

By John P. Wiley jr.

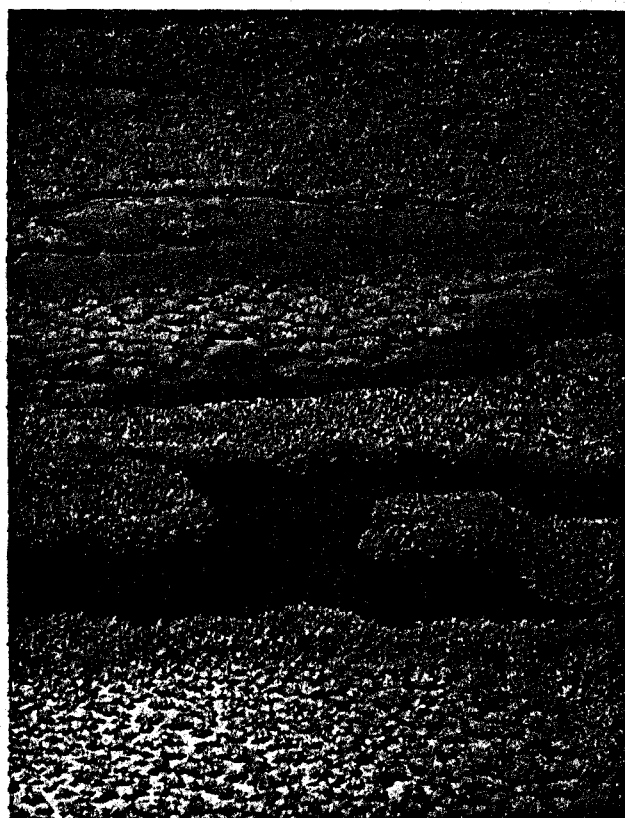
On tropical coasts mangroves blend the forest into the sea

These salt-tolerant trees are the primary producer in an intricate food web as they create habitat above and below the water

The world wears a belt of mangrove forests. Nearly impenetrable thickets where trees grow in saline water and mud, they are the salt marshes of the tropics. Nearly 75 percent of the coastlines between latitudes 25 degrees north and 25 south are dominated by the many species known collectively as mangroves, and like the tropical rain forests whose fate tends to dominate the environmental news, they are gaining the attention of scientists even while in some parts of the world they are being destroyed at a fearsome rate.

Mangroves can look monotonous, appearing as a homogeneous wall when seen from a boat, but their clumps and islands are broken by winding channels that to some of us are irresistibly inviting. Inside, whether in a small boat pushing into every open lead, or on foot climbing through the tangle of roots and trunks, they form a natural wonderland where land, water and sky blend into each other. There is something special about sitting in the branches of a tree and watching creatures of the sea from a dry, leafy perch. It is a safe world: sharks and barracudas are there, but in miniature form. And there is something special about swimming underwater with a dive mask, moving through a school of gray snapper that politely makes way for you, only to come up for air and be caught by the inscrutable stare of a pelican perched in the deep green canopy overhead. For those who brave the muck and the jungle gym of the mangroves'

Roseate spoonbills contest a perch in the branches of mangrove trees on a small island in Florida Bay.

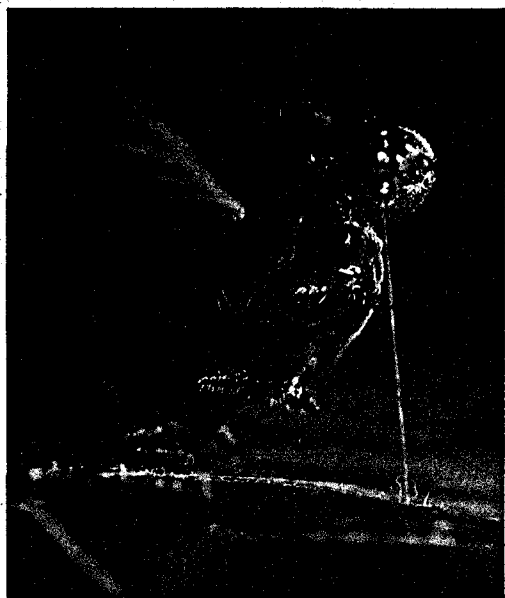


Mangrove-lined waterways and small mangrove islands shape the landscape in Everglades National Park.

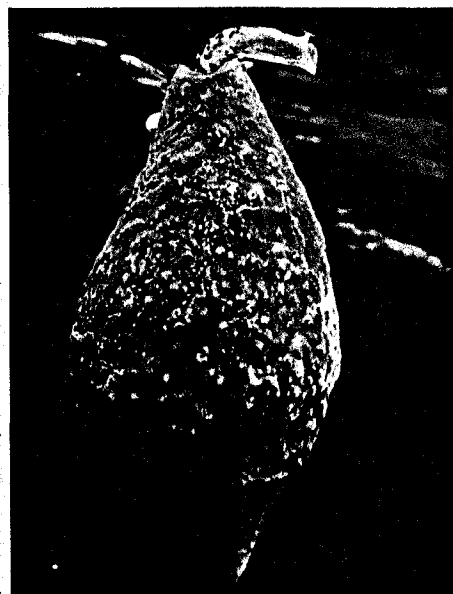
interior, there is extraordinary variety. Leather ferns, rubber vines, orchids and spider lilies grow among the trees; in the branches grow bromeliads and feathered puffballs that one day will become herons.

