathway is also efficient. Bacteria have been shown to incorporate dead grass into their cells with an efficiency greater than 20%; and shrimp,

*A fibrous substance making up the cell walls of plants.

the most valuable Gulf fishery species, feed directly on the resulting detrital material. The most valuable fishery species on the Gulf coast all have short food chains, feeding directly on plants or on plant detritus.

Value of Tidal Marshes

Marshes are economically valuable for fisheries far beyond the number of fishes that are caught directly in adjacent tidal streams. Most of the important coastal fishery species of the United States must have access to estuaries and marshes during some phase of their life history. Recent research has revealed how important this aspect of the marsh is: shrimp catches in fisheries around the world are directly related to the area of marsh in the shrimp nursery grounds, not to the area of estuarine or offshore coastal waters where they are caught.[11]

Protecting fisheries is not the only economic reason for conserving wetlands. The waterfowl that crowd Gulf coast marshes during the winter create a hunter's paradise, and fur-bearing muskrats are regularly trapped in brackish marshes. Harder to quantify are other free services provided by wetlands. When marshes are flooded by tidal waters, the vegetation traps sediments which might otherwise block navigation channels and harbors. For example, when the great marshes of the southeastern coast of England were first diked and filled in the 19th century, all the natural harbors silted in. As a result, constant dredging at a considerable cost to the public became necessary to keep the harbors operational.[12] Wetlands also buffer inland areas from the damaging effects of severe storms, acting as huge water reservoirs that reduce flooding in surrounding uplands.

Even more difficult to quantify are the aesthetic values of wetlands. Conversations with coastal residents, hunters, and sport fishermen usually reveal a deep appreciation for the beauty of wetlands. Our inability to put a dollar value on this kind of experience does not make it any less real or less important.

The diversity of these values leads to a serious problem in attempts to preserve wetlands; the private owner of a marsh seldom sees the dollars generated from the living resources of his land. On the Gulf coast he may lease his wetland for trapping and for duck hunting for about $10 an acre a year. In contrast, in a recent study of Louisiana wetlands the annual value of an acre of coastal marsh for commercial fishing was estimated at $94, for commercial trapping $3.47, and for sport fishing $12.[13] The wetlands along Lake Michigan are estimated to have an annual value of $31 per acre for waterfowl hunting.[14] The protection marshes afford inland urban areas against storms and their water-cleansing action save the public thousands of dollars per acre annually.[15] Thus, the value of the marsh in its natural condition is small indeed to the owner, compared to its value to the general public. The wetland property owner's economic incentive to drain and develop private acreage conflicts directly with the public's interest in maintaining the benefits of a natural marsh. This conflict will intensify as populations along our coasts expand and pressures to develop natural areas increase. A public informed of and interested in the functions and values of coastal wetlands is the best safeguard to insure reasonable protection of our wetland heritage.[16]

NOTES ON Tidal Marshes–The Boundary Between Land and Ocean

[1]This brochure describes estuarine intertidal emergent wetlands, which are technically "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface . . . characterized by erect, rooted, herbaceous hydrophytes." Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Office of Biological Services, Fish and Wildlife Service, U.S. Dept. of Interior. FWS/OBS-79/31. In this report marshes are defined as including vegetated wetlands along with adjacent streams and small lakes.

[2]Gosselink, J. G., and R. H. Baumann. 1980. Wetland inventories: wetland loss along the United States coast. Zeitschrift fur Geomorphologie 34:173-187.

[3]Gosselink, J. G., C. L. Cordes, and J. W. Parsons. 1979. An ecological characterization study of the Chenier Plain coastal ecosystem of Louisiana and Texas. 3 vol. U.S. Fish and Wildlife Service, Office of Biological Services. FWS/OBS-78/9 through 78/11.

[4]Miller, W. R., and F. E. Egler. 1950. Vegetation of the Wequetequock-Pawcatuck tidal marshes, Connecticut. Ecol. Monogr. 20: 144-172.

[5]Turner, R. E., and J. G. Gosselink. 1975. A note on standing crops of *Spartina alterniflora* in Texas and Florida. Contrib. Mar. Sci. 19:113-118.

[6]Frazier, D. 1967. Recent deltaic deposits of the Mississippi River, their development and chronology. Trans. Gulf Coast Assoc. Geol. Soc. 17:278-315.

[7]Condrey, R. E. 1979. Draft environmental impact statement and fishery management plan for the shrimp fishery of the Gulf of Mexico, United States waters. Gulf of Mexico Fishery Management Council, Tampa, FL. 220 pp.

[8]Teal, J. M., and M. Teal. 1969. Life and death of the salt marsh. Little, Brown and Co., Boston, MA. 278 pp.

[9]Hopkinson, C. S., J. W. Day, Jr., and B. T. Gael. 1978. Respiration studies in a Louisiana salt marsh. An. Centro. Cienc. del Mar Y Limnol. Univ. Nal. Autón. Mexico 5(1):225-238.

[10]Nixon, S. W. 1980. Between coastal marshes and coastal waters—a review of twenty years of speculation and research on the role of salt marshes in estuarine productivity and water chemistry *in* P. Hamilton and K. Mcdonald, eds. Estuarine and wetlands processes. Plenum Press. New York (in press).

[11]Turner, R. E. 1977. Intertidal vegetation and commercial yields of penaeid shrimp. Trans. Am. Fish. Soc. 106: 411-416.

[12]Coates, D. R., ed. 1972. Environmental geomorphology and landscape conservation. Vol. 1. Benchmark Papers in Geology. Dowden, Hutchinson and Rose, Stroudsburg, PA.

[13]Mumphrey, A. J., J. S. Brooks, T. D. Fox, C. B. Fromherz, F. J. Marak, and J. D. Wilkinson. 1978. The value of wetlands in the Barataria Basin, Louisiana. Dept. of Transportation and Development Coastal Resources Program, Baton Rouge, LA.151 pp.

[14]Jaworski, E., and C. N. Raphael. 1978. Fish, wildlife, and recreational values of Michigan's coastal wetlands. Michigan Dept. of Natural Resources, Lansing. 98 pp.

[15]Gosselink, J. G., E. P. Odum, and R. M. Pope. 1974. The value of the tidal marsh. Louisiana State University Center for Wetland Resources, Baton Rouge. Sea Grant Publ. No. LSU-SG-74-03.

[16]Recommended general references on tidal marshes are: Teal, J. M., and M. Teal (see note 8 above); Niering, W. A. 1966. The life of the marsh. McGraw-Hill Book Co., New York. 232 pp; Horwitz, E. L. 1978. Our Nation's wetlands. Interagency Task Force Report, Coordinated by Council on Environmental Quality. U.S. Government Printing Office, Washington, D.C. 70 pp.