SILENT SPRING RACHEL CARSON

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RACHEL CARSON

With essays by Edward O. Wilson and Linda Lear

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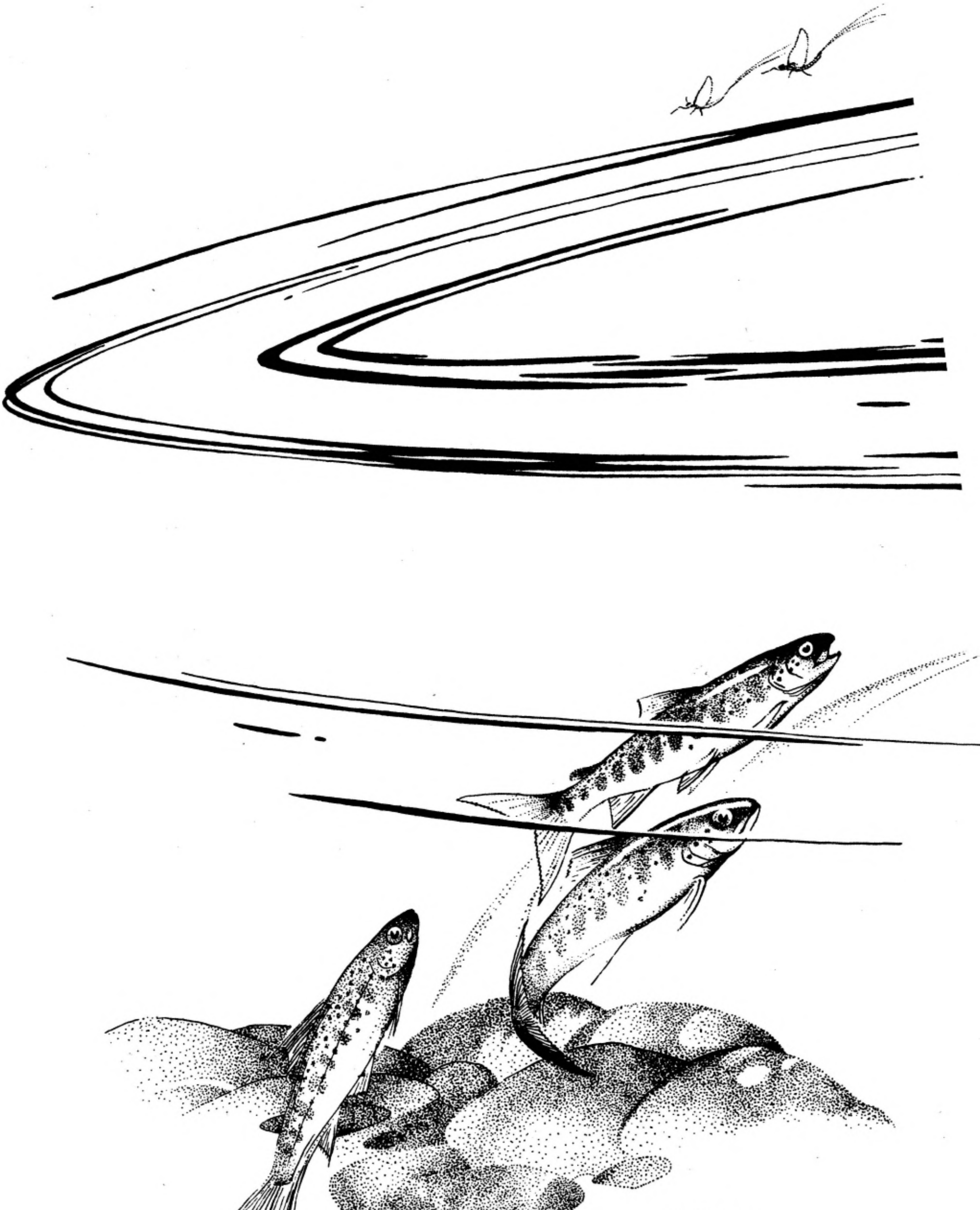