Three species—the red, the black and the white—grow in Florida, where significant stands occur from the Keys as far north as Cape Canaveral on the east coast and Tarpon Springs on the west. Smaller reds and whites grow farther north; black mangroves reach

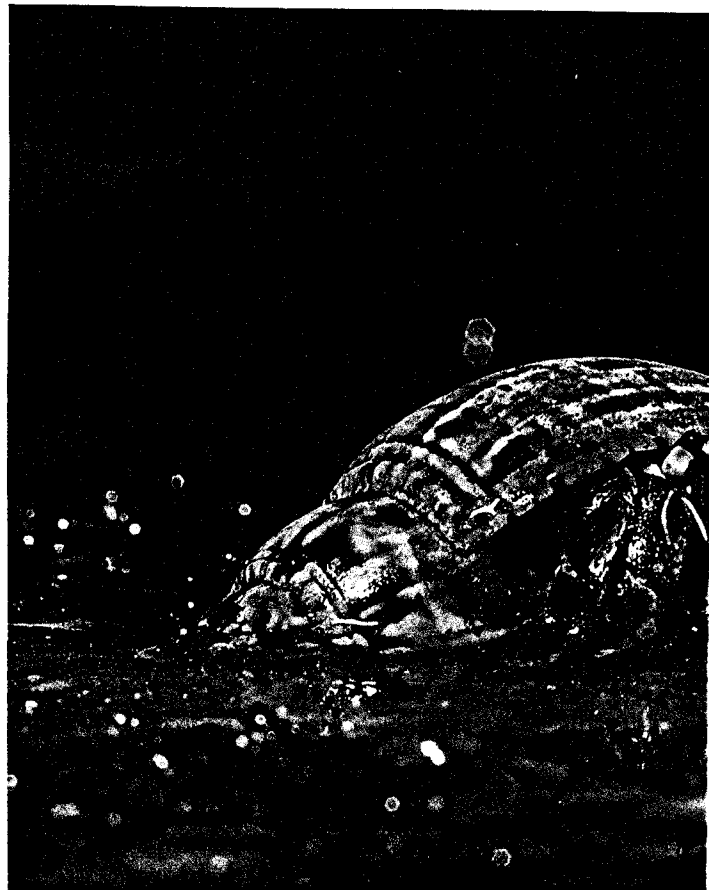
Photographs by Robert Noonan



Above water, a mangrove skipper larva feeds directly on the leaves of its host.



A marine snail, its shell obscured by coralline algae, grazes along the roots.



Hermit crab would appear to be contemplating a black mangrove seedling in some shallow water near Plantation Ke

Coffee-bean snails are feeding on the lower branches of a man
Small crabs and a host of other invertebrates also live there.



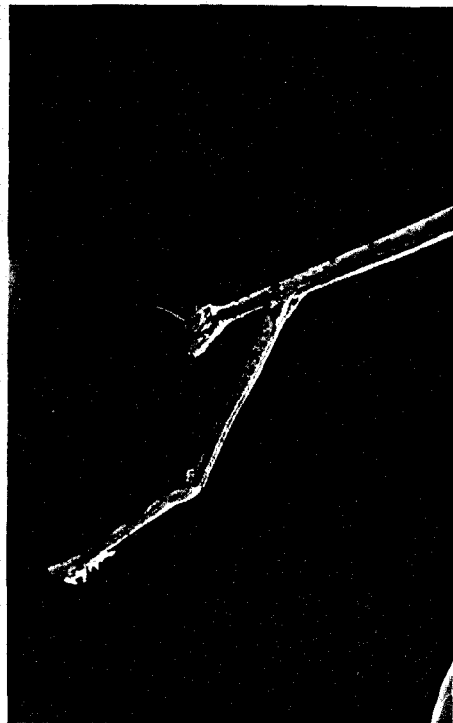
almost to Jacksonville and occur as scattered shrubs all along the north coast of the Gulf of Mexico to Texas. In this hemisphere, mangroves grow along both coasts of Central America, throughout the Caribbean, and along the northern coasts of South America. In Hawaii they were introduced in 1905 to control shoreline erosion on Molokai; extensive stands of red mangroves grow there today.

Only in the past 15 years or so have biologists been

able to document the role mangroves play in ecosystems and their value to us, the ultimate at the top of the food chain. Like the salt temperate climates, mangrove swamps can be of as nurseries, where many commercially in fish and crustaceans spend part or all of th They produce more than three tons of organi per acre per year, a crucial input to a complica web that involves not only their immediate s

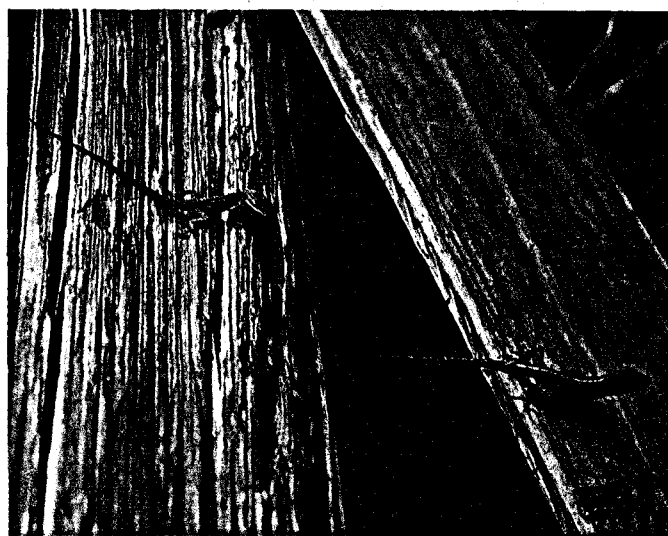


A small water snake, a common species that feeds on fish, takes the air along aptly named Snake Creek.



Wood-boring isopods can severely damage the stiltlike roots of red mangrove trees.

Looking more like a twig than a hunter, a praying mantis watches for the unwary.



A green anole (left) and a brown expore driftwood left high and dry in the mangroves by a storm tide.

ings but also the lagoons, tidal rivers and estuaries that they border. They protect the shoreline from winds and waves. They are an important habitat for creatures of the water, the air and the earth. In developing countries, they provide lumber, firewood and charcoal, tannin, medicines and even alcoholic beverages.

