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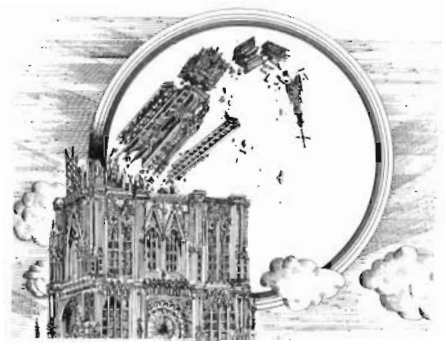

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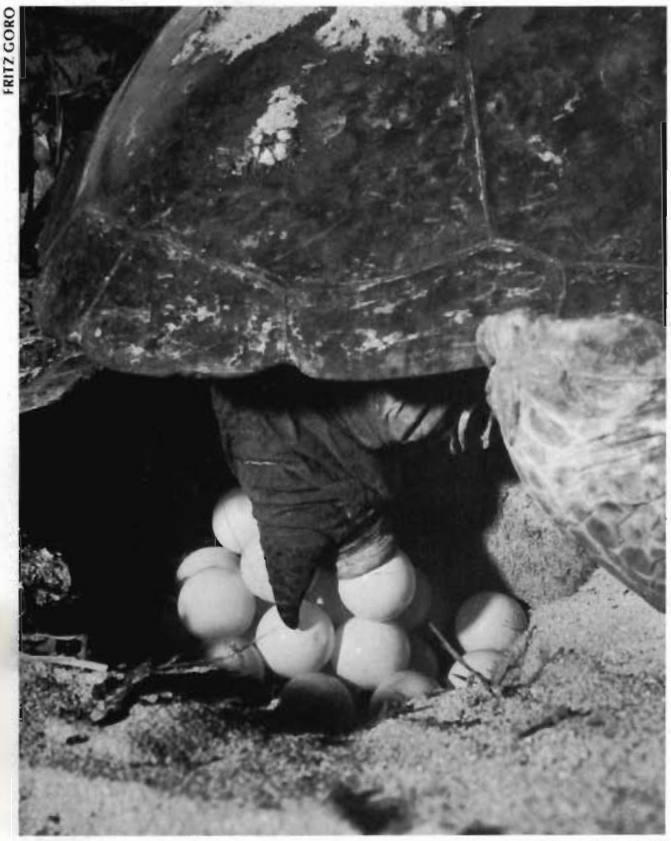
THE COVERS: Of all the world's sea turtles, the beautiful hawksbill is perhaps the most endangered. For it is the sole source for the fast-rising demand for tortoiseshell. A single hawksbill is worth $15 to a native hunter, its eggs are coveted, and its young are stuffed and polished and sold in curio shops. Protection is impossible, moreover, since the hawksbill is a solitary nester and is spread throughout tropical waters. In this issue, Archie Carr discusses the many dilemmas of sea turtle conservation. And Douglas Faulkner has provided these two cover portraits of the hawksbill. On the front, a young turtle weighing perhaps 40 pounds, swimming at 60 feet in the Philippine Sea off the barrier reef of the Palau Islands. On the back, a mature hawksbill resting on a Palau reef at a depth of 90 feet. Faulkner used a Rolleiflex with a Rolleimarine housing and an exposure of 1/125th second at f:8 with flash.

THE FRONTISPIECE: A portrait of the Masai giraffe. Photographed by Leonard Lee Rue III.

FRITZ GORO



A green turtle deposits her burden of eggs in the sand of Heron Island on the Great Barrier Reef. Can her kind survive?

Great reptiles, great enigmas

by ARCHIE CARR

ONLY A LITTLE WHILE AGO the oceans seemed unassailable—too big and stable to be hurt by man, too teeming with life to let him ever go hungry. But now we know better. Suddenly, even the myriad creatures of the sea are suffering from human intemperance. The offal of cities circles the world in the global currents; beaches are strewn with the cast-off artifacts of men two thousand miles away.

It is not just the quiet inhabitants of reefs and clam beds that are declining. The marching shoals of shrimps are dwindling, the peregrine sardines and tunas cycle fewer every season. Even as we came to know our dependence on the sea, our disruptions there were spreading.

For the past seventeen years most of my research time has been spent working with sea turtles, a group of animals that now are caught in the cross fire of ecologic decline and overexploitation. I was drawn to sea turtles partly because in those days there were gross blank places in their known natural history, and partly because I saw a hawksbill come ashore out of phosphorescent surf one night and dig in the sand while a thin moon climbed.

Today the plight of sea turtles is widely known, and efforts to learn more about them and slow their decline are in progress almost wherever they occur. But the concern was dangerously slow in coming. In the *Red Data Book* of the International Union for Conservation of Nature, three species of sea turtle are listed as endangered, and by the criteria the IUCN employs that is a reasonable judgment. But if, as the measure of peril, trends are used rather than fixed population levels, there is no cause for complacency over the survival outlook of any kind of marine turtle.

It is really not known how many kinds of sea turtles there are. An ornithologist would find the taxonomy of the group in an inconceivably rudimentary state. So the people whose ideal it is to save every single recognizable and genetically different form of every sea turtle genus are not even able to define the objects of their concern. As a first step in coping with the multiplying threats, somebody ought to tackle the job of showing how many genetically distinct forms there are among the various wholly separate breeding colonies.

At the moment, the recognizable kinds of sea turtles seem to me to be eight in number. There are surely many more, and some of them have been named, but I can't see that they have really been defined. There are five sea turtle genera: *Caretta,* the loggerheads; *Lepidochelys,* the ridleys; *Eretmochelys,* the hawksbills; *Chelonia,* the green turtles; and *Dermochelys,* the leatherbacks. Only in *Chelonia* and *Lepidochelys* are there clearly differentiated, named species. The various green turtle colonies of the eastern Pacific are easily told from the Atlantic green turtle, *Chelonia mydas,* although regions of confusion exist; and the flatback, *Chelonia depressa,* of northwestern Australia is a strikingly different animal that superficially looks more like a ridley than a green turtle.

If I had to judge the relative survival outlook of each of the eight kinds of sea turtles, I would list them in this order of decreasing security:

(1) *Dermochelys coriacea.* The leatherback is a spectacularly unique animal. Although nowhere abundant, it is less plagued by exploitation than the other genera. The eggs are taken in most nesting localities, but little use is made

of the meat. The skin is not used, the creature has no real shell, and though used in a few places as a cure-all, the oil smells too odd for Polly Bergen to put into cosmetics. Though by no means in reassuring shape—Costa Rica is losing its Matina rookery to egg poachers, and the famous Trengganu rookery in Malaya is clearly overexploited—the pelagic foraging habits of leatherbacks keep them relatively free of the nets of trawlers, and the new colonies that have been discovered, including an enormous one that has been studied by Peter Pritchard for the last four seasons in French Guiana, put *Dermochelys* a bit ahead of the others as a survival bet. Even so, by my book it is an endangered species.