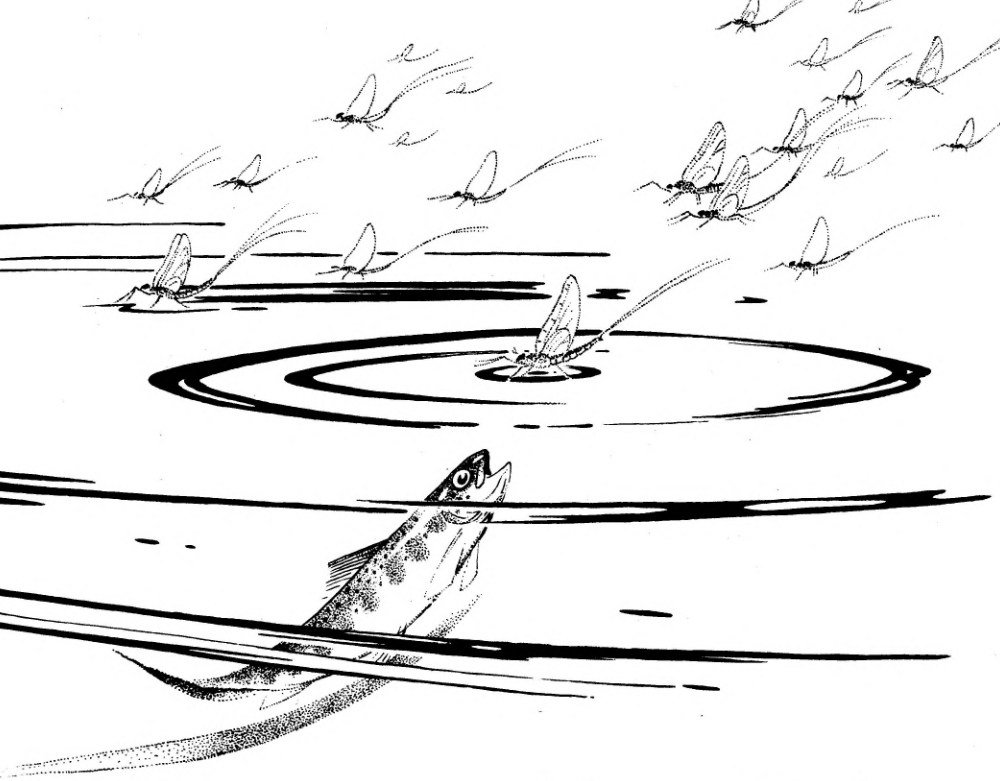

9. Rivers of Death

From the green depths of the offshore Atlantic many paths lead back to the coast. They are paths followed by fish; although unseen and intangible, they are linked with the outflow of waters from the coastal rivers. For thousands upon thousands of years the salmon have known and followed these threads of fresh water that lead them back to the rivers, each returning to the tributary in which it spent the first months or years of life. So, in the summer and fall of 1953, the salmon of the river called Miramichi on the coast of New Brunswick moved in from their feeding grounds in the far Atlantic and ascended their native river. In the upper reaches of the Miramichi, in streams that gather together a network of shadowed brooks, the salmon deposited their eggs that autumn in beds of gravel over which the stream water flowed swift and cold. Such places, the watersheds of the great coniferous forests of spruce and balsam, of hemlock and pine, provide the kind of spawning grounds that salmon must have in order to survive.

These events repeated a pattern that was age-old, a pattern that had made the Miramichi one of the finest salmon streams in North America. But that year the pattern was to be broken.

During the fall and winter the salmon eggs, large and thick-shelled, lay in shallow gravel-filled troughs, or redds, which the mother fish had dug in the stream bottom. In the cold of winter they developed slowly, as was their way, and only when spring at last brought thawing and release to the forest streams did the young hatch. At first they hid among the pebbles of the stream bed — tiny fish about half an inch long. They took no food, living on the large yolk sac. Not until it was absorbed would they begin to search the stream for small insects.

With the newly hatched salmon in the Miramichi that spring of 1954 were young of previous hatchings, salmon a year or two old, young fish in brilliant coats marked with bars and bright red spots. These young fed voraciously, seeking out the strange and varied insect life of the stream.

As the summer approached, all this was changed. That year the watershed of the Northwest Miramichi was included in a vast spraying program which the Canadian Government had embarked upon the previous year — a program designed to save the forests from the spruce budworm. The budworm is a native insect that attacks several kinds of evergreens. In eastern Canada it seems to become extraordinarily abundant about every 35 years. The early 1950's had seen such an upsurge in the budworm populations. To combat it, spraying with DDT was begun, first in a small way, then at a suddenly accelerated rate in 1953. Millions of acres of forests were sprayed instead of thousands as before, in an effort to save the balsams, which are the mainstay of the pulp and paper industry.

So in 1954, in the month of June, the planes visited the forests of the Northwest Miramichi and white clouds of settling mist marked the crisscross pattern of their flight. The spray — one-half pound of DDT to the acre in a solution of oil — filtered down through the balsam forests and some of it finally reached the ground and the flowing streams. The pilots, their thoughts only on their assigned task, made no effort to avoid the streams or to shut off the spray nozzles while flying over them; but because spray drifts so far in even the slightest stirrings of air, perhaps the result would have been little different if they had.

Soon after the spraying had ended there were unmistakable signs that all was not well. Within two days dead and dying fish, including many young salmon, were found along the banks of the stream. Brook trout also appeared among the dead fish, and along the roads and in the woods birds were dying. All the life of the stream was stilled. Before the spraying there had been a rich assortment of the water life that forms the food of salmon and trout — caddis fly larvae, living in loosely fitting protective cases of leaves, stems or gravel cemented together with saliva, stonefly nymphs clinging to rocks in the swirling currents, and the wormlike larvae of blackflies edging the stones under riffles or where the stream spills over steeply slanting rocks. But now the stream insects were dead, killed by the DDT, and there was nothing for a young salmon to eat.

Amid such a picture of death and destruction, the young salmon themselves could hardly have been expected to escape, and they did not. By August not one of the young salmon that had emerged from the gravel beds that spring remained. A whole year's spawning had come to nothing. The older young, those hatched a year or more earlier, fared only slightly better. For every six young of the 1953 hatch that had foraged in the stream as the planes approached, only one remained. Young salmon of the 1952 hatch, almost ready to go to sea, lost a third of their numbers.

All these facts are known because the Fisheries Research Board of Canada had been conducting a salmon study on the Northwest Miramichi since 1950. Each year it had made a census of the fish living in this stream. The records of the biologists covered the number of adult salmon ascending to spawn, the number of young of each age group present in the stream, and the normal population not only of salmon but of other species of fish inhabiting the stream. With this complete record of prespraying conditions, it was possible to measure the damage done by the spraying with an accuracy that has seldom been matched elsewhere.

The survey showed more than the loss of young fish; it revealed a serious change in the streams themselves. Repeated sprayings have now completely altered the stream environment, and the aquatic insects that are the food of salmon and trout have been killed. A great deal of time is required, even after a single spraying, for most of these insects to build up sufficient numbers to support a normal salmon population — time measured in years rather than months.