The first recorded reference to mangroves goes back to 3550 B.C. in Egypt. Human use of them for firewood and other purposes must date from much earlier. Wil-

liam Macnae, a South African mangrove expert, mentioned accounts of stands of mangroves with prop roots along sections of the Red Sea and Arabian Gulf more than 2,000 years ago, where none grows today. There is evidence in the fossil record that mangroves date back at least to the Eocene, some 50 million years ago. They seem to have originated in the area of Malaysia and spread from there, evolving and forming new species as they went. V. J. Chapman at the Univer-

Mangrove swamps blend forest and sea

sity of Auckland in New Zealand has suggested that the earlier species were able to migrate through the Tethys Sea, between Africa and Eurasia, and into the Mediterranean before continental drift closed that avenue. From there they moved to the west coast of Africa and the Americas, reaching the Pacific coasts of the Americas before the Central American land bridge had closed.

However it happened, it seems clear today that the world has two groups of mangroves. That in the Indo-Pacific, the Old World, is much richer both in numbers of species and luxuriance of growth than that in the Atlantic. Biologists count more than 60 species in the Old World, compared with only 12 in the New. In Florida, there are three.

Mangroves are terrestrial plants that have moved back to the sea, adapting themselves to live in saline water and saturated mud. Venture into a stand, and it is not easy to say where the land ends and the water begins. Go in from the land side, and it's a swamp. The ground gets wetter and wetter, until finally you are walking out into the water just as the trees have done. Approach in a boat, and work your way in among the trees as far as you can. Step out onto what looks like land, and you may sink into the unconsolidated sediments. It is not land at all, but more of an ooze, a very viscous liquid. When you finally do pull your feet out, you will also release the rotten-egg odor of hydrogen sulfide, the sign of an oxygen-deprived environment.

The overwhelming impression is of biological richness; it is like standing on—and in—a compost pile that stretches for miles. The muck is not five percent organic matter, like some good garden soil; it is close to 90 percent.

To travel in mangroves, you have to adapt to them. One day last year, a small band of us followed Pat

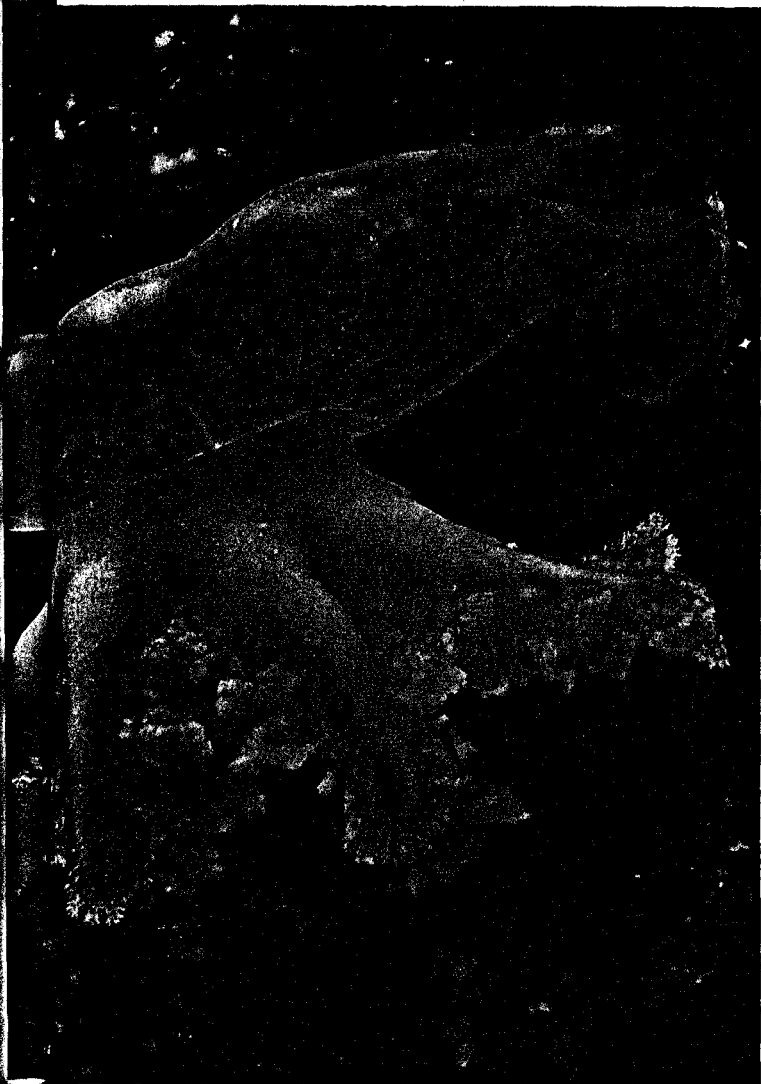


Cassiopeia jellyfish, a familiar sight in mangrove creeks, live a life more like that of a green plant.

Healy, ornithologist at the National Audubon Society research center at Tavernier, around Cowpens, a group of islands in Florida Bay, one of which is an Audubon sanctuary. (The name comes from the local legend that manatees, or sea cows, were once kept as a source of meat in the natural bowl formed by the islands. No the Intracoastal Waterway cuts right through the middle.) Healy moved easily through the mangrove even while maneuvering a long aluminum pole with a mirror on the end (like an oversize version of the dental instrument) with which she checked the progress of heron nestlings. The rest of us stumbled and splashed along, climbing over prop roots and the suddenly sinking ignominiously into the muck.

The trees themselves are perfectly at home. How

Mr. Wiley is on the Board of Editors. Mr. Noonan is a Baltimore photographer; his work in natural history appears often in the pages of SMITHSONIAN.



Symbiotic algae in wavy filaments photosynthesize, taking carbon dioxide from water and making food.