(2) *Chelonia depressa.* I rank the flatback in this position only because Dr. Robert Bustard of Australia attests so emphatically to its safety. The species has the second most restricted breeding range among sea turtles, and this seems pretty alarming; but Dr. Bustard says that stewardship for wild species runs high in Australia, and that the flatback is under strict protection and sure to remain so.

(3) *Caretta caretta.* If *Caretta* is really a single worldwide species, it may actually be better off than the preceding. The strong protection of the colonies nesting on the Zululand coast of southeastern Africa and at Heron Island on the Great Barrier Reef, combined with the remaining American rookeries, might hold the line for a time. But despite the more or less effective legislation in the United States and the conservation efforts of a number of individuals and organizations, the encroaching development, the wheeled vehicles on beaches and lights on coastal highways, the raccoon predation, and the human egg poaching that still goes on are all hindering reproduction. At the same time, drownings of turtles in the nets of shrimp and menhaden fishermen are steadily increasing.

Besides, it seems unlikely that there is really only one kind of loggerhead. The Pacific form was separated long ago under the name *Caretta caretta gigas,* and though the original grounds for the separation were not firm, there very probably are two or more kinds of loggerheads in the world. If so, then the Atlantic form is in bad shape. It has almost disappeared from most of its range in Cuba and on the Caribbean mainland coasts. Colonies on the coasts of Turkey and Senegal are exploited with unmonitored intensity. A few carefully protected places on the coasts of Florida, plus a few islands in Georgia, South Carolina, and North Carolina, may be the last stronghold of the Atlantic loggerhead, and the long-term trend is not heartening.

(4) *Chelonia agassizi,* the black turtle of the Pacific. If the survival of the black turtle depended on its Mexican and Central American populations, it would be in bad trouble. It is less sought after for meat than the Atlantic green turtle, but it gets involved in the vast slaughter the hide hunters and egg poachers wreak on the Pacific ridley. The black turtle of the eastern Pacific lacks the numbers to withstand that abuse, and may well become an incidental casualty along the American mainland shores. To my eye, however, the black turtle stock occurs elsewhere—in the Galápagos Islands, among the mid-Pacific Islands, and in parts of the Indian Ocean. With its range extending through so much territory, the complete loss of the Mexican and Central American colonies might not obliterate *Chelonia agassizi;* but here again, the name, as I am using it, surely covers a number of hitherto unnamed races. The sooner these are properly defined, the sooner concern over their plight will be generated.

(5) *Lepidochelys olivacea,* the Pacific ridley. Until lately this little turtle seemed on the way to extirpation from the eastern Pacific. The inane and catastrophic vogue for turtle leather has focused insupportable slaughter on both the migrating ridley flotillas and the onshore *arribadas,* as the Mexicans call the enormous nesting aggregations. While Mexico has organized programs of research and control, exploitation has far overreached the restraints, and for a while it seemed likely that the species would be wiped out of Mexico. And so it still may be. The Pacific ridley is probably the world's most abundant sea turtle, but it is also the most massively persecuted. No species better illustrates the inadequacy of population numbers as a sole measure of security. The ridley take in Mexico was more than a million in 1968—and those were just the legal, recorded landings. The famous *arribada* at Piedra de Tlacoyunque in the state of Guerrero declined from 30,000 in 1968 to a few hundred in 1969.

My reason for rating the species no lower in the list is some recent evidence that the leather trade may be dwindling. It is high time. Sea turtle leather is really not very good; its current vogue results from pure public relations. And with Dr. F. Wayne King of the New York Zoological Society revealing the irresponsible shortsightedness of the international traffic, with the Mexican population already reduced to a level that is scaring the industry and engendering renewed official protective efforts, and with new *flotas* and *arribadas* recently reported along the Central American coast, the situation now seems more fluid than desperate. So I am inclined to keep the antepenultimate place in my list for the Atlantic green turtle, which I think is in somewhat worse shape than the Pacific ridley. I ought to say that Dr. Peter Pritchard, an extraordinarily able turtle man who got a PhD doing research on ridleys, disagrees with this judgment. It goes to show how risky such comparisons can be.

(6) *Chelonia mydas,* the Atlantic green turtle. When I grouped all known "black turtle" colonies, there were left the *Chelonia* populations nesting in the Caribbean, in the Guianas, and at Ascension Island; plus—for lack of any demonstrated grounds for separating them—some Pacific colonies that are obviously not *C. agassizi* and so, simply because of our ignorance, have to be grouped with the Atlantic green turtle as *C. mydas.* The resulting unwieldy, surely unnatural "species" includes a lot of turtles—enough to allay the concern of anyone not aware of the losses and depletion that the species has undergone during the past two centuries, and of the rising rate of exploitation.

It is these trends, again, and not absolute population numbers, that seem the only sensible basis for assessing the survival outlook of the green turtle. In the case of the western Caribbean green turtle, the course of events is especially dismal. Because long-term tagging has roughed out the migratory cycle of the Tortuguero colony in Costa Rica, it can be shown to be increasingly under attack everywhere. Even in Florida, medieval legislation, staunchly supported in recent political controversy, permits the commercial exploitation of an almost vanished green turtle colony. Some of the Pacific rookeries are located where there are religious taboos against eating

meat. In some of these, however, the egg harvests are heavy; and, moreover, when the turtles leave the breeding ground they go out into wholly unknown resident range, where exploitation may be completely unmonitored.

The greatest need is for inviolate sanctuaries where the capture of turtles is prohibited on or anywhere near the beach, and where no eggs are taken. In the case of every existing green turtle sanctuary, migration takes the turtles away to resident range that, if known, is unprotected. For example, the nesting turtles of Ascension Island and at the sanctuaries in Surinam are fully protected, and in both locations poaching is almost nonexistent. But when they leave both places the turtles travel a thousand miles or more to feeding grounds along the coast of Brazil. There the pressure of exploitation is growing almost as fast as it is in the Caribbean.

So despite the sizable remaining populations of *Chelonia mydas*, as I define it here, and despite the rapid spread of anxiety over its decline and the efforts to arrange the international programs required to stop it, the position of the green turtle is clearly degenerating.

LAST IN THE LIST are the Mexican ridley, *Lepidochelys kempi*, and the hawksbill, *Eretmochelys imbricata*. I have thought a lot about the claim each has to being the most endangered sea turtle, and find it hard to judge between them. Taken together, they graphically show the difficulty inherent in such judgment, because for diametrically different reasons they both have insecure grips on the future. The hawksbill is in danger because it nests too diffusely to be protected, the ridley because it breeds in such concentrated gangs.