The smaller species, such as midges and blackflies, become re-established rather quickly. These are suitable food for the smallest salmon, the fry only a few months old. But there is no such rapid recovery of the larger aquatic insects, on which salmon in their second and third years depend. These are the larval stages of caddis flies, stoneflies, and mayflies. Even in the second year after DDT enters a stream, a foraging salmon parr would have trouble finding anything more than an occasional small stonefly. There would be no large stoneflies, no mayflies, no caddis flies. In an effort to supply this natural food, the Canadians have attempted to transplant caddis fly larvae and other insects to the barren reaches of the Miramichi. But of course such transplants would be wiped out by any repeated spraying.

The budworm populations, instead of dwindling as expected, have proved refractory, and from 1955 to 1957 spraying was repeated in various parts of New Brunswick and Quebec, some places being sprayed as many as three times. By 1957, nearly 15 million acres had been sprayed. Although spraying was then tentatively suspended, a sudden resurgence of budworms led to its resumption in 1960 and 1961. Indeed there is no evidence anywhere that chemical spraying for budworm control is more than a stopgap measure (aimed at saving the trees from death through defoliation over several successive years), and so its unfortunate side effects will continue to be felt as spraying is continued. In an effort to minimize the destruction of fish, the Canadian forestry officials have reduced the concentration of DDT from the ½ pound previously used to ¼ pound to the acre, on the recommendation of the Fisheries Research Board. (In the United States the standard and highly lethal pound-to-the-acre still prevails.) Now, after several years in which to observe the effects of spraying, the Canadians find a mixed situation, but one that affords very little comfort to devotees of salmon fishing, provided spraying is continued.

A very unusual combination of circumstances has so far saved the runs of the Northwest Miramichi from the destruction that was anticipated — a constellation of happenings that might not occur again in a century. It is important to understand what has happened there, and the reasons for it.

In 1954, as we have seen, the watershed of this branch of the Miramichi was heavily sprayed. Thereafter, except for a narrow band sprayed in 1956, the whole upper watershed of this branch was excluded from the spraying program. In the fall of 1954 a tropical storm played its part in the fortunes of the Miramichi salmon. Hurricane Edna, a violent storm to the very end of its northward path, brought torrential rains to the New

England and Canadian coasts. The resulting freshets carried streams of fresh water far out to sea and drew in unusual numbers of salmon. As a result, the gravel beds of the streams which the salmon seek out for spawning received an unusual abundance of eggs. The young salmon hatching in the Northwest Miramichi in the spring of 1955 found circumstances practically ideal for their survival. While the DDT had killed off all stream insects the year before, the smallest of the insects — the midges and blackflies — had returned in numbers. These are the normal food of baby salmon. The salmon fry of that year not only found abundant food but they had few competitors for it. This was because of the grim fact that the older young salmon had been killed off by the spraying in 1954. Accordingly, the fry of 1955 grew very fast and survived in exceptional numbers. They completed their stream growth rapidly and went to sea early. Many of them returned in 1959 to give large runs of grilse to the native stream.

If the runs in the Northwest Miramichi are still in relatively good condition this is because spraying was done in one year only. The results of repeated spraying are clearly seen in other streams of the watershed, where alarming declines in the salmon populations are occurring.

In all sprayed streams, young salmon of every size are scarce. The youngest are often "practically wiped out," the biologists report. In the main Southwest Miramichi, which was sprayed in 1956 and 1957, the 1959 catch was the lowest in a decade. Fishermen remarked on the extreme scarcity of grilse — the youngest group of returning fish. At the sampling trap in the estuary of the Miramichi the count of grilse was only a fourth as large in 1959 as the year before. In 1959 the whole Miramichi watershed produced only about 600,000 smolt (young salmon descending to the sea). This was less than a third of the runs of the three preceding years.

Against such a background, the future of the salmon fisheries in New Brunswick may well depend on finding a substitute for drenching forests with DDT.

The eastern Canadian situation is not unique, except perhaps in the extent of forest spraying and the wealth of facts that have been collected. Maine, too, has its forests of spruce and balsam, and its problem of controlling forest insects. Maine, too, has its salmon runs — a remnant of the magnificent runs of former days, but a remnant hard won by the work of biologists and conservationists to save some habitat for salmon in streams burdened with industrial pollution and choked with logs. Although spraying has been tried as a weapon against the ubiquitous budworm, the areas affected have been relatively small and have not, as yet, included important spawning streams for salmon. But what happened to stream fish in an area observed by the Maine Department of Inland Fisheries and Game is perhaps a portent of things to come.

"Immediately after the 1958 spraying," the Department reported, "moribund suckers were observed in large numbers in Big Goddard Brook. These fish exhibited the typical symptoms of DDT poisoning; they swam erratically, gasped at the surface, and exhibited tremors and spasms. In the first five days after spraying, 668 dead suckers were collected from two blocking nets. Minnows and suckers were also killed in large numbers in Little Goddard, Carry, Alder, and Blake Brooks. Fish were often seen floating passively downstream in a weakened and moribund condition. In several instances, blind and dying trout were found floating passively downstream more than a week after spraying."

(The fact that DDT may cause blindness in fish is confirmed by various studies. A Canadian biologist who observed spraying on northern Vancouver Island in 1957 reported that cutthroat trout fingerlings could be picked out of the streams by hand, for the fish were moving sluggishly and made no attempt to escape.

On examination, they were found to have an opaque white film covering the eye, indicating that vision had been impaired or destroyed. Laboratory studies by the Canadian Department of Fisheries showed that almost all fish [Coho salmon] not actually killed by exposure to low concentrations of DDT [3 parts per million] showed symptoms of blindness, with marked opacity of the lens.)