Teas, a specialist in mangroves at the University of Miami, explains that they have solved two problems that normally would make it impossible to grow where they do. The first is that the soil is anaerobic: there is no available oxygen. Like any living tissue, mangrove roots must have oxygen, and they cannot get it from the soil as their upland counterparts do. Instead they take in air through special above-ground pores called lenticels. These are covered by loose waxy cells that allow air to go through but not water. Red mangroves have lenticels on their prop roots. Blacks have them on pneumatophores, fingerlike projections that grow up through the muck. Whites have them on their trunks. From the lenticels the air moves through a system of fibers into the underground roots.

The other problem mangroves face is too much salt. It is the salt that allows them to grow where they do in the first place because it keeps out ordinary trees and shrubs. But even mangroves cannot simply ignore it:

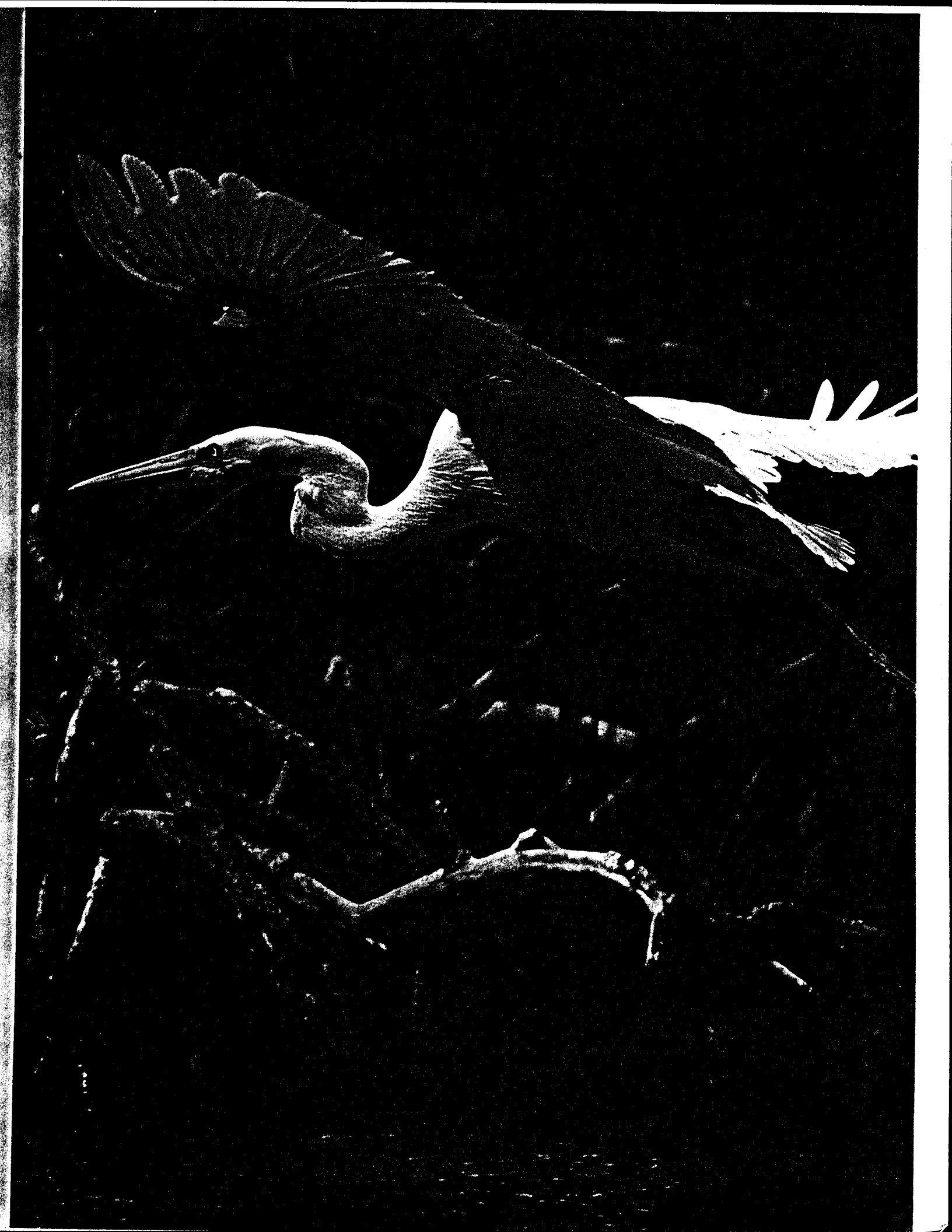


Gray snappers swim among algae-covered mangrove roots. They feed on crustaceans and small fish.

the salt content of even brackish water is much higher than that of the sap inside the cells of a mangrove tree. The reds use membranes to prevent most of the salt from entering the roots. Blacks and whites do let more of the salt in, but they then excrete it through small glands on their leaves. Unless it has rained recently, you can frequently identify a black mangrove by the salt crystals glistening on its leaves. Whites do the same thing, but less conspicuously. Blacks and whites do exclude a little, and all three may concentrate salt in a leaf before it drops off.

So far as we know, mangroves can live without either salt or periodic immersion in water—as long as there is no competition from terrestrial species. Mangroves live on dry land in Miami and have survived 50 years on tap water in the U.S. Botanic Garden in Washington. But like any plants, mangroves are sensitive to local conditions. Biologists commonly divide mangrove forests into types of communities, according to where they live and how well they are doing. At one extreme are nutrient-rich riverine forests where red mangroves may reach heights of 60 feet or more. At the other are nutrient-poor areas of south Florida and the Keys, where stunted versions of all three species eke out a living on the thin soil over salty flats of fossil-coral limestone. Here, trees less than four feet high may be 40 years old.

For years some scientists believed that mangrove growth followed a pattern of succession, eventually turning an aquatic environment into a terrestrial one. The analogy was made to terrestrial ponds that eventually fill with vegetation, becoming first swamps and finally dry land. The idea was that the mangroves similarly created land by trapping sediments and gradu-





Flowers of the red mangrove are seen all year long, but are most conspicuous in the spring and summer.



