audible click, with a force that sometimes hurls the ant backward through the air.

But of all of these, one ant glows in his memory—in the very center of the vacant lot rose a towering, unmistakable mound that, at a mere touch, exploded into a frenzy of furious ants. This moment in May of 1942 at 552 Charleston St. was the first conscious encounter between a human and *S. invicta*, the first awareness that this ant was something unfamiliar, something alien (Wilson, 1994). It would take a few more years for humans to realize that the South would never again be the same.

More than 60 years have passed since that moment. The ant and the South have had their civil war, which ended only after southerners finally recognized that the alien was unbeatable. Hating the fire ant has become a major industry among southerners, who spend millions of dollars on endless, futile guerrilla actions against the ant. Little by little, the ant has insinuated itself into southern lore. In my opinion, and in recognition of this fact, southerners should erect a monument to the fire ant, much as they did to the boll weevil. If they ever do so, it would celebrate not so much the fire ant itself as the way that it has drawn attention to their own cherished attributes—the will to endure, the ability to see humor in adversity, the taste for tall stories and eccentricity, and the magnet pull that dangerous, destructive, and wild things exert on all true southerners. It will be a monument to yet another defeat that merely stiffened southern defiance another notch.

From:
The Fire Ants
by Walter R. Tschinkel
2006, Harvard Univ. Press

5

La Conquista: Spreading Out

Each having made a beachhead in Mobile, *Solenopsis invicta* and *S. richteri* began to spread, and their increasing contact with people unleashed the Fire Ant Wars in all their political, social, and technological color and tumult. Although this saga has little to do with fire-ant social biology, it is a fine story, and telling it once more will do no harm. It is full of selective perception and wishful thinking, arrogance and misjudgment, myth and outrageous exaggeration, unwavering faith in technology, unintended consequences, and chips falling where they may—but also clear-sightedness, stubborn skepticism, and dogged opposition. Not least, had the Fire Ant Wars never been fought, this book could never have been written, because we would know little to nothing about fire ants. The USA harbors dozens of exotic ant species, some quite common, and we know little about the rest of them, but *S. invicta* drew notice with its mound and burned itself into our consciousness with its sting. Controversy and politics spawned the first research into the biology of the fire ant, and for many years, controversy fueled it. Although southerners have largely accepted (if not become fond of) the new immigrant, the ant still has a high profile, and the research continues. People from all walks of life are *interested* in fire ants, and along the way, we have discovered that this ant is a wonderful experimental animal.

Mine is not the first account of the Fire Ant Wars. I have taken the facts largely from documents and previous histories, colored by my own experience as a Fire Ant Warrior. From the beginning, people were deeply divided on the issues. The accounts of fire-ant history given by employees of the U.S. Department of Agriculture (USDA; Lofgren, 1986b) give an impression very different from those provided by conservationists (Hinkel, 1982) or scientists (Brown, 1961; Davidson and Stone, 1989). The tone of news accounts at the time was typically hysterical ("red menace advancing," "entire Mississippi counties scarred," "killing people and animals, destroying crops," "cobra-like venom," and perhaps the worst indictment of all, because it showed deep disrespect for authority, "fire ant spreading, postman attacked"). A few were fairly even-handed (Shapley, 1971a, b). The wars were a clash of the subcultures and ideologies of the era. At one extreme were the technologists with their unshakable belief in the ability and the right of humans to the other were (broadly defined) environmentalists and ecologists. To them, nature itself mattered; excessive tampering was unwise, unethical, and subject to unpredictable consequences. The Fire Ant Wars were born in politics, but it was science that finally ended them. They were not the only entomological wars—similar battles raged over DDT and several other persistent pesticides. They demonstrated the futility of chemical control as well as its high environmental costs and eventually turned science, government, and society away from "control" to "management" (i.e., prophylactic measures such as quarantine and "integrated pest management"). The Fire Ant Wars can be seen as a case study of how the effective application of scientific method can accrue information that slowly overcomes the inertia of ignorance. And of course, it is a great story.

Early Spread and Skirmishes

In the decade or so after its arrival, *S. richteri* gradually spread outward from Mobile Harbor. By 1928, it occupied the northwestern part of what is greater Mobile today. By 1932, it had spread 8 km northwest from the harbor to Whistler and 25 km southwest and southeast to St. Elmo and Fairhope on opposite shores of Mobile Bay (Murphree, 1947). By 1937, it occupied much of Mobile and Baldwin counties and had spread across the state line into Mississippi (Figure 5.1). It had become abundant enough and annoying enough that four county, state, and federal agencies joined to do battle against it. The opening skirmish (one cannot dignify it as a battle) of the Fire Ant Wars had begun. On about 800 hectares (ha), agents injected nest mounds with "grade A" calcium cyanide dust and claimed to have eliminated more than three-quarters of the colonies (Eden and Arant, 1949; Green, 1952). During this same period but farther east, Travis (1939a, b, 1940) waged a similar war against the native *S. geminata* on the quail-hunting plantations of southern Georgia and northern Florida, believing that the ants killed nestling quail. Killing quail was strictly reserved for wealthy humans with shotguns, so he applied cyanide mound drenches as well as poisoned baits containing thallium salts. His instructions suggest that "cyanide should not be taken internally" (good advice). His success was not high, but one wonders what else these deadly poisons eliminated. In 1936, in what amounted to a kind of "preview of coming attractions," myrmecologist M. R. Smith fingered the southern fire ant, *S. xyloni*, as an important pest causing crop damage, stinging people, eating okra and eggplant, gnawing on dahlia stems, stealing seeds from gardens, encouraging mealybugs, killing chickens, and gnawing holes in dirty clothes (Smith, 1936). He had only limited success in eliminating it with poisoned baits. The opening skirmish was abandoned during the early 1940s as American attention turned to a much larger war among hu-

Figure 5.1. Estimate
exotic fire ants betw
and 1949. Most of th
increase after about 1
probably by the mor
spreading *Solenopsi*
Adapted from Wilson