Wherever there are great forests, modern methods of insect control threaten the fishes inhabiting the streams in the shelter of the trees. One of the best-known examples of fish destruction in the United States took place in 1955, as a result of spraying in and near Yellowstone National Park. By the fall of that year, so many dead fish had been found in the Yellowstone River that sportsmen and Montana fish-and-game administrators became alarmed. About 90 miles of the river were affected. In one 300-yard length of shoreline, 600 dead fish were counted, including brown trout, whitefish, and suckers. Stream insects, the natural food of trout, had disappeared.

Forest Service officials declared they had acted on advice that 1 pound of DDT to the acre was "safe." But the results of the spraying should have been enough to convince anyone that the advice had been far from sound. A cooperative study was begun in 1956 by the Montana Fish and Game Department and two federal agencies, the Fish and Wildlife Service and the Forest Service. Spraying in Montana that year covered 900,000 acres; 800,000 acres were also treated in 1957. The biologists therefore had no trouble finding areas for their study.

Always, the pattern of death assumed a characteristic shape: the smell of DDT over the forests, an oil film on the water surface, dead trout along the shoreline. All fish analyzed, whether taken alive or dead, had stored DDT in their tissues. As in eastern Canada, one of the most serious effects of spraying was the severe reduction of food organisms. On many study areas aquatic insects and other stream-bottom fauna were reduced to a tenth of their normal populations. Once destroyed, populations of these insects, so essential to the survival of trout, take a long time to rebuild. Even by the end of the second summer after spraying, only meager quantities of aquatic insects had reestablished themselves, and on one stream — formerly rich in bottom fauna — scarcely any could be found. In this particular stream, game fish had been reduced by 80 per cent.

The fish do not necessarily die immediately. In fact, delayed mortality may be more extensive than the immediate kill and, as the Montana biologists discovered, it may go unreported because it occurs after the fishing season. Many deaths occurred in the study streams among autumn spawning fish, including brown trout, brook trout, and whitefish. This is not surprising, because in time of physiological stress the organism, be it fish or man, draws on stored fat for energy. This exposes it to the full lethal effect of the DDT stored in the tissues.

It was therefore more than clear that spraying at the rate of a pound of DDT to the acre posed a serious threat to the fishes in forest streams. Moreover, control of the budworm had not been achieved and many areas were scheduled for respraying. The Montana Fish and Game Department registered strong opposition to further spraying, saying it was "not willing to compromise the sport fishery resource for programs of questionable necessity and doubtful success." The Department declared, however, that it would continue to cooperate with the Forest Service "in determining ways to minimize adverse effects."

But can such cooperation actually succeed in saving the fish? An experience in British Columbia speaks volumes on this point. There an outbreak of the black-headed budworm had been raging for several years. Forestry officials, fearing that another season's defoliation might result in severe loss of trees, decided to carry out control operations in 1957. There were many consultations with the Game Department, whose officials were concerned about the salmon runs. The Forest Biology Division agreed to modify the spraying program in every possible way short of destroying its effectiveness, in order to reduce risks to the fish.

Despite these precautions, and despite the fact that a sincere effort was apparently made, *in at least four major streams almost 100 per cent of the salmon were killed.*

In one of the rivers, the young of a run of 40,000 adult Coho salmon were almost completely annihilated. So were the young stages of several thousand steelhead trout and other species of trout. The Coho salmon has a three-year life cycle and the runs are composed almost entirely of fish of a single age group. Like other species of salmon, the Coho has a strong homing instinct, returning to its natal stream. There will be no repopulation from other streams. This means, then, that every third year the run of salmon into this river will be almost nonexistent, until such time as careful management, by artificial propagation or other means, has been able to rebuild this commercially important run.

There are ways to solve this problem — to preserve the forests and to save the fishes, too. To assume that we must resign ourselves to turning our waterways into rivers of death is to follow the counsel of despair and defeatism. We must make wider use of alternative methods that are now known, and we must devote our ingenuity and resources to developing others. There are cases on record where natural parasitism has kept the budworm under control more effectively than spraying. Such natural control needs to be utilized to the fullest extent. There are possibilities of using less toxic sprays or, better still, of introducing microorganisms that will cause disease among the budworms without affecting the whole web of forest life. We shall see later what some of these alternative methods are and what they promise. Meanwhile, it is important to realize that chemical spraying of forest insects is neither the only way nor the best way.

The pesticide threat to fishes may be divided into three parts. One, as we have seen, relates to the fishes of running streams in northern forests and to the single problem of forest spraying. It is confined almost entirely to the effects of DDT. Another is vast, sprawling, and diffuse, for it concerns the many different kinds of fishes — bass, sunfish, crappies, suckers, and others — that inhabit many kinds of waters, still or flowing, in many parts of the country. It also concerns almost the whole gamut of insecticides now in agricultural use, although a few principal offenders like endrin, toxaphene, dieldrin, and heptachlor can easily be picked out. Still another problem must now be considered largely in terms of what we may logically suppose will happen in the future, because the studies that will disclose the facts are only beginning to be made. This has to do with the fishes of salt marshes, bays, and estuaries.

It was inevitable that serious destruction of fishes would follow the widespread use of the new organic pesticides. Fishes are almost fantastically sensitive to the chlorinated hydrocarbons that make up the bulk of modern insecticides. And when millions of tons of poisonous chemicals are applied to the surface of the land, it is inevitable that some of them will find their way into the ceaseless cycle of waters moving between land and sea.

Reports of fish kills, some of disastrous proportions, have now become so common that the United States Public Health Service has set up an office to collect such reports from the states as an index of water pollution.