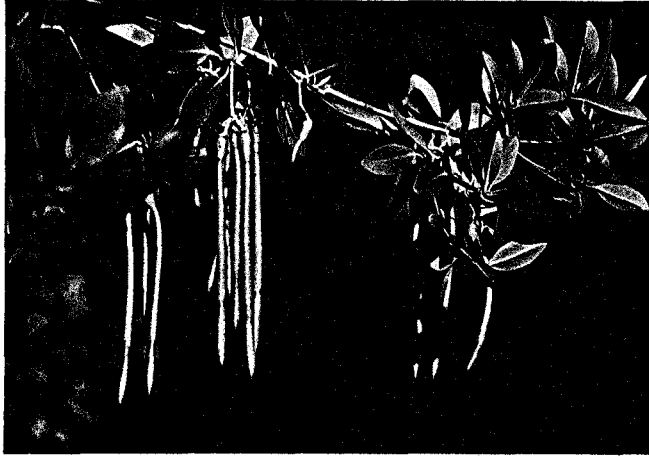
Prop roots of red mangrove are exposed at low tide. Fallen leaves are the beginning of a complex food web.

ally building up the bottom. As this happened, the species most adapted to living in water would continually advance farther toward the sea, trailing the succession species behind. Terrestrial species were considered to be the climax. There is no doubt that in some places mangroves are marching into the sea. Migration at the rate of 115 yards a year has been recorded in Sumatra; in Java the rate has approached 180 yards a year. William Macnae reported that a seaport visited by Marco Polo in Sumatra is now 30 miles inland.

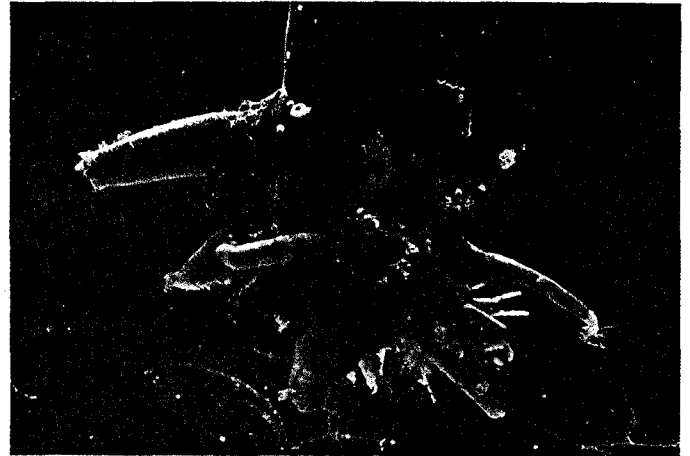
But opinion is swinging to the opposite view—that mangroves follow rather than lead, that they are effect and not cause. Where land is being formed, as in a river delta or the shallow banks created by marine sediments in places like the Bahamas, mangroves will grow on it, giving the impression that they are building land. In most cases, they are not.

Whether or not they are making new land, mangroves do a lot for the space they occupy. Their physical structure itself provides habitat for other plant and animal life. Above the water, trunks, branches and prop roots look pretty much like any other woody plant. But put on a diving mask and approach them underwater, and it is an entirely different world. Each root is alive with fuzzy, filamentous algae, loaded to many times their diameter with barnacles, oysters, mussels and sponges, with worms, snails and a host of other invertebrates. Small fish are everywhere, protected in the roots from large predators. Crabs patrol the bottom. In the Keys, juvenile spiny lobsters lurk among the roots.

Above water the trunks and branches are home to more snails, the herbivorous mangrove crab, lizards, spiders and at least 200 species of insects. The en-



Red mangrove embryos, called propagules, grow as long as ten inches before dropping into mud or water.



Once a propagule has been in the water for a certain number of days, roots begin developing at lower end.

dangered American crocodile—only about 200 are left—sometimes nests in mangrove swamps in upper Florida Bay and on Key Largo. Terrestrial mammals make use of mangrove swamps, although they are of course not limited to them. Skunks, raccoons and bobcats are commonly found there. River otters dwell among them, and Florida panthers are seen.

The most conspicuous users of mangroves are the birds. For birds, mangroves add a new dimension—the vertical—to shorelines. Rich mud flats and thick growth of trunks, branches and leaves offer a complete habitat for feeding, resting, roosting and nesting. All the usual marsh, wading and water birds are there. Shorebirds—willetts, plovers and dowitchers—probe the ooze. Other wading foragers are there—the herons, egrets and white ibis—stalking and striking. Surface feeders and divers are there, the terns and kingfishers plunging into schools of baitfish.

In south Florida, some birds nest only in the mangroves. One survey found that 100 percent of the roseate spoonbills (p. 122) and brown pelicans nest there, as does the uncommon reddish egret. The great white heron, a south Florida color phase of the familiar great blue, nests on the mangrove islands in Florida Bay. Other birds choose the mangroves in varying degrees. About 90 percent of the great blue herons choose mangroves, as do 70 percent of the tricolored herons, 80 percent of the double-crested cormorants, and perhaps half the snowy egrets. The mangroves can also be a haven of last resort for other birds. Normally only about ten percent of the white ibis nest in mangroves, but when drought strikes the Everglades, breeding colonies in mangrove areas near the coast account for the only reproduction.