The Mexican ridley forms the most heavily aggregated reproductive gatherings of any reptile—any vertebrate animal, probably. Except for occasional isolated single nestings elsewhere along the southern coast of the Gulf of Mexico, its breeding and nesting is restricted to a few mass emergences, in which as many as forty thousand turtles used to come out in a single day on a short stretch of the coast of Tamaulipas near the town of Rancho Nuevo. No other *arribadas* of *L. kempi* are known anywhere, and the occasional lone nestings south and north of the Rancho Nuevo area are probably too isolated to be of any consequence to the ultimate survival of the animal. As to exploitation, the big threat is the hide hunters, who have repeatedly tried to get permits from the Mexican government to raid the colony. An efficient turtling team could reduce the species to half its numbers in one year. By the end of a second season they would probably insure the subsequent extinction of *Lepidochelys kempi* by the chronic background drain imposed by trawl-net drownings and egg poachers. The predicament of the Gulf ridley is thus a classic case, in which a small population with minuscule reproductive range is undergoing constant poaching and accidental inroads, and faces the constant threat of sudden disastrous commercial raiding.

The hawksbill is in a very different position. If the main weakness of the ridley is its restricted breeding range, the hawksbill's trouble is overdeployment of its reproductive effort. Hawksbills are spread throughout the world's tropical waters. They forage mainly around reefs, and they nest on almost any stretch of sand shore, no matter how short it may be. No other sea turtle is so solitary in its nesting. In a few places small groups may come out together, but mainly reproduction is carried out by females that go ashore alone, sometimes where other species nest, sometimes on little scraps of beach that any other sea turtle, except possibly a Pacific ridley or Galápagos black turtle, would spurn. The exploitation of the hawksbill has increased drastically during the past two decades. Besides a steady growth of the tortoiseshell market in Europe and Japan, the skins and calipee are bought in some places, and the turtle itself is eaten. As a result, Caribbean hawksbills now bring the hunter as much as $15 apiece, which is usually more than he could earn in a week by any other work available. So, with hawksbill eggs more favored by local people than any other, and with scuba divers snatching young hawksbills out of their reef retreats for the hell of it, and marine curio shops selling young ones stuffed and polished for hanging on your wall, there is cause for the gravest concern over the hawksbill. And its attenuated nesting range makes it impossible to provide adequate breeding sanctuaries.

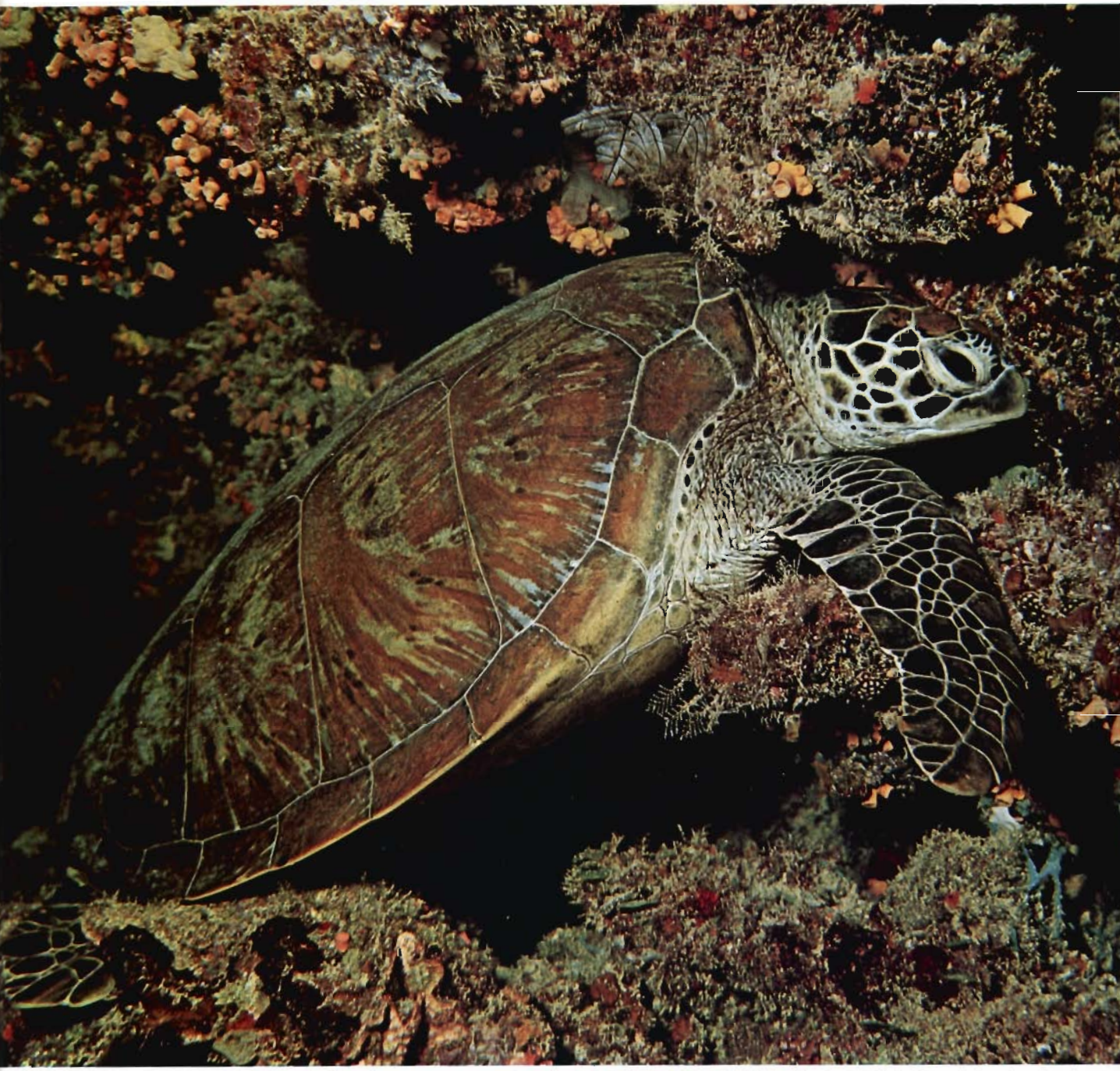
So there is really little choice between hawksbill and Mexican ridley as the most threatened kind of sea turtle. If the tortoiseshell trade could be killed, the hawksbill would probably survive. The fate of the ridley depends wholly on the ability of the species to withstand the casual inroads of the trawlers, on abolishment of the legal commercial turtling still permitted in Florida—which is a main migratory station of the ridley—and, above all, on the good will and good luck of the Mexican government in protecting the Rancho Nuevo breeding ground.

When I first went to Costa Rica with a National Science Foundation grant to study the ecology of sea turtles, my main aim was to work out the routes and stations of the migratory travels of *Chelonia*. I soon found it difficult to stay clear of the complex relationships between turtles and people. It was obvious that the Tortuguero nesting ground, where I had set out to develop a long-term tagging project, was on the way to oblivion. There was organized exploitation along the entire nesting beach. The turtles were turned for the market as soon as they came up out of reach of the surf. Up at the Nicaraguan resident ground, the bag limit was simply the capacity of the turtle schooners to carry turtles away.