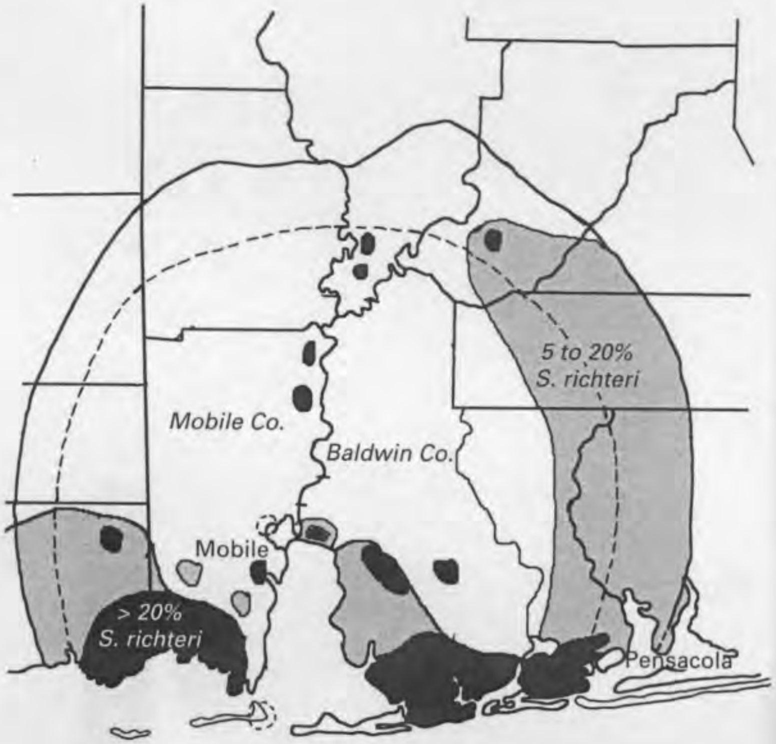
was but a minor action, a patrol firing scattered shots over the heads of a hostile force, very few of which hit their targets.

This was probably also the era when *S. richteri* established three separate northern populations, one each in the Artesia and Meridian areas of Mississippi and one in the Selma area in Alabama. All of these northern populations were separated from the main Mobile population by 150 to 300 km and were almost certainly the result of transport by shipping of some type. They also all centered on towns. Either fire ants found it easier to hitch rides to towns, or the environment there was more conducive to their establishment, or fire ants were less likely to be spotted in rural areas. In 1949, these fire-ant populations were only 20 to 40 km across, and densities were high only at their centers, suggesting that they had only existed for a few years. Wilson estimated that the Artesia population arose about 1935 and the Meridian one about 1940. The ants did not appear in Selma, Alabama, until 1944.

The Arrival of *S. invicta* and the First Fire Ant War

The arrival of *S. invicta* about 1933 was far worse news for *S. richteri* than any cyanide-puffing humans, for this Johnny-come-lately spread much more rapidly than *S. richteri*. Wherever *S. invicta* appeared, *S. richteri*

e 5.2. The displacement
lenopsis richteri by S.
a, as it appeared in 1949.
tantial populations of S.
ri remained only near the
and as a few enclaves
n the spreading S. invicta
lation. Adapted from
n (1951).



most of the *S. richteri* from the Mobile area, and *S. richteri* remained only along the gulf coast and along the eastern and western perimeter of the species' collective range (Figure 5.2). Even there it survived as a minority in a mixed population in 1949 and has since vanished from these areas. By 1953, the northern Artesia population of *S. richteri* occupied an area of about 500 km^2, but the hot breath of *S. invicta* was perceptible from the south. Although *S. invicta* eventually surrounded this northern population and reduced it in extent, it continues to persist, in part, as a pure *S. richteri* population to this day, although it has hybridized with *S. invicta* along the northeastern contact zone. Also by 1953, the Selma and Meridian populations had been completely swamped by *S. invicta*, first existing as mixed populations then being completely eliminated by *S. invicta*. Perhaps, as a result of interbreeding, *S. richteri* left behind some genes in the advancing *S. invicta* population, but as a distinct species, it vanished from most of the territory it had occupied.

After about 1945, most of the range increase of fire ants was due to *S. invicta*. Why this species, which seems so similar to *S. richteri*, spread so much more rapidly is unknown, as are why and how *S. invicta* displaces *S. richteri* or the native species of fire ant, *S. geminata* and *S. xyloni*. The answers must lie in the details of their biology, but neither comparative

exist. The fire ants that reached Meridian, Mississippi, and Selma, Alabama, by 1948 were probably mostly *S. invicta* rather than *S. richteri*. In any case, the State Plant Board of Mississippi was alarmed enough by their "devastation of the hay industry" to mount the First Fire Ant War, seeking nothing less than eradication. The legislature appropriated $15,000, and the war was on. This time the antiant forces were armed with the newly developed insecticide chlordane, a chlorinated hydrocarbon, which was made available to farmers as a 5% dust to be dumped onto the mound or mixed into it. This program was begun with little or no knowledge of the biology of the ant, a pattern that was to be repeated twice more. Although chlordane may be capable of killing fire ant colonies, it proved no match for the reproductive and dispersal abilities of *S. invicta*. By 1951, the ant was found throughout the state, and the chlordane program was discontinued, having cost mere peanuts compared to those to come.

At about this time, the first fire-ant studies were begun at Mississippi State University (Lyle and Fortune, 1948; Eden and Arant, 1949), and in 1949, the USDA set up a research station at Spring Hill near Mobile. The station's duties were to determine the current range of the fire ant through surveys and to find insecticides to kill it. Studying the biology of the adversary was little mentioned. The survey found varying fire-ant population densities, from low to high, in 28 contiguous counties in Alabama, Mississippi, and west Florida (Figure 5.3) (Bruce et al., 1949).

Also during the spring and summer of 1949, the Alabama Department of Conservation hired E. O. Wilson, a student at the University of

Figure 5.3.
fire-ant sur
population
light shadi
population
Surveyed s
ants were
filled circle
Lofgren (1

Alabama, and J. H. Eads, who owned a car, to study the distribution of fire ants and to make a first determination of the possible economic impact of their presence. For three months, these two meandered the roads of Alabama, Mississippi, and Florida, looking for ants and interviewing farmers. Their mimeographed report (Wilson and Eads, 1949) and the publications resulting from it (Wilson, 1951, 1953b, 1952) provided the first detailed maps of the extent of the fire-ant population and included the first biological observations of both *S. invicta* and *S. richteri*, sketching the basics of colony size, nest structure, worker longevity, queen number, alate production, colony founding, and habitat preference. They also remarked on the apparent absence of parasites and significant predators of fire ants, waxed dramatic about fire-ant stings, and reported some observations on the species' food habits. Their estimates of economic losses were based only on farmer opinion in response to survey questions. In many instances, Wilson and Eads observed no fire-ant damage to the crop in question, even though farmers reported losses. Of course, no control was available for comparison. Damage to wildlife, they felt, was "a matter of opinion." Interestingly, Wilson reported that fire ants like to gnaw on peanuts and that farmers were of the opinion that the ants helped control boll weevil, a serious pest of cotton. All in all, it is interesting to note how much of the outlines of both future fire-ant research and future controversy over the ecological and economic effects of the fire ant are already visible in this early report.