This is a problem that concerns a great many people. Some 25 million Americans look to fishing as a major source of recreation and another 15 million are at least casual anglers. These people spend three billion dollars annually for licenses, tackle, boats, camping equipment, gasoline, and lodgings. Anything that deprives them of their sport will also reach out and affect a large number of economic interests. The commercial fisheries represent such an interest, and even more importantly, an essential source of food. Inland and coastal fisheries (excluding the offshore catch) yield an estimated three billion pounds a year. Yet, as we shall see, the invasion of streams, ponds, rivers, and bays by pesticides is now a threat to both recreational and commercial fishing.

Examples of the destruction of fish by agricultural crop sprayings and dustings are everywhere to be found. In California, for example, the loss of some 60,000 game fish, mostly bluegill and other sunfish, followed an attempt to control the riceleaf miner with dieldrin. In Louisiana 30 or more instances of heavy fish mortality occurred in one year alone (1960) because of the use of endrin in the sugarcane fields. In Pennsylvania fish have been killed in numbers by endrin, used in orchards to combat mice. The use of chlordane for grasshopper control on the high western plains has been followed by the death of many stream fish.

Probably no other agricultural program has been carried out on so large a scale as the dusting and spraying of millions of acres of land in southern United States to control the fire ant. Heptachlor, the chemical chiefly used, is only slightly less toxic to fish than DDT. Dieldrin, another fire ant poison, has a well-documented history of extreme hazard to all aquatic life. Only endrin and toxaphene represent a greater danger to fish.

All areas within the fire ant control area, whether treated with heptachlor or dieldrin, reported disastrous effects on aquatic life. A few excerpts will give the flavor of the reports from biologists who studied the damage: From Texas, "Heavy loss of aquatic life despite efforts to protect canals," "Dead fish . . . were present in all treated water," "Fish kill was heavy and continued for over 3 weeks." From Alabama, "Most adult fish were killed [in Wilcox County] within a few days after treatment," "The fish in temporary waters and small tributary streams appeared to have been completely eradicated."

In Louisiana, farmers complained of loss in farm ponds. Along one canal more than 500 dead fish were seen floating or lying on the bank on a stretch of less than a quarter of a mile. In another parish 150 dead sunfish could be found for every 4 that remained alive. Five other species appeared to have been wiped out completely.

In Florida, fish from ponds in a treated area were found to contain residues of heptachlor and a derived chemical, heptachlor epoxide. Included among these fish were sunfish and bass, which of course are favorites of anglers and commonly find their way to the dinner table. Yet the chemicals they contained are among those the Food and Drug Administration considers too dangerous for human consumption, even in minute quantities.

So extensive were the reported kills of fish, frogs, and other life of the waters that the American Society of Ichthyologists and Herpetologists, a venerable scientific organization devoted to the study of fishes, reptiles, and amphibians, passed a resolution in 1958 calling on the Department of Agriculture and the associated state agencies to cease "aerial distribution of heptachlor, dieldrin, and equivalent poisons — before irreparable harm is done." The Society called attention to the great variety of species of fish and other forms of life inhabiting the southeastern part of the United States, including species that occur nowhere else in the world. "Many of these animals," the Society warned, "occupy only small areas and therefore might readily be completely exterminated."

Fishes of the southern states have also suffered heavily from insecticides used against cotton insects. The summer of 1950 was a season of disaster in the cotton-growing country of northern Alabama. Before that year, only limited use had been made of organic insecticides for the control of the boll weevil. But in 1950 there were many weevils because of a series of mild winters, and so an estimated 80 to 95 per cent of the farmers, on the urging of the county agents, turned to the use of insecticides. The chemical most popular with the farmers was toxaphene, one of the most destructive to fishes.

Rains were frequent and heavy that summer. They washed the chemicals into the streams, and as this happened the farmers applied more. An average acre of cotton that year received 63 pounds of toxaphene. Some farmers used as much as 200 pounds per acre; one, in an extraordinary excess of zeal, applied more than a quarter of a ton to the acre.

The results could easily have been foreseen. What happened in Flint Creek, flowing through 50 miles of Alabama cotton country before emptying into Wheeler Reservoir, was typical of the region. On August 1, torrents of rain descended on the Flint Creek watershed. In trickles, in rivulets, and finally in floods the water poured off the land into the streams. The water level rose six inches in Flint Creek. By the next morning it was obvious that a great deal more than rain had been carried into the stream. Fish swam about in aimless circles near the surface. Sometimes one would throw itself out of the water onto the bank. They could easily be caught; one farmer picked up several and took them to a spring-fed pool. There, in the pure water, these few recovered. But in the stream dead fish floated down all day. This was but the prelude to more, for each rain washed more of the insecticide into the river, killing more fish. The rain of August 10 resulted in such a heavy fish kill throughout the river that few remained to become victims of the next surge of poison into the stream, which occurred on August 15. But evidence of the deadly presence of the chemicals was obtained by placing test goldfish in cages in the river; they were dead within a day.

The doomed fish of Flint Creek included large numbers of white crappies, a favorite among anglers. Dead bass and sunfish were also found, occurring abundantly in Wheeler Reservoir, into which the creek flows. All the rough-fish population of these waters was destroyed also — the carp, buffalo, drum, gizzard shad, and catfish. None showed signs of disease — only the erratic movements of the dying and a strange deep wine color of the gills.