In their community profile of south Florida man-

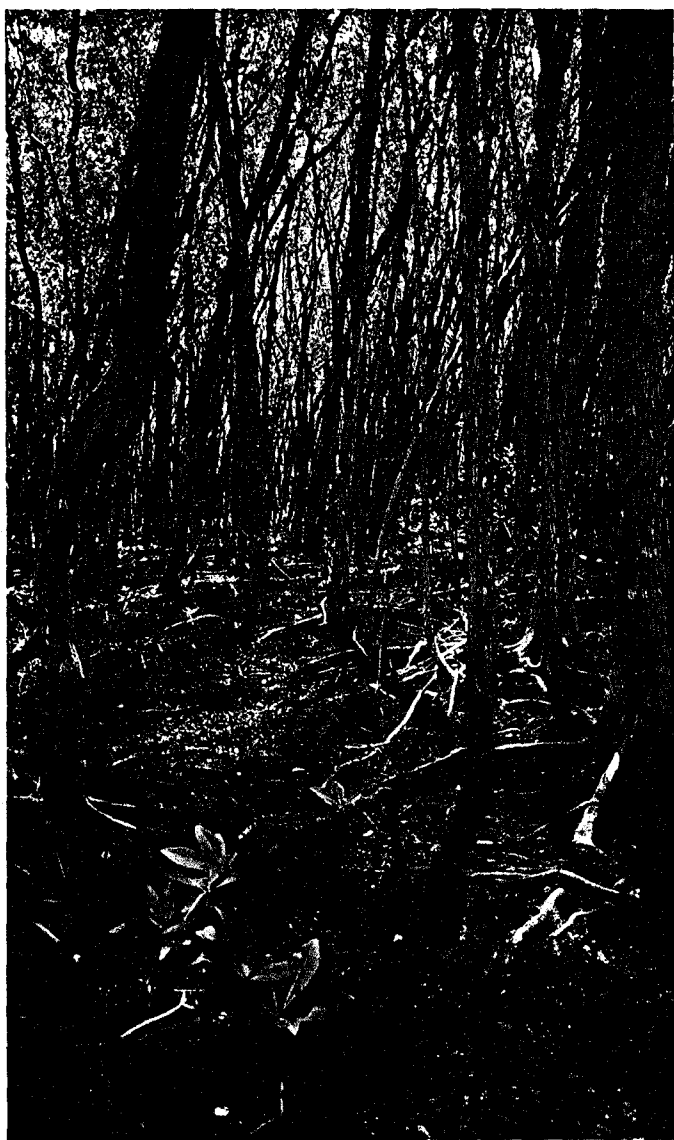
groves, William E. Odum, Carole C. McIvor and Thomas J. Smith III reported that 181 species of birds use the habitat at one time or another during the year. At least 66 are known to nest there.

The authors state flatly: "The bald eagle, osprey and peregrine falcon are dependent upon mangrove ecosystems for their continued existence in south Florida." Both the eagle (p. 133) and the osprey feed on the fish population and roost and nest in the mangroves. Peregrines winter there, establishing territories in which they feed on shorebirds and waterfowl.

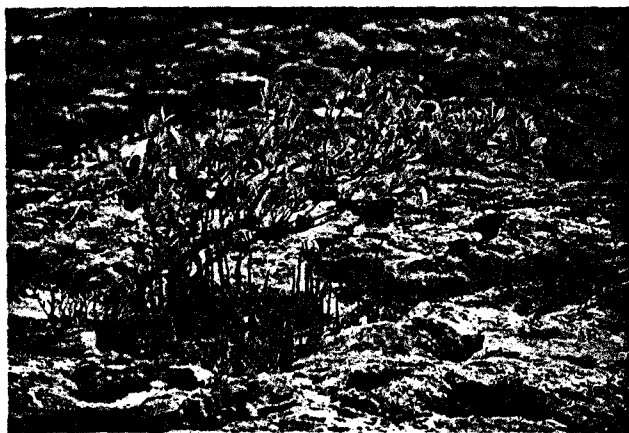
To an outsider, the mangroves of south Florida appear to support a richness of bird life seldom seen in temperate zones. Drifting in the Marco River at sunset, past islands known simply as A, B and C, one can watch long lines of pelicans, as many as 200 to a group, coming home to roost from their fishing grounds to the southwest, while white ibis in equal numbers arrive from the marshes to the northeast. Anywhere from 4,500 to 20,000 birds of 12 to 14 species roost on these islands.

And yet the experts are worried. Bernie Yokel, estuarine ecologist and president of the Florida Audubon Society, says there may be 150,000 wading birds in south Florida. They face their second crisis in little more than a century, and one more difficult to resolve. According to Yokel, there may have been nearly 2.5 million wading birds in south Florida in 1850. Some were killed for food (white ibis were once known as Florida chicken), but it was the plume hunters who nearly did them in. Protection came early in this century, and by 1930 the population had rebounded to about two million. Now it is dropping fast.

No one can say for sure what is happening. Most biologists agree that it probably has something to do



Red mangroves, front, have rooted in white mangrove forest at the Fairchild Tropical Garden in Miami.



A young black mangrove grows amid its pencil-like pneumatophores in a hollow in limestone rock.

with the changes in water flow through the Everglades. That is now completely controlled, with water being released only at certain times and places. They suspect that this change has in turn caused the fish populations in the estuaries to decline, reducing the food supply to fish-eating birds. James Tilmant, a marine biologist at the Everglades National Park research center, says scientists are now working to determine just what fish the herons eat and whether these kinds of fish would indeed be affected by the flow of fresh water.