Between 1949 and 1953, the USDA laboratory at Spring Hill carried out a more complete survey of the southern states. At first, they searched generally in areas likely to support fire ants and found few. After noticing that several isolated populations were located in nurseries, they switched to inspecting only nurseries and began finding large numbers of isolated populations throughout the Southeast. By the end of the survey, *S. invicta* had been found in 102 counties in 10 southern states (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, and Texas; Figure 5.4) (Culpepper, 1953). Most important, this survey firmly established a link between the shipment of nursery stock and the spread of the fire ant. During the post-war building boom of the 1950s, nurseries did a brisk trade providing the plantings for the many new subdivisions. As a result, by 1953, the fire ant's range consisted of a continuous core population centered on Mobile and almost 50 small, separated, incipient populations centered on nurseries throughout the southeast, from Texas to North Carolina. Some of these incipient populations were as much as 800 km from the main core population. Such jumps were of immeasurable value to *S. invicta* in its conquest, for most of the range increase after 1953 was the result of outward spread from these population foci to form a single continuous population. Many of these foci were separated from each other by only 100–200 km, a distance the fire ant could cover without human help in about five years. A comparison of the range in 1953 with that in 1957 shows this coalescence effect clearly (Figure 5.4).

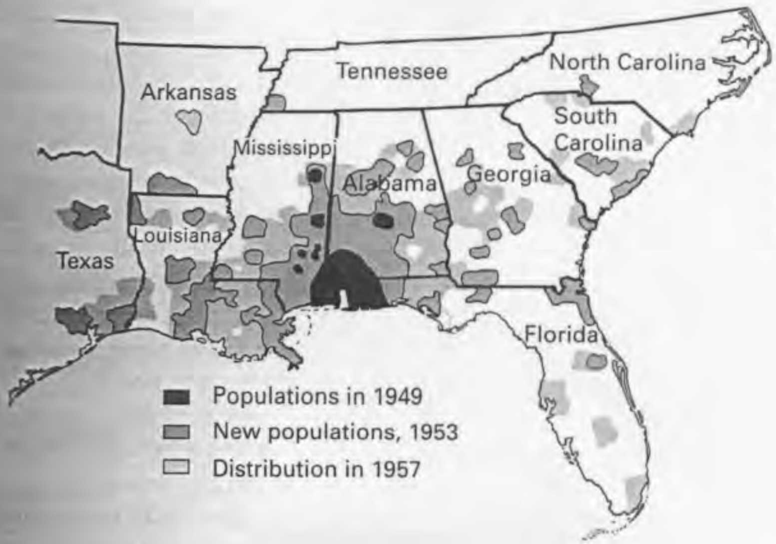


Figure 5.4. Distrib
Solenopsis invict
revealed by an in
of plant nurseries
the southeastern
1957, many of the
populations had c
Adapted from Cul
and Lofgren (198

The means by which the scattered foci were established seems clear enough—they resulted when obliging nurserymen unwittingly gave rides to hitchhiking fire ants. The mechanism of "natural spread" is less well understood, partly because experiments on the flight range of newly mated fire-ant queens are not easily reconciled with the observed rate of spread. On the average, over large areas and many years, the fire-ant population front has advanced at about 8 km per year, but several studies on postmating flight range have indicated that the vast majority of queens fly less than 1–2 km from their home colonies. The most generous estimate is that fewer than 10–15% of newly mated queens fly 1.6 km (1 mile) before settling, and the least generous is that only 3% fly that far.

The discrepancy might be explained in a number of ways. First, we know that fire ants are *capable* of flying 10–15 km and do so over water (where they might be expected to land only unwillingly), so perhaps a tiny minority of newly mated queens elects to fly very far, even over land (flight distance is known to have a genetic and physical basis). Because such long-distance fliers would be very few, they would be very difficult to find by searching. If their chances of successful founding are about 10%, they could produce densities between one and 50 young colonies per square kilometer 10–20 km ahead of the main population front. Wilson's maps show a zone of "light infestation" 10–15 km wide along the spreading front of the main population. Upon reaching maturity, these extreme outliers could then help to "backfill" the habitat lying between themselves and the main population front.

A second possibility leaves the fire ant out of the formula. Human traffic is mostly quite local, flowing to and fro daily on the scale of a few kilometers. Commuters travel to and from their jobs, goods are delivered limited distances from distribution centers, relatives often live in nearby towns, and so on. The likelihood of transportation of newly mated queens or small colonies over moderate distances in houseplants, soil, earthmoving machinery, fill dirt, farm products, sod, trash, and so on is probably high (U.S. Department of Agriculture, 1958). The tendency of fire-ant populations to spread along roads has been noted repeatedly. Net movement would always be from high density to low, much as molecules diffuse down a concentration gradient.

Local human transport cannot be easily distinguished from spread by natural mating flights. Both tend to establish low-density populations at the margins of the main population. The USDA quarantine described below was applied to counties and would not have slowed local spread of this type, which operated on a within-county scale, quickly spreading the ant across counties, a distance of 30–50 km in several southeastern states. Perhaps this type of spread can account for the 45 km of annual range increase the ant achieved in Texas. Everyone knows Texans drive way too much.

Fire ants can also be spread by water. Many observers have seen entire fire-ant colonies—workers, brood, sexuals, queen, and all—floating as mats after high water flooded them from their nests. Such colonies can drift on rivers, lakes, or ponds for weeks and can reestablish a nest after the flood subsides or they drift ashore (Morrill, 1974a). Indeed, floating colonies, complete with their abundant myrmecophiles, were first reported in South American species of *Solenopsis* as early as 1894 (Ihering, 1894; Reichensperger, 1927b). In addition, newly mated queens sometimes settle on water or on floating debris and can be similarly transported. These modes are not likely to be very important, however. From its Mobile beachhead, the fire ant spread mostly northward, but nearly all the rivers in the Southeast flow southward toward the Gulf of Mexico. Only on the Atlantic Piedmont of Georgia and the Carolinas would the rivers and the ants have been going in the same direction; colonies could have rafted down the French Broad, the Savannah, or the Great Pee Dee.

A perplexing aspect of the rate of spread is seen in comparisons between *S. richteri*, and *S. invicta*. The range of *S. richteri* increased by about 2–3 km per year, but when *S. invicta* had largely replaced *S. richteri*, the population front moved north at 8–12 km per year. Surely a great deal of the difference resulted from transport by humans, but what critical differences in the biology of these two species caused one to be transported so much faster than the other? Their biology seems very similar, so perhaps the difference simply resulted from increased abundance and shipping among nurseries.

Another puzzling point is that, although it became clear in 1953 that fire ants spread primarily through the movement of nursery stock and soil-containing products, such movement was not quarantined until 1958. The agricultural authorities instead wagered their resources on a draconian attempt to eradicate fire ants from North America.