It seemed then that the mayhem on the nesting beach was the main threat, and that once that was stopped the colony might withstand the drain to the turtle boats. In fact, it occurred to me that in *Chelonia* the world had a marine herbivore that, with a little study and wise management, could be made a resource of great importance. People were getting nervous over their own growing numbers, and talk of turning to the sea for food was spreading. The green turtle appeared to have special promise in this respect, being not only good to eat but virtually the only edible vertebrate able to harvest the vast crops of submarine vegetation that spread in shallow, warm, protected water. I preached this so hard that lately I have been reproached for having helped snowball the exploitation that now threatens to destroy the resource.

What I had in mind, however, was not green turtle on every table but rather turtle on the tables of the seaside people who had fished out their reefs and couldn't afford the equipment for deepwater fishing. This was Joshua

DOUGLAS FAULKNER

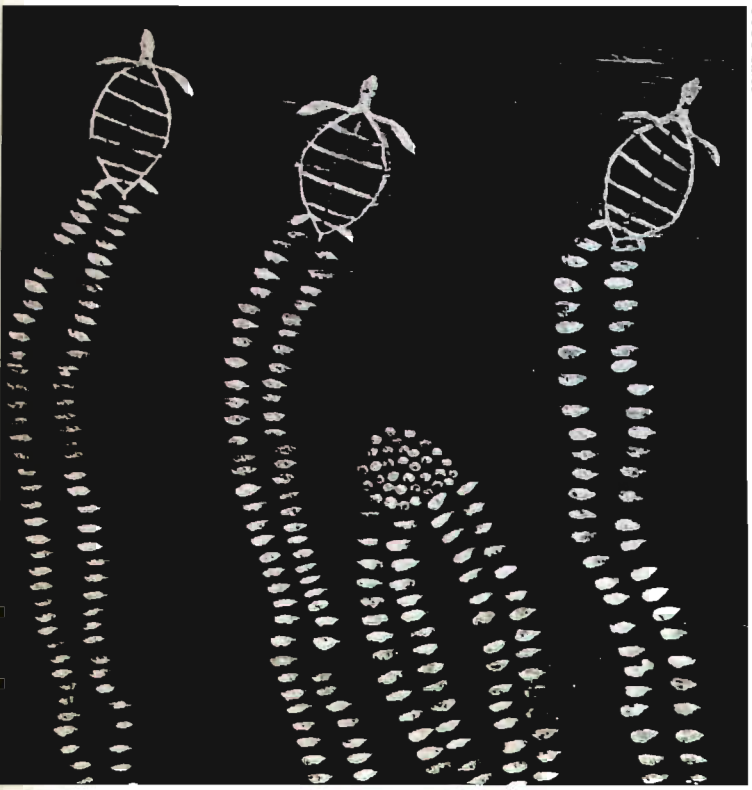


In a rare photograph, a green turtle sleeps on a coral ledge at a depth of 35 feet on Australia's Great Barrier Reef.

Powers' aim when he organized the Brotherhood of the Green Turtle in 1957, and that of the Caribbean Conservation Corporation that grew out of the Brotherhood. None of us visualized the demand that would come when countries that once were poor grew prosperous, and when seafood restaurants began to feel insecure if turtle was missing on their menus. Just the other day, looking back through some of the first things I wrote about sea turtles, I found this passage in *Handbook of Turtles:*

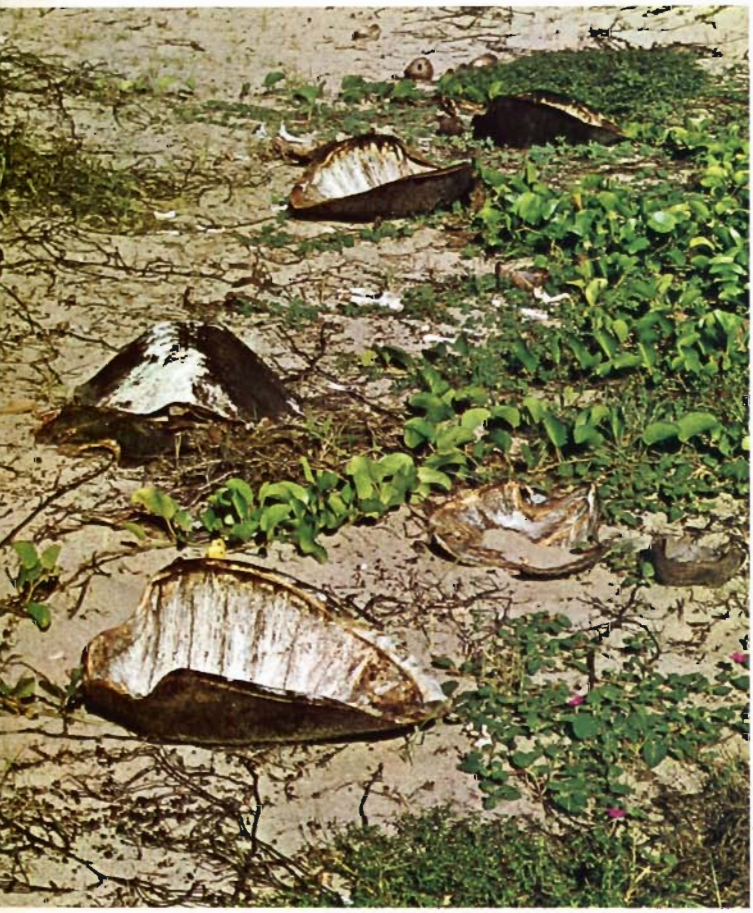
"Although the green turtle is in no immediate danger of extinction, it will support no resurgence of the industry. It seems almost certain that with modern methods of refrigeration and food preservation to enlighten the inland public concerning the gastronomic properties of this succulent reptile, the pathetic remnant of the once-teeming hordes will be pursued with harpoon and stop net, and the centers of activity will invade even more remote waters until the animal is backed against the wall."

Now the resurgence I spoke of has come to pass, and I am as sure now as I was in 1952 that it is going to be insupportable. It was brought on by three changes in the world: the spread of a more imaginative attitude toward eating in the United States some twenty years ago; the prosperity of Western Europe; and an increased demand for turtle byproducts. The first factor came into play after the Second World War, when a lot of GIs came home



FRITZ GORO

An aboriginal bark painting from northern Australia shows turtles returning to the sea after laying their eggs. And the beach at Guerrero, Mexico, is littered with the shells of Pacific ridleys slaughtered for turtle leather.



PETE PRITCHARD

more open-minded about victualing than they once had been. Seafood restaurants broke out all up and down the steak-and-potato belt. They made big industry out of the shrimp business, and green turtle became the touchstone of the exciting menu. This latter vogue—and it is really more vogue than gastronomy, because restaurant turtle steak is mostly dismal—has practically wiped out the feeble remnant of the Florida green turtle population. Coming on top of the original luxury soup trade, it is a major new threat to the green turtle in the western Caribbean.