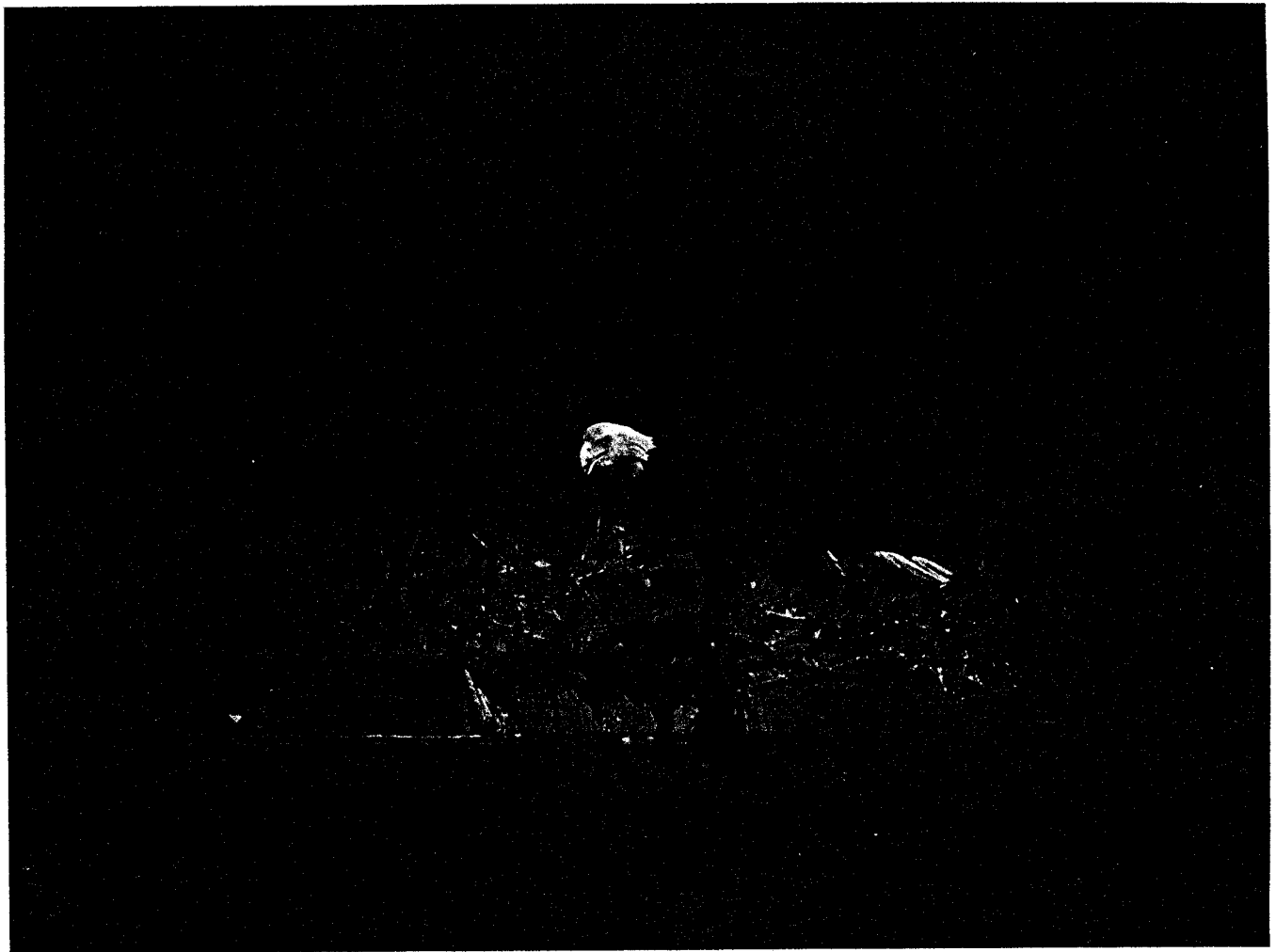
Panhandling herons raise more young

There is some interesting evidence that fish populations are the limiting factor for some birds. George V. N. Powell, of the National Audubon Society's research center at Tavernier, has discovered that panhandling great white herons—those that solicit food from humans—reproduce with greater success than do those that depend strictly on natural sources. Powell studied herons that nested on mangrove islands in Florida Bay and did their begging in the Keys. He found that their clutch sizes were larger and that they fledged more young. The clutch sizes of the natural feeders were not only smaller than those of the panhandlers, they were smaller than for herons in other parts of the country and smaller than the clutch sizes in the same part of Florida Bay back in 1923.

As added evidence for a causal relationship between smaller fish stocks and declining bird populations, a National Park Service study conducted in Florida Bay revealed that the numbers of ospreys—a fish-eating bird—had dropped over a ten-year period but is now leveling off. Young ospreys had been found starving in the nest, presumably because parents had been unable to find fish to feed them.

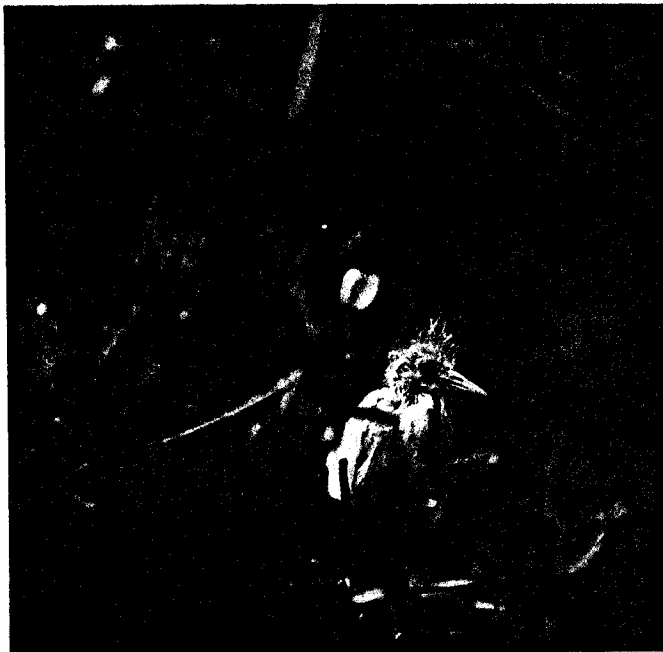
The mangrove is far more than the physical substrate for other forms of life. It is the beginning of life, the organism that makes its own food and thus is the source of food for other forms of life. It is the mangroves that capture the energy of tropical sunlight and turn it into food—not directly for the spectacular creatures that humans come to see but for the uncounted millions of microorganisms that work the litter on the bottom.