In the warm enclosed waters of farm ponds, conditions are very likely to be lethal for fish when insecticides are applied in the vicinity. As many examples show, the poison is carried in by rains and runoff from surrounding lands. Sometimes the ponds receive not only contaminated runoff but also a direct dose as crop-dusting pilots neglect to shut off the duster in passing over a pond. Even without such complications, normal agricultural use subjects fish to far heavier concentrations of chemicals than would be required to kill them. In other words, a marked reduction in the poundages used would hardly alter the lethal situation, for applications of over 0.1 pound per acre to the pond itself are generally considered hazardous. And the poison, once introduced, is hard to get rid of. One pond that had been treated with DDT to remove unwanted shiners remained so poisonous through repeated drainings and flushings that it killed 94 per cent of the sunfish with which it was later stocked. Apparently the chemical remained in the mud of the pond bottom.

Conditions are evidently no better now than when the modern insecticides first came into use. The Oklahoma Wildlife Conservation Department stated in 1961 that reports of fish losses in farm ponds and small lakes had been coming in at the rate of at least one a week, and that such reports were increasing. The conditions usually responsible for these losses in Oklahoma were those made familiar by repetition over the years: the application of insecticides to crops, a heavy rain, and poison washed into the ponds.

In some parts of the world the cultivation of fish in ponds provides an indispensable source of food. In such places the use of insecticides without regard for the effects on fish creates immediate problems. In Rhodesia, for example, the young of an important food fish, the Kafue bream, are killed by exposure to only 0.04 parts per million of DDT in shallow pools. Even smaller doses of many other insecticides would be lethal. The shallow waters in which these fish live are favorable mosquito-breeding places. The problem of controlling mosquitoes and at the same time conserving a fish important in the Central African diet has obviously not been solved satisfactorily.

Milkfish farming in the Philippines, China, Vietnam, Thailand, Indonesia, and India faces a similar problem. The milkfish is cultivated in shallow ponds along the coasts of these countries. Schools of young suddenly appear in the coastal waters (from no one knows where) and are scooped up and placed in impoundments, where they complete their growth. So important is this fish as a source of animal protein for the rice-eating millions of Southeast Asia and India that the Pacific Science Congress has recommended an international effort to search for the now unknown spawning grounds, in order to develop the farming of these fish on a massive scale. Yet spraying has been permitted to cause heavy losses in existing impoundments. In the Philippines aerial spraying for mosquito control has cost pond owners dearly. In one such pond containing 120,000 milkfish, more than half the fish died after a spray plane had passed over, in spite of desperate efforts by the owner to dilute the poison by flooding the pond.

One of the most spectacular fish kills of recent years occurred in the Colorado River below Austin, Texas, in 1961. Shortly after daylight on Sunday morning, January 15, dead fish appeared in the new Town Lake in Austin and in the river for a distance of about 5 miles below the lake. None had been seen the day before. On Monday there were reports of dead fish 50 miles downstream. By this time it was clear that a wave of some poisonous substance was moving down in the river water. By January 21, fish were being killed 100 miles downstream near La Grange, and a week later the chemicals were doing their lethal work 200 miles below Austin. During the last week of January the locks on the Intracoastal Waterway were closed to exclude the toxic waters from Matagorda Bay and divert them into the Gulf of Mexico.

Meanwhile, investigators in Austin noticed an odor associated with the insecticides chlordane and toxaphene. It was especially strong in the discharge from one of the storm sewers. This sewer had in the past been associated with trouble from industrial wastes, and when officers of the Texas Game and Fish Commission followed it back from the lake, they noticed an odor like that of benzene hexachloride at all openings as far back as a feeder line from a chemical plant. Among the major products of this plant were DDT, benzene hexachloride, chlordane, and toxaphene, as well as smaller quantities of other insecticides. The manager of the plant admitted that quantities of powdered insecticide had been washed into the storm sewer recently and, more significantly, he acknowledged that such disposal of insecticide spillage and residues had been common practice for the past 10 years.

On searching further, the fishery officers found other plants where rains or ordinary clean-up waters would carry insecticides into the sewer. The fact that provided the final link in the chain, however, was the discovery that a few days before the water in lake and river became lethal to fish the entire storm-sewer system had been flushed out with several million gallons of water under high pressure to clear it of debris. This flushing had undoubtedly released insecticides lodged in the accumulation of gravel, sand, and rubble and carried them into the lake and thence to the river, where chemical tests later established their presence.

As the lethal mass drifted down the Colorado it carried death before it. For 140 miles downstream from the lake the kill of fish must have been almost complete, for when seines were used later in an effort to discover whether any fish had escaped they came up empty. Dead fish of 27 species were observed, totaling about 1000 pounds to a mile of riverbank. There were channel cats, the chief game fish of the river. There were blue and flathead catfish, bullheads, four species of sunfish, shiners, dace, stone rollers, largemouth bass, carp, mullet, suckers. There were eels, gar, carp, river carpsuckers, gizzard shad, and buffalo. Among them were some of the patriarchs of the river, fish that by their size must have been of great age — many flathead catfish weighing over 25 pounds, some of 60 pounds reportedly picked up by local residents along the river, and a giant blue catfish officially recorded as weighing 84 pounds.

The Game and Fish Commission predicted that even without further pollution the pattern of the fish population of the river would be altered for years. Some species — those existing at the limits of their natural range — might never be able to re-establish themselves, and the others could do so only with the aid of extensive stocking operations by the state.

This much of the Austin fish disaster is known, but there was almost certainly a sequel. The toxic river water was still possessed of its death-dealing power after passing more than 200 miles downstream. It was regarded as too dangerous to be admitted to the waters of Matagorda Bay, with its oyster beds and shrimp fisheries, and so the whole toxic outflow was diverted to the waters of the open Gulf. What were its effects there? And what of the outflow of scores of other rivers, carrying contaminants perhaps equally lethal?