As to the effect of European opulence, the demand that it has generated is a brand new and surprising factor. The biggest market for turtle outside the United States is now West Germany. According to Alfred Knopf, a reliable source of such lore, the best turtle soup in the world is now West German. John Lusty, proprietor of the famous London turtle soup factory and grandson of its founder, disagrees. Mr. Knopf's opinion is a straw in the wind all the same. Turtle soup used to be ritualistically English, although always the fare of the elite. Such days are gone. Mr. Lusty makes instant turtle soup tablets, and German initiative is ransacking the Earth to supply the chefs of Munich and Frankfurt.

The only hope to save the Atlantic populations of the green turtle is wholehearted international cooperation and an as yet unborn willingness to put the survival of the species before immediate self-interest. The first effort to generate that kind of shared responsibility was made by the Caribbean Conservation Corporation. Through its Operation Green Turtle, a dozen countries and islands were for eight years made partners in a joint restocking effort and were provided whatever information or techniques came out of the Tortuguero project. While no new breeding colonies have as yet been detected, a realization of the plight of *Chelonia* in the Caribbean was planted in places where none had been before. Meantime, the CCC has continued its monitoring of the Tortuguero nesting ground, and has provided facilities for varied research projects there and elsewhere in the Caribbean. Its operations in Costa Rica were a point of condensation for a Tortuguero National Park, one of three projects of the vigorous new national park service of Costa Rica.

More recently, the International Union for Conservation of Nature vastly extended the outlook for international sea turtle stewardship by establishing a special committee of its Survival Service Commission. The members of this Marine Turtle Group were carefully chosen for their involvement with sea turtle biology or conservation in strategic localities around the world. The World Wildlife Fund has financed two meetings of the group at IUCN headquarters in Morges, Switzerland. There was nothing ceremonial or perfunctory about those meetings. Each time, a dozen or more people from practically everywhere spent five days sharing information, hopes, and forebodings, and objectively searching for answers to problems and ways to avert disasters. Some rays of hope came out of the sessions, but the main advance was the shared understanding of the scope and gravity of the problems presented by avidly exploited animals with international migratory ranges.

With the possible exception of the Australian flatback, no kind of sea turtle can be given a sure survival outlook by protecting it within the frontiers of a single country.

To date, there is no international program protecting a species throughout its range. There almost was. The world's first approach to a closed system of migratory sea turtle protection almost materialized in 1969. Disturbed by the poor nesting season we had reported at Tortuguero for 1968, and urged on by expressions of concern from a great many people, a group of high-level delegates from Costa Rica, Nicaragua, and Panama met in a *conferencia tripartita* in San José. Nicaragua was there because, according to calculations based on our tag returns, at least two-thirds of the Tortuguero nesting colony is derived from the extensive turtle grass pastures off the coast of Nicaragua. Panama is a resident ground or migratory station for perhaps half of the remainder. So those three countries working together could almost certainly insure the survival of *Chelonia* in the western Caribbean.

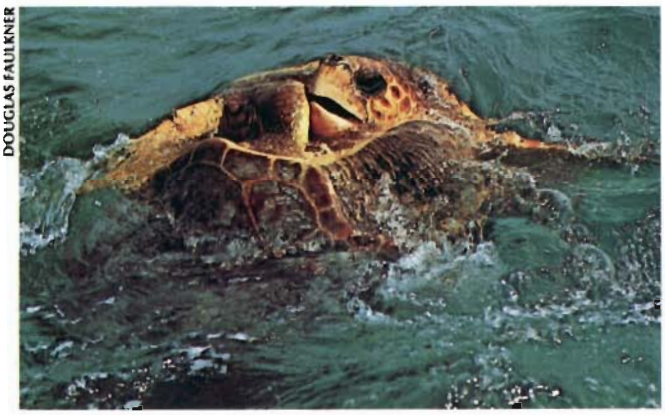
After three days' deliberations, the delegates agreed to call a three-year moratorium on turtling in all their home waters, while they worked out a permanent plan that would give Costa Rica, custodian of the nesting ground, a fair share of a strictly controlled yearly harvest without raiding the nesting colony. Then they went home to obtain what was expected to be automatic ratification. When Billy Cruz, Costa Rican representative of the CCC, cabled me the news, I happily telephoned colleagues who for years had been hoping that some such thing would happen. I wrote IUCN headquarters, too, suggesting that congratulations were in order, and there was great rejoicing. The day of international sea turtle conservation had dawned.

Only it hadn't. What Nicaragua did was sweep the San José agreement under the rug and build two big, modern, turtle processing plants, kick out the Cayman turtle schooners, and seduce the Miskito Indians—the Turtle Indians, probably the most specialized turtle culture in the world—into killing feverishly for the factories. Now the Miskitos are taking home a little cash instead of meat, and with it buying an inadequate diet to replace the good one provided for ages by the turtle colony with which their society had evolved. Dr. Bernard Nietschmann of the University of Michigan has a forthcoming article on this

On an island of the Great Barrier Reef, a Melanesian native strips a female green turtle of its eggs, meat, intestines.

FRITZ GORO

DOUGLAS FAULKNER



DAVID HUGHES/BRUCE COLEMAN INC.

Vignettes of green turtle life . . . Mating at sea, a violent, acrobatic, and rarely observed affair . . . digging a hole for one of many egg deposits . . . a hatchling's emergence.

debacle in the *Journal of Human Ecology*. It is a hair-raising story, not only because of what is happening to the Indians and the turtles, but because the development killed the rising resolve of the Costa Rican officials to curb the turtling at Tortuguero.

For Costa Rica also has two turtle processing plants. They are supplied by boats that cruise along the nesting shore from June through August and harpoon the mating pairs or the females going ashore or returning through the surf. Taking turtles on the beach has been illegal for twelve years. But the harpoon boats come in so close you might as well turn the hunters loose on shore.

Two special aspects of this situation make it stick badly in my craw. One is the absence of any extenuating ignorance by the parties involved as to what they are doing. *Chelonia* is the best known of the sea turtles, and the life cycle of the Tortuguero nesting colony is better known than that of any other population. Both countries know that Costa Rica has charge of the only green turtle breeding ground remaining in the western Caribbean, and that the Nicaraguan pastures are populated by turtles that hatch on the Costa Rican shore and nowhere else. This simple ecologic picture has been repeatedly made plain. And still they continue to subject the declining resource to growing exploitation. The other bitter pill is that both countries are depriving the poor coastal people of turtles they desperately need, while at the same time espousing an export industry that is bound to obliterate the resource.

So the world's first international agreement for sea turtle conservation has disintegrated, and about all we can do is wait and see whether new losses, sure to come, will scare the decision-makers into making a new effort at cooperative control. Meantime, turtles still come to Tortuguero to nest each season, and we still see tags that we have put on them as long as eight or ten years before. As time passes, these contacts accumulate, and various kinds of new information are emerging from the records

of such repeated encounters with individual nesters.