The Second Fire Ant War: Heptachlor and Dieldrin

Every failed program can teach a lesson. The lesson agricultural officials and researchers seem to have learned from the experience with chlordane might be caricatured as, "If it doesn't work, use a bigger hammer." In 1957, the USDA petitioned the U.S. Congress to provide money for a fire-ant control program, ostensibly because of pressure from the Southern Association of Commissioners of Agriculture and from various organizations and members of the public. Of these entreaties, little record exists. In any case, the House Appropriations Committee obliged in July 1957, allocating $2.4 million for "control and eradication" of fire ants (Canter, 1981) even though only two of the 10 affected states listed fire ants among their top 20 pests, and neither ranked it high. This expensive program was mounted because "[*S. invicta*] is a destroyer of plant, animal, and bird life; it builds mounds that interfere with farm operations and *mar landscapes* [emphasis mine]; it [has] a fiery sting, which . . . is painful and can cause serious illness." The federal money was to be matched by state, local, and individual funds in a typical "cooperative program," but in practice over the next three years, contributions by local authorities and individuals were sometimes not forthcoming and were often waived. When you are fighting the good fight, what difference does money make?

In October 1957 the USDA and the Southern Plant Board met in Memphis to draw up plans for a control and eradication campaign. First, the USDA finally proposed a quarantine on shipping soil-containing products from areas with fire ants to areas without them. The quarantine went into effect in May of 1958 and prohibited the shipment of soil-containing nursery stock, grass sod, stumpwood, sand, gravel, or timber with soil attached, unless the shipment was first treated with specified insecticides or washed free of soil. The appearance of new fire-ant populations decreased sharply after this quarantine took effect but, of course, it was already much too late.

At the same meeting, the USDA and Southern Plant Board developed a plan to spray 8–12 million ha of fire ant–infested land in 10 states from the air or ground, laying down over 22 kg of clay granules containing 10% heptachlor per hectare, over 2.2 kg of active ingredient per hectare. The *Mobile Press Register* reported that "Uncle Sam is ready to use a fleet of 60 planes to go to war against the dreaded imported fire ant" (Dunning, 1957). After rain disintegrated the clay granules, the heptachlor was expected to persist in the soil, remaining lethal to fire ants (and who knows what else) for three to five years (Blake et al., 1959)! Populations of the ant were to be treated from their edges inward until they were extinguished and North America was fire ant–free. The new organic insecticides had been so effective that many agencies and individuals became completely reliant on their use, neglecting other approaches to insect control and retarding the study of insect ecology by decades. Such was the atmosphere in 1957. Spokesmen for the USDA said "only the modern airplane, dropping insecticides on the [8 million hectares] . . . , can hope to stop the menace" (Dunning, 1957).

The research basis of this plan was minimal, to put it mildly. Neither the effectiveness of the treatment nor its impact on human health, wildlife, and other nontarget organisms was assessed, nor was any money provided for research or posttreatment monitoring. When the plan was announced, conservationists, entomologists, and wildlife officials objected vociferously. All worried about toxicity to mammals and birds and other environmental side effects of such a massive spray program. Both heptachlor and dieldrin were known to be much more toxic to wildlife, fish, and other aquatic life than that old favorite, DDT (Tarzwell, 1958). One USDA bulletin (U.S. Department of Agriculture, 1958) addressed this issue by stating, "Wildlife stands to gain from the eradication of this pest." Other officials answered with bland assurances that everything had been carefully planned, and all concerns taken into account (Brown, 1961). The record shows otherwise.

In spite of all appeals, spraying began almost immediately in October and November of 1957, as mandated by Congress and presumably advised by USDA. Despite a last-minute rush, wildlife-monitoring efforts by various agencies were not in place until after large areas had been treated with poison. The USDA first met with officials from the U.S. Department of Fish and Wildlife one month after spraying began. Enthusiasm for the cooperative program among the states seems not to have been very high, and only four (Alabama, Florida, Georgia, and Louisiana) appropriated the money expected of them during the first year. The USDA therefore organized an "education campaign" to show southerners that the spray program was needed. Eventually, Texas also ponied up.

The environmental effects of the spraying were disastrous. Wildlife mortality was widespread, domestic livestock and pets died, and birds were eradicated from large areas. This disaster energized the environmental movement and helped to move Rachel Carson to write her classic book, *Silent Spring* (1962). One USDA author noted that the first applications were carried out at the beginning of an unusually cold, wet winter and wrote, "[T]he actual truth of how much damage was due to insecticide and how much to severe environmental conditions will never be known" (Lofgren, 1986b). In fact, plenty of adequate, careful

studies put the blame mostly on the insecticide, although interaction between the insecticide and weather conditions cannot be ruled out. Without the insecticide, bird and mammal mortality would have been low. A few examples follow.

Bobwhite quail is a much-prized species on the hunting plantations of south Georgia and north Florida. There, prescribed fire and other land-use practices are used to boost quail populations for the sport of rich people. During the winter of 1957–58, large areas of these plantations were treated with heptachlor or dieldrin. During the breeding season three months later, Rosene (1958) compared the abundance of bobwhite quail on 4000 ha of land treated with insecticide with that on 4000 ha of similar, untreated land. He counted 297 calling males at predetermined stops along six transect routes on the untreated land but only 37 on the six transects on treated land, a difference of almost 90%. Most males heard on the treated land were near untreated land. Six months after treatment, quail had not repopulated the treated areas.

Game officials in Alabama, Louisiana, and Texas searched areas treated with insecticide for dead birds and mammals and found them in abundance (Baker, 1958; Glasgow, 1958; Lay, 1958; Newsom, 1958; Byrd, 1959). Their photos of the accumulated victims laid out in windrows make sad viewing. In Alabama, 13 coveys of quail completely disappeared from the 1200 ha of treated land. Four of the five found dead contained enough insecticide to have caused their deaths. Searches recovered 187 dead vertebrates belonging to 53 species. Of the 100 specimens analyzed for pesticide, all but six contained lethal doses. Similar observations were reported from Texas, where a mere 43 man-hours of searching found 114 dead birds of 19 species and numerous mammals belonging to seven species, as well as dead fish, frogs, and crayfish in the water and 50 species of dead insects. All 41 mammal specimens analyzed contained lethal amounts of insecticide. The same study reported that bird counts declined by about 95% within two weeks after treatment. Even on the edges of the treated areas, bird counts declined by 50%. Nesting success among blackbirds dropped 50–100%, and many birds were found dead at their nests. Bird counts were still subnormal seven months later, when the report was written. The hatching rate of eggs laid by breeding quail fed only 0.001% dieldrin in their diet dropped 50%.