At present our answers to these questions are for the most part only conjectures, but there is growing concern about the role of pesticide pollution in estuaries, salt marshes, bays, and other coastal waters. Not only do these areas receive the contaminated discharge of rivers but all too commonly they are sprayed directly in efforts to control mosquitoes or other insects.

Nowhere has the effect of pesticides on the life of salt marshes, estuaries, and all quiet inlets from the sea been more graphically demonstrated than on the eastern coast of Florida, in the Indian

River country. There, in the spring of 1955, some 2000 acres of salt marsh in St. Lucie County were treated with dieldrin in an attempt to eliminate the larvae of the sandfly. The concentration used was one pound of active ingredient to the acre. The effect on the life of the waters was catastrophic. Scientists from the Entomology Research Center of the State Board of Health surveyed the carnage after the spraying and reported that the fish kill was "substantially complete." Everywhere dead fishes littered the shores. From the air sharks could be seen moving in, attracted by the helpless and dying fishes in the water. No species was spared. Among the dead were mullets, snook, mojarras, gambusia.

> The minimum immediate over-all kill throughout the marshes, exclusive of the Indian River shoreline, was 20–30 tons of fishes, or about 1,175,000 fishes, of at least 30 species [reported R. W. Harrington, Jr., and W. L. Bidlingmayer of the survey team].
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> Mollusks seemed to be unharmed by dieldrin. Crustaceans were virtually exterminated throughout the area. The entire aquatic crab population was apparently destroyed and the fiddler crabs, all but annihilated, survived temporarily only in patches of marsh evidently missed by the pellets.
>
> The larger game and food fishes succumbed most rapidly . . . Crabs set upon and destroyed the moribund fishes, but the next day were dead themselves. Snails continued to devour fish carcasses. After two weeks, no trace remained of the litter of dead fishes.

The same melancholy picture was painted by the late Dr. Herbert R. Mills from his observations in Tampa Bay on the opposite coast of Florida, where the National Audubon Society operates a sanctuary for seabirds in the area including Whiskey Stump Key. The sanctuary ironically became a poor refuge after the local health authorities undertook a campaign to wipe out the salt-marsh mosquitoes. Again fishes and crabs were the principal victims. The fiddler crab, that small and picturesque crustacean whose hordes move over mud flats or sand flats like grazing cattle, has no defense against the sprayers. After successive sprayings during the summer and fall months (some areas were sprayed as many as 16 times), the state of the fiddler crabs was summed up by Dr. Mills: "A progressive scarcity of fiddlers had by this time become apparent. Where there should have been in the neighborhood of 100,000 fiddlers under the tide and weather conditions of the day [October 12] there were not over 100 which could be seen anywhere on the beach, and these were all dead or sick, quivering, twitching, stumbling, scarcely able to crawl; although in neighboring unsprayed areas fiddlers were plentiful."

The place of the fiddler crab in the ecology of the world it inhabits is a necessary one, not easily filled. It is an important source of food for many animals. Coastal raccoons feed on them. So do marsh-inhabiting birds like the clapper rail, shorebirds, and even visiting seabirds. In one New Jersey salt marsh sprayed with DDT, the normal population of laughing gulls was decreased by 85 per cent for several weeks, presumably because the birds could not find sufficient food after the spraying. The marsh fiddlers are important in other ways as well, being useful scavengers and aerating the mud of the marshes by their extensive burrowings. They also furnish quantities of bait for fishermen.

The fiddler crab is not the only creature of tidal marsh and estuary to be threatened by pesticides; others of more obvious importance to man are endangered. The famous blue crab of the Chesapeake Bay and other Atlantic Coast areas is an example. These crabs are so highly susceptible to insecticides that every spraying of creeks, ditches, and ponds in tidal marshes kills most of the crabs living there. Not only do the local crabs die, but others moving into a sprayed area from the sea succumb to the lingering poison. And sometimes poisoning may be in-direct, as in the marshes near Indian River, where scavenger crabs attacked the dying fishes, but soon themselves succumbed to the poison. Less is known about the hazard to the lobster. However, it belongs to the same group of arthropods as the blue crab, has essentially the same physiology, and would presumably suffer the same effects. This would be true also of the stone crab and other crustaceans which have direct economic importance as human food.

The inshore waters — the bays, the sounds, the river estuaries, the tidal marshes — form an ecological unit of the utmost importance. They are linked so intimately and indispensably with the lives of many fishes, mollusks, and crustaceans that were they no longer habitable these seafoods would disappear from our tables.

Even among fishes that range widely in coastal waters, many depend upon protected inshore areas to serve as nursery and feeding grounds for their young. Baby tarpon are abundant in all that labyrinth of mangrove-lined streams and canals bordering the lower third of the western coast of Florida. On the Atlantic Coast the sea trout, croaker, spot, and drum spawn on sandy shoals off the inlets between the islands or "banks" that lie like a protective chain off much of the coast south of New York. The young fish hatch and are carried through the inlets by the tides. In the bays and sounds — Currituck, Pamlico, Bogue, and many others — they find abundant food and grow rapidly. Without these nursery areas of warm, protected, food-rich waters the populations of these and many other species could not be maintained. Yet we are allowing pesticides to enter them via the rivers and by direct spraying over bordering marshlands. And the early stages of these fishes, even more than the adults, are especially susceptible to direct chemical poisoning.

Shrimp, too, depend on inshore feeding grounds for their young. One abundant and widely ranging species supports the entire commercial fishery of the southern Atlantic and Gulf states. Although spawning occurs at sea, the young come into the estuaries and bays when a few weeks old to undergo successive molts and changes of form. There they remain from May or June until fall, feeding on the bottom detritus. In the entire period of their inshore life, the welfare of the shrimp populations and of the industry they support depends upon favorable conditions in the estuaries.