The usual motive for tagging a migratory animal at its breeding ground is to find out where the colony comes from—whether the animals are derived from a single year-round habitat, or from several distant places. That was the first aim of the tagging program at Tortuguero when I set it up in 1955. To turtlers and fishermen, green turtles were already known to be long-distance migrants, but this had never been demonstrated to the satisfaction of zoologists, and was, in fact, generally doubted. Why, I was never able to figure out. It seemed to me that, over and above the risk involved in ignoring lay opinion on such matters, the mere distribution of the nesting sites vis-à-vis the nearest feeding pastures indicated periodic long-range travel. In any case, only a few months after our first season at Tortuguero an international tag return came in. It was from up in the Miskito Cays, where the Cayman turtle boats were operating, and it reinforced what the captains had told me: that the Nicaraguan turtles nested in Costa Rica.

As years passed, repeated long-distance recoveries soon filled in the pattern of migration. They showed that while Nicaragua was the main source of the colony, other sizable parts of it came from Panama, the Guajira Peninsula of Colombia, and the Yucatán Peninsula of Mexico. Returns from more far-flung localities—Trinidad, Florida, and Martinique, for example—have slowly trickled in. Later on, the relative volumes of returns from different places began to give some indication of the relative sizes of the resident colonies there.

A significant aspect of the long-distance recoveries is that none has been made on any other nesting beach. However, we have recently learned that turtles from two different rookeries may mix on the feeding ground. This was shown when the northernmost Brazilian recoveries of turtles tagged at the Ascension Island nesting ground began overlapping the southernmost recovery localities for turtles tagged in Surinam by Dr. J. P. Schulz and his associates, and by Dr. Peter Pritchard.

The growing pattern of long-distance recoveries strongly suggested that the migrants are accomplished open-sea navigators, and the tagging program at the midocean nesting ground at Ascension Island was organized to test that possibility. The consistent recovery of Ascension females on the coast of Brazil confirmed the existence of an island-finding ability, and of some kind of advanced navigation mechanism.

THOSE ARE THE THINGS to be learned from long-distance tag recoveries. Over and above their intrinsic interest as natural history, the results led into two separate collateral avenues: research to explain open-sea orientation, and planning for the international conservation efforts obviously necessary to save the green turtle. But further insight into the life cycle comes from repeated contacts with the turtles at the nesting beach. These contacts are of two kinds: short-term recoveries, made after the twelve- to fourteen-day renesting intervals of a female during her stay at the nesting beach; and remigration returns, the successive migratory visits that an individual turtle makes at intervals of two or more years. One thing we hoped to discover from these was the growth rate of the female turtles after they reach maturity. Being reptiles, they supposedly had no definitive upper size limit, but simply kept on growing after reaching maturity, as rattlesnakes or largemouth bass presumably do. The females that come to Tortuguero range widely in shell length—from around 28 inches up to the 46 inches of the big wind-turtles, as the local people call them. It seemed reasonable to attribute this wide range in body length to age, but as time passed we could detect no growth in the turtles we measured. Whatever increase there was could not be reliably measured with the big wooden calipers we used. Finally, however, when the data had accumulated for a dozen years, we took the whole lot over to the statistics department and got back a tenth of an inch per year as the average increase in overall body length.

The figure was surprising, and its bearing on our studies of the colony became apparent when, after the bad nesting season at Tortuguero in 1968, nesting was very heavy in 1969, and we began trying to account for the sudden increase. Naturally, we looked for evidence of the arrival of an unusually big group of new nesters. But how do you identify a first-time nester? With only the negative evidence of her failure to bear a tag, there was always the chance that the turtle was merely one that had been missed by the tagging crew during an earlier nesting season. This problem of spotting the true neophytes among the untagged arrivals was aggravated by the excruciatingly slow growth rate, which suggested that the wide range in shell length meant simply that the females matured at different sizes—just as humans do. So we couldn't just tally all big, untagged turtles as old ones that we had missed earlier, and all small ones as new recruits to the breeding population. Some of the big ones were big because they were old; while some were already big, because of genetic or ecologic factors, when they made their first trip to the nesting beach.

Nevertheless, there was bound to be *some* relation between size and age, and finding it seemed important to our understanding of what was going on in the turtle population. My wife closeted herself with the tagging logs, and after long toil came up with a size group that was almost self-evidently neophyte. It was the 36-inch or shorter shell length class. Any turtle encountered with an overall shell length of no more than 36 inches could be tallied as a new addition to the nesting colony without introducing any important error. This may seem a small advance, but it wasn't. It was a way of determining whether part of the nesting peak in 1969 was produced by the maturing of new recruits. And that turned out to be the case. There was a marked increase in the number of 36-inch nesters that year.

But those newly matured females were not wholly responsible for the peak. Another factor was an internal, lifting-yourself-by-your-shoestrings kind of change, which, like the growth rate, came to light only because we had stayed in the tagging business so long a time. We had known for years that the females of the western Caribbean population nest on dual cycles—that some of them come back to the beach after a two-year absence, and some after a lapse of three years. The three-year cycle is the more frequent, in ratio of about two to one. We have never recorded a return to Tortuguero after a single year's absence. You find such nonannual breeding rhythms in some kinds of birds—condors, albatrosses, penguins, the sooty

tern—but they have in no case been accounted for. It seems possible that they simply represent the amount of time the female requires to prepare for the physiologic tour de force of traveling hundreds of miles to a breeding ground and then, in the case of *Chelonia,* remaining along an almost foodless shore until as many as five, or possibly even six or seven, nesting emergences have been carried out at two-week intervals.

PERHAPS THIS FEAT requires more than one year's physiologic preparation. And perhaps the two-year and three-year dichotomy just reflects variable feeding conditions in the home range of the individual turtles. That the Surinam green turtles often nest annually does nothing to clarify the puzzle. Little is known about fluctuations in the productivity of turtle grass pastures; but currents wax, wane, and shift about in the western Caribbean, and the hurricane belt moves back and forth. Such changes probably affect the condition of the pasturage or interfere with the daily grazing regimen, and thus influence the reproductive cycle. In any case, it seemed most likely that some kind of ecologic changes at the resident ground caused the shifting between the two cycles. But whatever the cause of the duality in nesting cycles, the bearing on the productivity of the population was clear: the more prevalent the two-year cycle, the more young the colony would produce.

It took ten years to learn that an individual female may shift back and forth from the longer to the shorter cycle, or vice versa. We had to await the accumulation of two-time returns of tagged females to the nesting beach, and we have now recorded 50 of these, as well as five three-time returns. These include cycle shifts in both directions. Changes to the shorter cycle have been far more frequent than the other way around, however. There was a rash of shortened cycles in 1969, and this should probably be considered, along with the coming of newly matured females, as a factor in the increased nesting of that year.

Besides those two well-documented, interchangeable nesting cycles, we have slowly grown to suspect that occasional female turtles may wait four years between nestings. This is hard to prove because the four-year intervals that we have recorded might merely reflect defective patrolling of the beach—cases in which a turtle nesting on a two-year cycle was missed on her first return, and then seen again on a second migration four years after she was originally tagged. It will take statistical analysis to prove the reality of the four-year cycle, and for that the efficiency of the sampling done by the tagging crews has to be known. It will probably turn out that a four-year reproductive cycle is infrequent but normal in the Tortuguero population.