The experience in Louisiana was similar. A search of 280 ha of pasture and cropland three to 10 days after treatment with heptachlor found 20 dead birds and 13 dead mammals, including two dead dogs. Residents of the area lost 72 domestic ducks. Similar counts were recovered from other Louisiana sites. Nesting success of birds dropped drastically, and bird counts decreased 65–80%. Two dead rabbits and 133 dead birds, including 95 geese and 10 other species, were recovered one week after spraying. Of 17 birds analyzed, all but one contained lethal amounts of pesticide. In an 81-ha marsh treated with about 1 kg of dieldrin per hectare, an estimated one million fish and all the crabs died.

The effects were not limited to wildlife. A great deal of mortality was reported among domestic livestock and pets; many animals died suddenly in fits of convulsions. Following heptachlor treatment, the town of Monroeville, Alabama, hauled more than 700 domestic bird corpses and 60 cat and dog corpses to the city dump. A veterinarian reported the deaths of 100 head of cattle in treated areas and reproductive failure in 150 brood sows but found no similar losses in untreated areas. Angry farmers in Alabama sought payment for their losses (Cottam, 1958). In Louisiana, sugarcane farmers petitioned for relief from losses to sugarcane borer, claiming that heptachlor treatment had upset the natural balance, allowing the pests to proliferate. Beekeepers joined in as well, claiming heavy losses after aerial application of pesticide.

The disastrous consequences of this ill-conceived program were not lost on the public. Toward the end of 1958, about one year after spraying began, Alabama's Senator John Sparkman and Representative Frank Boykin cosponsored a bill to stop the spraying until the benefits and costs of the program could be determined. The bill failed to pass, but in 1960, Alabama, Florida, and eventually Texas refused to pay their share of the spraying program. Support was evaporating. Many landowners refused to participate in the cooperative program. At legislative hearings in Alabama, witnesses testified that the fire ant was merely a nuisance, not a serious pest causing losses of crops and livestock. The Plant Commissioner of Florida freely admitted defeat in the battle for eradication and opined that eradication was impossible, a rare voice of clairvoyance. The Southeastern Association of Game and Fish Commissioners went on record as opposing the spraying program. One speaker at the association's conference commented "the control procedure is so drastic and destructive that it is analogous to scalping the patient to cure dandruff!" (Cottam, 1958).

The USDA's response to this disaster, and to the storm of criticism by environmentalists and wildlife officials, was to reduce the amount of heptachlor to 1.4 kg of active ingredient per hectare in 1959. In 1960, they began testing applications of 0.27 kg per hectare, applied at three- to six-month intervals. The lesson drawn this time seems to have been, "If a sledge hammer is the wrong tool, perhaps a tack hammer is the correct one." The idea that perhaps a wrench or a screwdriver might be more appropriate seems not to have occurred to USDA officials. Faith in chlorinated-hydrocarbon insecticides remained unshaken, as subsequent events in the Fire Ant Wars confirmed.

The final blow to hopes of eradication came in early 1960 when the U.S. Food and Drug Administration reduced the tolerance for heptachlor and dieldrin residues on harvested crops to zero—heptachlor is degraded to an even more toxic epoxide, which turns up as residues in meat and milk when fed to livestock. Croplands could no longer be treated. Even use on pasture was not advised by a number of state entomologists. The heptachlor program continued sporadically for two more years, until it finally ceased in 1962, about four years after it began and three years after severe environmental damage was reported. In all, a million ha, 10% of the intended total, were treated with insecticide at a total cost of $15 million (1962 dollars).

And the fire ant? Between 1957, when spraying began, and 1962, when it ended, the fire ant increased its range from 8 million ha to about 12 million. Many of the treated areas were quickly reinvaded, and isolated populations thought to have been eradicated reappeared. Furthermore, reports began to appear that reinvasion resulted in much higher densities of colonies (Blake et al., 1959), another "preview of coming attractions."

The Third Fire Ant War: Mirex

What did the USDA and other pesticide proponents learn from their experience with heptachlor and dieldrin? Simply this: that a *different* hammer was needed, perhaps a lighter-weight one, but a hammer was still the right tool. If only one could devise a hammer that could accurately and selectively hit fire ants, everything would be fine and eradication could still be achieved. The search for that accurate hammer was the task given to the newly organized Methods Development Laboratory in Gulfport, Mississippi, and between 1960 and 1962 staff there came up with what they hailed as "the perfect pesticide," the accurate hammer that would nail fire ants and fire ants only. This miraculous hammer was a poison called mirex. A new weapon brought new hope for a final victory. In the sense that World War II was a continuation of World War I, the Third Fire Ant War was a continuation of the second. Much like the "Wunderwaffe" V-2 rocket renewed hope of German victory, a new weapon, mirex, buoyed the spirits of the USDA.

The first poisoned bait developed by the laboratory used the toxicant kepone mixed into peanut butter and dispersed in short sections of soda straws. Kepone's slow action solved two problems often encountered by poisoned baits intended for ants (Williams, 1983). First, it could be shared widely among nestmates before the poison took effect. A poison that killed foragers quickly would not be effectively transported back to the nest and shared. Second, it reduced the problem of bait-shyness, the avoidance of toxic foods after initial contact. By the time the poison took effect, avoidance no longer mattered. Two additional properties were also desirable: the toxin was not repellent when mixed with food, and it was lethal over a wide range of doses, so delivering uniformly high doses mattered less. Kepone, which will reappear as a player later in this drama, was soon replaced by mirex, which had all four desired properties. Allied Chemical Corporation had patented mirex as an insecticide in 1954. Hooker Chemical Co. (later made famous by the story of Love Canal) had patented it as a flame retardant. Here was a remarkable literary coincidence: a quencher of fire and of fire ants.

Chemically, mirex and kepone differ only slightly—where kepone contains an oxygen atom, mirex contains two chlorine atoms. Both are impervious molecular cages of 10 carbon atoms. Strictly speaking, mirex is a chlorocarbon ($C_{10}Cl_{12}$) rather than a chlorinated hydrocarbon (see Alley, 1973, for a review of the chemistry and toxicology of mirex). The bait was a solution of mirex in soybean oil, which acted as food and attractant. This poisoned oil was absorbed by ground corncobs (grits), and the result was a free-flowing, granular powder that was 85% corncob grits, 15% soy oil, and only 0.3% mirex (Lofgren et al., 1964). When development of mirex bait was announced in 1962, the same year in which Rachel Carson published *Silent Spring*, serious biological research on fire-ant biology had yet to be done. Beginning that same year, mirex replaced the discredited heptachlor and was applied by ground or air to large areas in several southern states at the rate of 11.2 kg per hectare. By 1963, the standard application rate was lowered to 2.8 kg per hectare, and in 1965 to 1.4 kg per hectare. The lowest rate deposited less than 5 g of the mirex toxicant per hectare. In a later formulation that reduced this amount still further, the corncob grits were first soaked in nontoxic oil and the toxic oil applied only as a coating on the outside. Perhaps it seemed inconceivable to USDA officials and pesticide proponents that such a small amount of toxic material could be problematic. In fact, they listed the bait's lack of toxic residue in the soil as a "disadvantage," because fire ants would be able to reinvade treated areas and treatment would have to be repeated.