Do pesticides represent a threat to the shrimp fisheries and to the supply for the markets? The answer may be contained in recent laboratory experiments carried out by the Bureau of Commercial Fisheries. The insecticide tolerance of young commercial shrimp just past larval life was found to be exceedingly low — measured in parts per *billion* instead of the more commonly used standard of parts per million. For example, half the shrimp in one experiment were killed by dieldrin at a concentration of only 15 parts per billion. Other chemicals were even more toxic. Endrin, always one of the most deadly of the pesticides, killed half the shrimp at a concentration of only *half of one part per billion.*

The threat to oysters and clams is multiple. Again, the young stages are most vulnerable. These shellfish inhabit the bottoms of bays and sounds and tidal rivers from New England to Texas and sheltered areas of the Pacific Coast. Although sedentary in adult life, they discharge their spawn into the sea, where the young are free-living for a period of several weeks. On a summer day a fine-meshed tow net drawn behind a boat will collect, along with the other drifting plant and animal life that make up the plankton, the infinitely small, fragile-as-glass larvae of oysters and clams. No larger than grains of dust, these transparent larvae swim about in the surface waters, feeding on the microscopic plant life of the plankton. If the crop of minute sea vegetation fails, the young shellfish will starve. Yet pesticides may well destroy substantial quantities of plankton. Some of the herbicides in common use on lawns, cultivated fields, and roadsides and even in coastal marshes are extraordinarily toxic to the plant plankton which the larval mollusks use as food — some at only a few parts per billion.

The delicate larvae themselves are killed by very small quantities of many of the common insecticides. Even exposures to less than lethal quantities may in the end cause death of the larvae, for inevitably the growth rate is retarded. This prolongs the period the larvae must spend in the hazardous world of the plankton and so decreases the chance they will live to adulthood.

For adult mollusks there is apparently less danger of direct poisoning, at least by some of the pesticides. This is not necessarily reassuring, however. Oysters and clams may concentrate these poisons in their digestive organs and other tissues. Both types of shellfish are normally eaten whole and sometimes raw. Dr. Philip Butler of the Bureau of Commercial Fisheries has pointed out an ominous parallel in that we may find ourselves in the same situation as the robins. The robins, he reminds us, did not die as a direct result of the spraying of DDT. They died because they had eaten earthworms that had already concentrated the pesticides in their tissues.

Although the sudden death of thousands of fish or crustaceans in some stream or pond as the direct and visible effect of insect control is dramatic and alarming, these unseen and as yet largely unknown and unmeasurable effects of pesticides reaching estuaries indirectly in streams and rivers may in the end be more disastrous. The whole situation is beset with questions for which there are at present no satisfactory answers. We know that pesticides contained in runoff from farms and forests are now being carried to the sea in the waters of many and perhaps all of the major rivers. But we do not know the identity of all the chemicals or their total quantity, and we do not presently have any dependable tests for identifying them in highly diluted state once they have reached the sea. Although we know that the chemicals have almost certainly undergone change during the long period of transit, we do not know whether the altered chemical is more toxic than the original or less. Another almost unexplored area is the question of interactions between chemicals, a question that becomes especially urgent when they enter the marine environment where so many different minerals are subjected to mixing and transport. All of these questions urgently require the precise answers that only extensive research can provide, yet funds for such purposes are pitifully small.

The fisheries of fresh and salt water are a resource of great importance, involving the interests and the welfare of a very large number of people. That they are now seriously threatened by the chemicals entering our waters can no longer be doubted. If we would divert to constructive research even a small fraction of the money spent each year on the development of ever more toxic sprays, we could find ways to use less dangerous materials and to keep poisons out of our waterways. When will the public become sufficiently aware of the facts to demand such action?

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ERICH HARTMANN/MAGNUM PHOTOS

RACHEL CARSON (1907–1964) spent most of her professional life as a marine biologist with the U.S. Fish and Wildlife Service. By the late 1950s, she had written three lyrical, popular books about the sea, including the best-selling *The Sea Around Us*, and had become the most respected science writer in America. She completed *Silent Spring* against formidable personal odds and despite critical attacks that echoed the assault on Charles Darwin when he published *The Origin of Species*, and with it shaped a powerful social movement that has altered the course of history.

Despite the enormous impact of *Silent Spring*, Carson remained modest about her accomplishment; as she wrote to a friend, "The beauty of the living world I was trying to save has always been uppermost in my mind—that, and anger at the senseless, brutish things that were being done . . . Now I can believe I have at least helped a little."

Among the many honors and awards Carson received during her lifetime were the National Book Award, for *The Sea Around Us* (1951); a Guggenheim fellowship (1951–1952); the John Burroughs Medal (1952); the Henry G. Bryant Gold Medal (1952); the Women's National Book Association Constance Lindsay Skinner Award (1963); the Conservationist of the Year Award from the National Wildlife Federation (1963); and a Gold Medal from the New York Zoological Society (1963).

Rachel Carson lived in Silver Spring, Maryland, until her untimely death.

From the Introduction by Linda Lear

In *Silent Spring,* and later in testimony before a congressional committee, Rachel Carson asserted that one of the most basic human rights must surely be the "right of the citizen to be secure in his own home against the intrusion of poisons applied by other persons." Through ignorance, greed, and negligence, government had allowed "poisonous and biologically potent chemicals" to fall "indiscriminately into the hands of persons largely or wholly ignorant of their potentials for harm." When the public protested, it was "fed little tranquillizing pills of half-truth" by a government that refused to take responsibility for or acknowledge evidence of damage. Carson challenged such moral vacuity. "The obligation to endure," she wrote, "gives us the right to know."

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