If so, one is tempted to reason further and suggest that western Caribbean green turtles must take whatever amount of time is necessary to prepare for their arduous breeding venture—that none can get ready in a single year, that some need two years to prepare, some three years, and others still longer times. This possibility can only be tested by statistics that we accumulate through continued tagging.

A very different way the renesting and remigration tag returns have paid off is in our studies of the goal sense and site fixity shown by the females when they return to nest. It is a challenge to explain not only how a thousand-mile open-sea course is navigated, but also how the journey can so often wind up with the migrant hauling out within a few yards of where she nested two or three years before. Practically, it is important to restoration efforts to know what goal sense it is that attracts a female ashore at the point she chooses as a nesting site.

Back in 1952 and 1953 I did a lot of scouting of Caribbean beaches, looking for sea turtle nesting grounds. Local people kept telling me that if you marked where a turtle came ashore on a given night, you only had to go back there two weeks later and you would find her again at exactly the same spot. The same thing is said by resident turtle people all around the world. While it is not altogether true, it is true enough to make you wonder how such insight ever comes to the people who tell you about it. All I can suggest is that the discovery of site tenacity is not made by turtle hunters, but by egg hunters, who don't kill the turtle but only sit waiting beside her till she has laid her eggs, and so have the chance to memorize her scars, deformities, or peculiar patterns of barnacles. Otherwise, the only way to learn about nest-site homing would be by the purposeful tagging of turtles, discovering first that they come ashore more than once in a given season—which, obviously, would not be self-evident—and then noticing that second nests are often dug close to the first ones.

The amazing reliability of that folklore has kept me open-minded when talking to backcountry people about turtles, even when their yarns had a wild sound to them. We have been tagging at Tortuguero for seventeen seasons now, and have gradually refined our system of marking the beach so that the positions of nests can be accurately recorded. What the records now show is that the females neither scatter at random along the rookery shore, nor come back to precisely the same spots each time, but instead recognize short *sections* of shore, and come back there time after time to nest. Although the occasional female nests five or six miles from a former landing place, the average separation of the points at which a turtle nests on two successive visits to the Tortuguero beach is about 1,000 yards. But the more arresting figure is the *modal* distance—the *usual* separation between two landings. This has proved to be 200 yards, just under an eighth of a mile. The figure is almost the same for the separation of the nests of a given season, of which we have thousands of records, and for the 500-odd intermigration returns after two or three years or more.

There have been so many of these 200-yard intervals, spread through so many nestings and so many years, that they alone seem all the proof you need that a sea turtle recognizes and returns to, not some familiar topographic feature, but a home section of shore that is most often 200 yards long, and is marked off for her by utterly unknown signs. What kind of delimitation could she possibly be using to locate such a strip of beach, with no durable topographic skyline behind it; where there are only dunes and coco plum ledges that grow or disappear through the years; where the surface of the sand is constantly scoured

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Archie Carr, author of So Excellent a Fishe, The Windward Road, *and* Ulendo, *and professor of zoology at the University of Florida, is a new* Audubon *contributing editor.*

by torrential rains and occasionally is stripped away completely and relaid by storms; and where strong longshore currents vary sporadically in direction and speed, and in the volume of freshwater they carry from the coastal rivers.

It seems impossible to put your finger on any mark that would last through a single two-year cycle, much less through the decade and more that some of our records cover. The local people, wise as they sometimes are, are no help in this case. They tell you vaguely it is Turtle Mountain—a 500-foot volcanic relic that rises alone just back of the northernmost end of the nesting beach—that directs the turtles in to their landing places. But over and above the fact that sea turtles see poorly above water, it seems unlikely that a seaside hill at one end of the nesting beach could be the beacon for such performances as the returns of a female that we recorded ashore eight times in six years on one half-mile span of the twenty-mile nesting shore, and in a position from which the mountain was completely out of sight from the eye level of a turtle.

So for quite a while smell has seemed a logical possibility as the landing sense. When a female turtle comes ashore she repeatedly pokes her chin and muzzle into the sand and holds it there a moment, sometimes moving along while her nose plows through the sand. All the shelled turtles—that is, all sea turtles except the shell-less leatherback—do this, some more industriously than others, but all often enough to demand an explanation. So for want of an explanation of site tenacity, we put two and two together and started calling sand *nuzzling* sand *smelling*.

But now that we have a lot more data on the fineness of the homing returns, I don't know what to think. Unless some smellable essence of the home strip oozes up from the groundwater and keeps reimpregnating the sand with a characteristic odor, there seems no way in which smell could guide the female.

WHATEVER THE GUIDE-SIGNS, they must be imprinted in the young at the time they hatch out, or while they travel down the beach to the sea and swim through the surf to begin a developmental migration that lasts six years or so. Although it is conceivable that the little turtles inherit their instructions for finding their hatching place when they return to nest, the capacity to be imprinted with the guide-signs seems a much less complex adaptation. The best assumption is that baby turtles leave their natal place with some indelible olfactory impressions that help them recognize the site six years later.

An observation that might lend strength to that idea is the dearth of nesting on sections of the Tortuguero shore where people live. You might be inclined to say that the people just scare the turtles away from the beach in front of their *ranchos*, but this is doubtful. There is no coastal highway at Tortuguero, no stream of car lights behind the dunes—only a few people in thatched dwellings, where the dim lamps are turned out early in the evening. What seems more probable is that through former decades the killing of nesting turtles and taking of eggs simply deleted from the colony the individuals that, as hatchlings, were imprinted with the tendency to nest in front of the little settlement.

Conversely, when big storms chop up a section of the shore where a turtle has faithfully returned to nest for years, she often will keep coming back there year after year, even though coco plums have been uprooted, old palms have fallen, and she has to climb a four-foot, wave-cut bluff to get to good nesting sand. Obviously, this neither proves that hatchling imprinting occurs, nor gives any clue as to what signs are imprinted.

In our theorizing about the phenomenon of green turtle navigation in the open ocean, imprinting has again been appealed to. At one time it was my tendency to relax and say that turtles probably find midocean islands by celestial navigation—the same way birds migrate, according to some ornithologists. But the more I thought about this, the harder it was to visualize the monumental evolutionary process it would take to build the necessary almanac instinct, the sense of the relation of changing signs in the sky to points on the surface of the Earth. Then Dr. David Ehrenfeld and Dr. Arthur Koch found that green turtles could hardly see anything with their heads out of water, and this further weakened the celestial navigation theory by ruling out stellar orientation.