Early successes with mirex rekindled the fond dream of eradicating the fire ant from North America. Once again, a coalition of large farm interests, farm bureaus, local politicians, and commissioners of agriculture went to work to convince the U.S. Congress to spend large amounts of money on the Fire Ant Wars, again through a federal-state cooperative program. Success did not come immediately or easily. The U.S. Budget Bureau pressured for a reduction in budget in 1964, but Jamie Whitten, congressman from Mississippi, chairman of the Committee on Agriculture (and thus in charge of the USDA's budget), and a stalwart, unyielding General for Eradication in the Fire Ant Wars, overruled the budget cut. His counterpart in the Senate, Spessard L. Holland of Florida, was lavishly in favor of the program, claiming that folks in his district were "screaming for relief" from the fire ant. The Government Accountability Office (GAO, Congress's watchdog agency) issued a scathing report on the fire-ant control program, accusing the Agricultural Research Service (the USDA's research arm) of ignoring scientific opinion and wasting government money. The GAO blocked funding for the program in 1965 and 1966, and it began to appear that the federal-state cooperative program might be discontinued.

Once again, the Southern Plant Board and the USDA went to work and proposed the goal of eradication to Congress. Their support came from a loose, by-now familiar coalition of large landowners, livestock and dairy organizations, farmers, truck farmers, local granges, farm bureaus, commissioners of agriculture, and local politicians courting the farm vote. Congressional hearings were stacked with commissioners of agriculture and colorful locals who trotted out a "parade of horrors" richly illustrated with photos of fire ant stings. Under this pressure, no southern member of these congressional committees had the courage to vote against the appropriations. President Lyndon Johnson cut the fire-ant program from the recommended budget, but Representative Whitten reinstated a $5 million recommendation, which was raised to $8 million by Senator Holland (Shapley, 1971b). Such favorable treatment of fire-ant appropriations did not change until Senator Holland retired in 1970 and Senator Gale McGee of the fire ant–free state of Wyoming took over his chairmanship. In 1967, however, the Agricultural Appropriations Subcommittee of the Senate ordered that money be transferred to the Agricultural Research Service's Insects Affecting Man and Animals Research Laboratory in Gainesville, Florida, to pay for large-scale tests of the feasibility of eradicating the fire ant.

The eradication-feasibility trials were to take place on three blocks of land totaling 1.2 million ha in Georgia, South Carolina, Mississippi, and Florida: 104,000 ha in the Starkville-Columbus area of Mississippi, mostly occupied by *S. richteri*; 254,000 ha in the Tampa-St. Petersburg area of Florida; and 863,000 ha centered on Savannah, Georgia. The last two were occupied by *S. invicta* (Banks et al., 1973a). Granular mirex bait was first applied in the autumn of 1967, then again the following spring and autumn. Commercial applicators under USDA supervision used aircraft—Lockheed PV-1s and PV-2s, as well as refurbished World War II B-17 bombers—that dispersed the bait in swaths 60 to 70 m wide along the flight path. Two additional contractors provided electronic guidance ensuring that adjacent swaths overlapped by about 15 m.

Six months after the last application, almost all colonies on randomly located check plots were dead, as were those in general searches, demonstrating the lethality of multiple applications of mirex. Searches one and two years later turned up small colonies up to 40 km inside the treatment boundaries, although most were within 8 km of the untreated source populations. The USDA authors conjectured that queens had flown in from the surrounding untreated areas to found these colonies, but queens do not regularly fly that far. Technical problems, they said, were surmountable, concluding that "total elimination of imported fire ants from large isolated areas may be technically feasible." The opposite conclusion was reached by an earlier National Academy of Sciences report (Mills, 1967) requested by the USDA at about the time of the eradication trials. Eradication, it said, was neither biologically nor technically feasible, nor was it justified, because only the weakest evidence indicated that fire ants did significant harm to human health, agricultural production, or land values.

The USDA went right ahead to propose the complete eradication of the fire ant from North America. USDA staff members calculated (Lofgren and Weidhaas, 1972) whether it would be theoretically possible to eradicate the fire ant from the USA and concluded (surprise!) that it was. It was, that is, if the entire then-current range of *S. invicta*, all 51 million ha of it, could be sprayed three to nine times with mirex bait over a period of 12 years, at an estimated cost of $200 million (1970 dollars). Eradication "by an effective, acceptable, and economical procedure [was] a commendable goal." Success depended primarily on availability of "a highly effective method of control that is inexpensive relative to the benefits gained by eradication." Once again, a fleet of World War II bombers was to be launched (déjà vu all over again) to distribute 213,200 metric tons of mirex bait containing over 800 metric tons of mirex toxin. Like an echo from the Second Fire Ant War, a high USDA official said, ". . . nothing can prevent the fire ant from moving westward to California unless an eradication program is carried out now" (Nordheimer, 1970). By the end of 1970, 5.7 million ha had been sprayed with mirex, as the eradication effort got under way.

This program was not the only one spraying mirex, however. Even while it was going on, mirex was being applied to huge areas in Florida, Georgia, and Mississippi by the USDA-state-local cooperative program, in spite of poor coordination and erratic state funding. In Florida alone, the Florida Department of Agriculture sprayed mirex on 7000 large farms after the owners paid a mere $0.37 per hectare. In addition, individual farmers, who could buy mirex bait at a low price, treated areas of unknown and unrecorded size. The USDA estimates that mirex was ultimately applied to over 45 million ha between 1967 and 1975. Much of this area may have been treated two or three times, so the extent of the treated area may be less, but at least 58,900 metric tons of mirex bait were nevertheless applied to the landscape during this period.

Proponents of mirex were dead wrong in their judgment that such a small amount of toxin per hectare could do no harm—several properties of mirex made even trace amounts problematic. In 1969, a scientific panel called together by the U.S. Department of Health, Education and Welfare determined that mirex was a moderate (class B) carcinogen and recommended limiting its use to situations involving human health. Other problems also surfaced—mirex was extremely persistent in the environment, was bioconcentrated and biomagnified in the food web, was very toxic to aquatic life, and was not specific to fire ants. I discuss these properties in greater detail below.