The mangrove food web begins with a leaf falling into the water. Crabs and snails break it up, and soon the pieces are covered with a frosting of bacteria, yeasts and fungi. The leaf begins to fall apart into even smaller particles, while protozoa (microscopic animals) arrive to graze on the bacteria and fungi. The bits of leaf, called detritus, with their cargo of bacteria, fungi and protozoa are now a rich food for small fish and for worms, crustaceans and countless other invertebrates. These in turn are the prey of larger car-

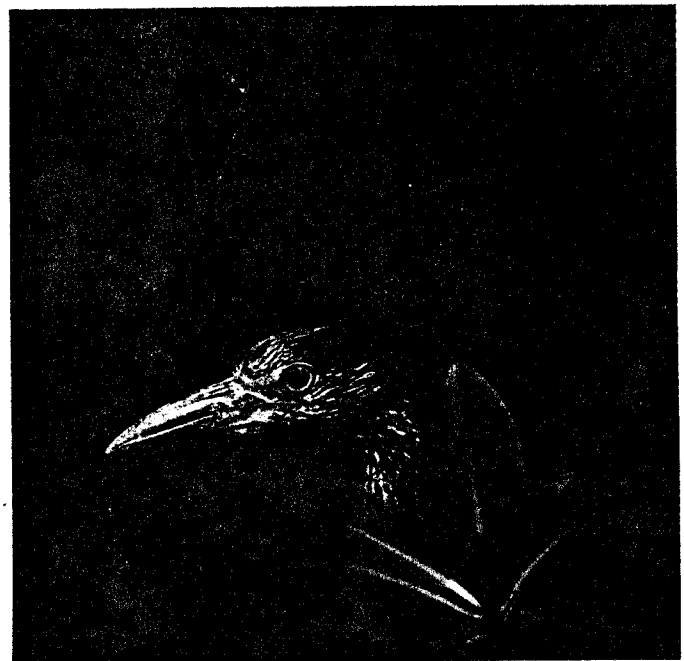


A bald eagle uses a young mangrove as a platform to tear apart and eat victim, apparently a cormorant.

When the eagle finished four hours later, all that was left of its prey were two long black feathers.



An adult little blue heron and a chick keep an eye on things from their refuge on a mangrove island.



Immature yellow-crowned night heron peers over mangrove leaves at a nesting site in Florida Bay.

nivores, crabs, eels and bigger fish. At the top level of the mangrove food web are the names we know best: snappers and jacks, red drum and sea trout, tarpon, dolphin and snook under the water, and the herons and egrets, eagles and ospreys overhead. All from a leaf that fell into the water, the tons of leaves that each acre of mangroves drops into the water, one at a time, in the course of a year.

Humans have learned to value this production. The millions of pounds of pink shrimp caught off the Tortugas spend part of their life cycle in the Everglades mangroves. Macnae put together records of catches from Mozambique east to north Australia and calculated that 250 acres of mangroves produced four tons of shrimp a year. Numbers for finfish are smaller, but the Florida mangroves alone contribute millions of pounds to the commercial catch. Aside from commercial considerations, mangroves are habitat for some of our most spectacular birds, and for at least seven endangered species, including American crocodiles and the Atlantic ridley (a sea turtle).

In Florida, mangroves are increasingly protected. The tide probably turned for good in 1976 when the Corps of Engineers rejected a proposal to dredge and fill 3,000 acres of mangroves on and near Marco Island for commercial real estate development (SMITHSONIAN, January 1977). The developers came right back in 1977 with an application for 4,000 acres, only to settle last year for just 300. For the right to develop 300 acres of mangroves and some valuable upland property near Miami, the company deeded 13,000 acres of mangrove wetlands to the state.

Developers have been assessed as much as \$800,000 for cutting mangroves, with fines based on the assumed productivity of the trees. Dade County requires a landowner to obtain permission not only to cut down a mangrove, but even to trim it for a better view of the water.

In fact, the losses in Florida have not been very great. Odum, McIvor and Smith estimate that only five percent of the mangroves that were there in the last century have been destroyed. (The percentage reaches 100, of course, in heavily developed areas, as in portions of Biscayne Bay.) Depending on how the counting is done, as many as half a million acres remain in Florida.

In other parts of the world, mangroves were often seen as something to be used rather than preserved. For millennia they have been cut for firewood and charcoal, as well as lumber for buildings and boats.

Their habitat has been converted to fish farms, rice paddies and salt ponds.

Even in Third World countries with a real and present need for firewood, however, the tide is changing. Indonesia, for example, has about nine million acres of mangroves, and traditions many centuries old of exploiting them. But now the nation is moving toward management and even protection. Some areas are harvested on a 30-year cycle; forests are divided into 300-acre tracts, and just ten acres are cut each year. The government now requires that a belt 45 to 180 yards wide be left along the coast.



A great white takes to the air from a shallow bank peppered with mangrove seedlings. Note band on leg.

Mangroves are being planted these days in places where they once grew and in places they never grew. Howard Teas in Miami has experimented with replanting, and has introduced them along causeways and on dredge islands. He has even developed a method for planting from a helicopter: seedlings are placed in paper bags with fertilizer and weighted with sand; fins or paper tails are attached. They splash into the mud in an upright position.

Given half a chance, the mangroves will do it themselves. All three Florida species are viviparous: their embryos develop while they are still attached to the

parent plant. Known as propagules, these young plants drop off the trees into the water to be carried wherever the currents take them. Those of the red mangrove are eight to ten inches long (p. 131) before they drop; they can be a major part of the wrack floating around the prop roots.

The sight of young trees emerging from salt water (below) is startling at first. Mangroves thrive where no other terrestrial trees can live, and create an ecosystem all their own. They are coming into their own as well, as they are increasingly appreciated as a resource and as an important part of tropical biology.