As a matter of fact, there is no good explanation of the open ocean navigation of any animal, either aerial or aquatic. But in the case of the South Atlantic green turtle, which cruises across 1,200 miles of featureless ocean and makes pinpoint landings on Ascension Island, the steady current that flows from the island to the Brazilian resident grounds makes smell a reasonable component of the guidance process. The theory is that an Ascension smell fans out downstream in the South Equatorial Current, stays smellably strong until it reaches Brazil, and serves to keep the migrants to Ascension in the latitude of the island as they travel eastward. The necessary easterly heading, the theory suggests, is maintained by a compass sense, which now has been found to be widely prevalent among both vertebrate and invertebrate animals. The main virtue of this theory is that all it would require of evolution would be a built-in capacity to be imprinted by, and to perceive and judge relative concentrations of, a special smell—and not the fantastically complicated map sense that celestial position-finding would require.

The most frustrating aspect of my work with sea turtles has been our efforts at electronic open-sea tracking. The olfaction theory could easily be tested if the migratory paths of the turtles, or sections of them, could be accurately tracked. If smell is actually the key to latitude in the Ascension journey, female turtles taken from the island before completing their nesting, and released a hundred miles or so across the current from Ascension, should prove unable to establish proper return headings. Others, carried downstream, should make successful approaches to the island, perhaps on zigzag courses indicating appraisal of the home smell in the current coming from the island. Our efforts to get these track plots by long-range, surface-to-surface radio contact have yielded only meager results.

It would be comforting to find the smell part of the open-ocean navigation theory also involved in landfall recognition and nest site tenacity. But what kind or combination of odors could guide a migrant in, at the end of her trek across hundreds of miles of open water, to one 200-yard stretch of beach? We really have made very little progress in accounting for either the long-range navigation of turtles, or their ability to recognize their hatching place.

The things I have been speaking of all bear on the

practical problem of saving sea turtles from overexploitation and loss of habitat. It has never been clearly known, for instance, what in the eyes of a turtle constitutes a good nesting beach. Why do green turtles more often than not travel hundreds of miles from their year-round pasture ground to nest on a piece of beach that looks, to a man, like hundreds of miles of closer shore? The answer may partly be that the beaches that now are empty were long ago exhausted by overexploitation. Certainly, mass nesting once was much more widespread in the Caribbean than it is today, when big assemblages gather only at Tortuguero and Aves Island, a tiny islet in the middle of the eastern Caribbean. But there are cases in which no such explanation seems to apply.

The question of nest habitat choice is important to any effort to establish new breeding colonies. In Operation Green Turtle, the Caribbean Conservation Corporation, using transportation provided by the U.S. Navy, moved thousands of eggs and hatchlings from the Tortuguero rookery to eighteen likely looking beaches around the Caribbean. No new breeding colonies have as yet grown up, and nobody knows why. Perhaps the inoculations were just too weak—too few hatchlings were put out in each locality. Or possibly the surviving hatchlings went back to Costa Rica when they reached breeding age. But there is also the nagging thought that the places where the releases were made were unacceptable as nesting ground. An effort was made to select sites where nesting had once occurred; but perhaps changed conditions had made them unfavorable for nesting.

It has been suggested that there is a relation between nesting and the size and shape of sand grains, but exceptions in this respect make generalization profitless. Certainly a beach with too much clay or mud in the sand, or one composed of overlarge shell fragments, is never chosen; but practically anything else in the way of texture seems acceptable, providing drainage is good. So in trying to account for the clumped nesting of the green turtle, something other than the obvious physical features of the shore has to be proposed. After reviewing the case for olfactory piloting in a recent paper, I suggested that perhaps, in the opinion of a green turtle, a good nesting beach is any well-drained ocean shore swept by a current that (1) carries dissolved chemicals that the migrating adults can smell or taste a long way off and (2) transports the hatchlings to wherever they spend the first months of their lives. For these practical implications, as well as to gratify biologic curiosity, it seems urgent to test the idea that smell is used as a guide-sign.

IN THE LONG RUN, marine turtles, like the seas themselves, will be saved only by wholehearted international cooperation at the governmental level. That is an almost legendary substance. While waiting for it to materialize, the critical tactical needs seem to me to be three in number: more sanctuaries, more research, and a concerted effort by all impractical, visionary, starry-eyed, and antiprogressive organizations, all little old ladies in tennis shoes, and all persons able to see beyond the ends of their noses, to control the international commerce in sea turtle products.

For some time, organizations concerned with the survival of species of animals that are being commercially exploited have been faced with the obligation of deciding whether to mount international campaigns to discourage the use of products derived from the animals, or to encourage artificial culture projects. Actually the two courses are not mutually exclusive, but the aspirant farmers say they are, and they bemoan any move to depopularize products derived from animals that they say they will one day save from extinction by farming.

At Tortuguero, Costa Rica, where the author's green turtle research continues, a female lumbers back to her realm.

If things are left as they are, the commercial sea turtle industry seems certain to go on cynically mining to exhaustion its sources of supply. In the process, some of the species involved will probably be dragged down to nonviable population levels. In the case of the green turtle, prospective farmers say that if conservationists will only hold back in their trade-killing campaign, a commerce based on artificial culture can be developed, and this will quickly make poaching and commercial turtle hunting unprofitable.

The same is said by the people who plan to farm crocodilians. Superficially it sounds good, but there is fuzzy thinking in it. I have yet to see or hear of a work plan for any reptile ranch that shows in realistic detail how it expects to achieve a volume of production so great that it will do anything other than *increase* both demand and prices. If the enterprise is a commercial one, it will obviously do everything possible to create new markets. Just as obviously, it will not be able to satisfy these, and so will exacerbate, rather than relieve, the predicament of the natural populations.

And meanwhile, because nobody has yet worked out the problem of breeding sea turtles at production levels in enclosures, turtle farms will remain dependent on natural sanctuaries for the eggs from which they get the little turtles they propose to grow to slaughter size, and to flood the market with. Individual female green turtles have mated and laid in captivity, but nobody has ever approached the successful production of eggs in volume.

It obviously will be many years before turtle farms will do anything other than weaken the position of wild species. If turtle farming—as an alternative to depopularization—is to be espoused by people interested in the survival of natural species, the only effort to be encouraged should be a nonprofit, government-sponsored campaign in which many small, widespread, purely experimental projects simultaneously attack the problems of nutrition, disease control, and captive breeding; and which, from the beginning, freely share all information bearing on procedure and results. That sort of cooperative, nonprofit, pilot program might possibly lay groundwork for a pantropical turtle farm industry that would be able to spring into existence and from the beginning fill any new demand that it created. If this appears a reasonable possibility, then conservationists might logically give the campaign support.

For the time being, however, the only realistic course is a worldwide effort to discourage international traffic in sea turtle products of every kind. The demand can be built back quickly in that distant time when the farms are prepared to meet it. ■

After perhaps 50 million years of land life, a number of reptiles entered the sea. They were huge and formidable creatures. Some had oarlike limbs by which they rowed through the water; some were web-footed, with long, serpentine necks. These grotesque monsters disappeared millions of years ago, but we remember them when we come upon a large sea turtle swimming many miles at sea, its barnacle-encrusted shell eloquent of its marine life.

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