In response to these revelations, opposition to the mirex program and to eradication began to coalesce, making the years 1970 and 1971 very active ones (Nordheimer, 1970). The U.S. Department of the Interior, whose Fish and Wildlife Service had fought bloody battles against the USDA during the Second Fire Ant War, reviewed the mirex program. In 1970, Secretary Walter Hickel banned all but small-scale use of mirex on lands under his jurisdiction, citing harm to fish and other aquatic life and striking a body blow to the concept of eradication. Another blow came when a Select Study Committee on Mirex called by the governor of Florida recommended that Florida postpone its participation in the eradication effort until a list of environmental questions had been answered (Livingstone et al., 1970). The members referred to the program as "another of the endless rounds of Russian roulette with our environment." Although presidential candidate Richard Nixon had promised effective control of the fire ant during his 1968 presidential campaign, in March of 1971 his own Council on Environmental Quality reviewed the USDA's plans, recommending that the use of mirex be limited and that alternate modes of fire-ant control be sought.

In response to this storm of criticism, and to the two withdrawals from the program, the USDA stopped calling it an eradication program in 1971, referring to it thenceforth as a control program. Eradication had called for three treatments in a row, but control used only single treatments for "relief" from fire ants. In August 1970, the Environmental Defense Fund and other citizens' environmental groups filed a motion in U.S. district court in Washington, D.C., to stop the spraying (Shapley, 1971a). The new National Environmental Policy Act required that the USDA file a detailed, final environmental impact statement on the mirex program before spraying could begin, but the USDA went ahead with its spraying program in the fall of 1970 anyway, having filed only a preliminary impact statement. In court, the USDA agreed to stop spraying in November but to resume the following spring. Although the Environmental Defense Fund's motion was denied in April 1971, other such motions followed.

Another setback for mirex followed when the regulation of pesticides was transferred from the USDA to the newly formed U.S. Environmental Protection Agency (EPA). On 18 March 1971, the EPA issued a "notice of cancellation" of mirex's label (the label is essentially a use permit), citing that enough questions existed to justify a full review of the scientific foundations of the program, such as they were. These hearings did not get under way until July 1973. Meanwhile, the state support for the mirex program was faltering. By April of 1971, only Georgia and Mississippi had pledged enough funds to proceed. Other states were virtually out of the program or made deep cuts. A governor-appointed committee in Florida recommended a pause, even though the 1970 Florida legislature had already appropriated almost a million dollars to spray 7.7 million ha in 1971. Florida's Division of Health (like several similar bodies in other states) rated the fire ant below mosquitoes, sand flies, stable flies, horseflies, midges, bees, wasps, chiggers, and other mites on their list of nuisances and pests—not exactly a powerful justification for a multimillion-dollar eradication effort.

Justification of a different sort was offered by a USDA official at a meeting I attended toward the end of 1971. Describing the mirex program's plans for 1972, he said that funds were available to spray 8 million ha, and that "aerial contractors are needin' the work. Our cooperators won't be satisfied by the one-treatment status for long. They're gonna be hollerin'. . . . The program is in dire need of assistance" (personal notes, 1971 Fire Ant Workshop).

The year 1971 also finally saw a sharp increase in the research effort on fire-ant biology, much of which was funded by a one-time release by the USDA of $800,000 in cooperative-research agreements with university scientists. As a result, research on a wide range of biological topics began. Most fundamental, George Markin and his group finally published the basic outlines of the life cycle and biology of *S. invicta* in the early 1970s. At about the same time, and perhaps in response to criticism of mirex, the USDA was busy developing "improvements" to mirex baits. One of these was "microencapsulated" mirex bait, tiny droplets of poisoned soybean oil, each packaged within a thin film of gelatin or plastic (Markin and Hill, 1971; Markin et al., 1975a, b). For reasons not clear to me, National Cash Register Corporation produced these baits. Gone was the bulk of corncob grits. The capsules had a longer field life and were effective during cool weather too. The baits could be produced with as little as one-fourth as much mirex, in the hope of assuaging critics. Best of all, without the bulky grits, airplanes could spray five times as much area without reloading.

In 1972, a report by a study panel of the National Academy of Sciences said that mirex was a serious hazard to aquatic life. As a result, in 1973 the EPA prohibited the aerial application of mirex to any coastal counties, bodies of water, or heavily forested areas. In Florida, half the counties are coastal, so this ruling effectively limited the application of mirex to ground treatment on open land only. If Florida had not already abandoned the eradication effort, this prohibition would certainly have ended it.

On 4 April 1973, the EPA finally published a Notice of Intent to Cancel Mirex. The issues to be covered in the cancellation hearings were summarized by William Ruckelshaus, administrator of the EPA, in the *Federal Register* (Ruckelshaus, 1973). Using his authority under the Federal Insecticide, Fungicide and Rodenticide Act, he announced hearings to determine whether mirex presented an unreasonable hazard to the environment and to humans; whether the benefits of mirex, as used, exceeded the costs; and whether alternative control measures were available.

The promised scientific hearings began on 11 July, Judge David Harris, an administrative law judge, presiding. In the role of plaintiff was the EPA, and in the role of respondents, the USDA and Allied Chemical Corporation, the manufacturer of mirex bait. If anyone had any doubts about which the USDA served, those doubts were promptly dispelled. For two years, each side arrayed its experts and presented its case before Judge Harris, parrying and thrusting through cross-examination and redirect, piling datum upon datum. As a young assistant professor at Florida State University, I had the good fortune to play a role in this case as a result of a peculiar circumstance. Almost all of the many independent experts on pesticide chemistry and biochemistry, effects on nontarget species, movement of mirex through food chains, economic aspects, fire-ant biology, and so on either worked for the USDA or had received research funds from the USDA. I was one of the few who did not have such a conflict of interest, so the EPA signed me on as their expert on fire-ant biology. The testimony I prepared was drawn mostly from published and unpublished USDA results, as well as from my own experience. It was great fun.

The Case Against Mirex

By the time the hearings were suspended in 1975, over 100 witnesses had given testimony, creating a court record of 13,000 pages. The facts established in the case encapsulate nearly all of the controversy surrounding the fire ant and the mirex program, which I summarize here.

As an insecticide, mirex was far from perfect. Its highly symmetrical molecule is resistant to oxidative attack, so it remains in an animal's body for most of its life. Resistance to microbial degradation gives mirex a half-life in the environment of about 12 years, longer even than that of DDT, so it is one of the most environmentally stable compounds known (Hinkle, 1982; Metcalf, 1982). Eighty percent of the mirex applied to a site could be recovered unchanged from the soil after five years, and 50% of it after 10 years. Some of the breakdown products, including kepone, were themselves toxic.

Mirex is only very slightly soluble in water but quite soluble in fat. In the bodies of animals, it accumulates in their fat and resists excretion. Rats fed radioactively labeled mirex stored 82% of it in their tissues, especially in fat, in unchanged form. Such accumulation is called bioconcentration, a phenomenon already known from experience with dieldrin and DDT (Gaines, 1969; Gaines and Kimbrough, 1970). As long as an animal's diet contains mirex, mirex will continue to accumulate, reaching ever-higher concentrations in the animal's tissues, far in excess of its concentration in the food. Mirex leaves the body through processes that mobilize fat, such as egg laying in birds and lactation in mammals.

Mirex accumulates at even higher concentrations as it moves up the food chain, a process called biomagnification (already known from DDT). At each step in the food chain, predators retain most of the mirex already bioconcentrated in the fatty tissues of their prey, so even trace amounts of mirex in the environment came to reach toxic concentrations in animals near the top of the food pyramid. For example, in a mirex-treated area of Louisiana, mirex occurred at 0.01 to 0.75 parts per million (ppm) in whole animals at the bottom of the food web; 1.2 to 1.91 ppm in birds, one level up; and 74 ppm in the fat of top predators. Biomagnification was even more obvious in the aquatic food web. In an estuary, minnows, shrimp, and blue crabs carried concentrations of mirex in their bodies that were 2300- to 41,000-fold higher than its concentration in water. Mirex found its way into the bodies of a large number of fish species (Kaiser, 1974) and into the eggs of many bird species, including four species of hawks.

News flash: humans are not exempt from the laws of nature. Samples of fatty tissue from people in southeastern states contained from 0.16 to almost 6 ppm, not so different from the amounts in birds (Kutz et al., 1974). In an EPA study, a quarter to a third of southerners in eight states had mirex in their tissues; the average was 0.4 ppm and the range from a trace to 1.32 ppm. The frequencies of mirex residues were much higher in states that were heavy mirex users. Samples of food contained mirex residues, but no systematic estimates of exposure through diet were conducted. A retired USDA official went on record to say, "if [mirex] was the most dangerous thing facing us, we would be in a hell of a good shape" (Crider, 1977). Few unretired officials could afford to be so cavalier.

The risk to humans did not derive from mirex's toxicity, however, but from its carcinogenicity. Between 1969 and 1973, the National Cancer Institute carried out two high-dose feeding studies of mirex's carcinogenicity in mice and rats and found a highly significant increase in hepatomas (liver cancers), approximately equal to that in positive controls (rats fed known carcinogens). A second study of mirex confirmed the elevated levels of carcinomas and hyperplastic nodules (precancerous growths).

Although mirex's toxicity is low, that of its breakdown product, kepone, is not. Kepone is a carcinogen like mirex, but its more immediate effects became disastrously apparent some time later in Hopewell, Virginia. A plant that manufactured kepone had contaminated the James River and much of Chesapeake Bay with over 35,000 kg of kepone waste and had exposed factory workers to high levels of kepone. Many suffered severe poisoning symptoms, including weight loss and liver damage, stillbirths in women, and sterility in men, as well as tremors, memory loss, and slurred speech.

The claim that mirex posed no health threat to humans was no longer tenable. USDA officials therefore had good reason to worry when, later in 1975, kepone "in very small amounts" was found as a degradation product of mirex in the field. The discovery that it broke down into kepone under environmental conditions, however small the amounts, was the death knell for mirex. Kepone, like its mother mirex, could be expected to show up in humans in due time.

No deaths or reproductive effects were expected in birds, mammals, or fish at the rate at which mirex was applied (Alley, 1973), but at high doses, chickens, Japanese quail, and rats developed liver lesions (Davison et al., 1976). In contrast to its low toxicity to vertebrates, mirex was extraordinarily toxic to aquatic animals, especially crustaceans, even at minute concentrations (reviewed by Alley, 1973), and caused great concern for aquatic ecosystems and fisheries. Mirex entered the aquatic systems as particles readily taken up by filter feeders or from solution—adult blue crabs concentrated solutions of 0.22 parts per billion (ppb) of mirex 140-fold in their tissues (Schoor, 1974).

As if the effect on aquatic systems were not enough, mirex turned out not to be very specific on land either. Native ants disappeared from mirex-treated plots in broadleaf forests. Forests were often sprayed, even though they harbored no *S. invicta*, and the forest ant community was devastated (Lee, 1974). In open areas, mirex killed at least 14 species of the native ants, some of which probably competed with *S. invicta* (see Showler and Reagan, 1987, for a list of species and references). Mirex could in no way be considered specific to fire ants—"perfect pesticide" indeed!

Mirex was not even specific to ants. Ground beetles and rove beetles, both predators of sugarcane pests, were reduced 60 to 70% by a single application of mirex. Second applications, when fire ants were no longer present to remove the bait quickly, were devastating to populations of crickets and beetles, which fed directly on the bait (Markin et al., 1974a). Studies in sugarcane corroborated these findings. Like heptachlor (Long et al., 1958), mirex had detrimental effects on sugar yield because it reduced populations of ground beetles, rove beetles, and crickets (Reagan et al., 1972). Mirex was not a hammer that nailed only fire ants; there was never any reason to expect that it would be.

Effects of Fire Ants on Humans and Public Health

The habitat created by humans for their own use is the very habitat most congenial to fire ants, allowing them to reach high densities. Ant and human are therefore inevitably thrown together and frequently come into contact, especially when humans blunder into "ant beds." The ants surge forth from their violated nest to sting in defense of their home. Agricultural workers were considered to be particularly at risk. During the EPA hearings, various experts justified the mirex program on the grounds that fire ants could interfere with hand harvesting of citrus, cotton, strawberries, tung nuts, and pecans. No attempts to quantify such problems were made.

Although victims occasionally seek medical help, stings are rarely of much health significance. At the time of the mirex cancellation hearings, the USDA had made no serious estimates of the magnitude of the public-health problems posed by *S. invicta*. Not until the mid-1970s and later did limited surveys estimate frequencies of stings, medical attention, and costs (by extrapolation) (Clemmer and Serfling, 1975; Adams and Lofgren, 1981, 1982; Lofgren and Adams, 1982; Drees, 1995). For example, a study at Fort Stewart (Georgia) revealed that about 3% of the population per year sought medical help for fire-ant stings, at a total cost of about $5000 (1981 dollars). In a nonmilitary Georgia population of 77 families, 95 individuals were stung at least once during the year; stings were more likely among rural and young people. In 240 New Orleans households, the overall sting rate was about 30% per year; it was over 50% among children under 10 years old. Just over 4% of those stung sought medical attention. A few cases of indoor attacks have been reported. For the great majority of southerners, this ant is just a nuisance and hardly justifies a huge eradication program. During the cancellation hearings, many experts testified to the low ranking of fire ants as serious pests.

There are exceptions, however. A very small percentage of individuals suffer anaphylactic shock when stung and may even die. For such hypersensitive individuals, relying on the control of fire-ant populations for personal safety is probably ill advised. A much better strategy would be to carry an emergency kit containing injectable epinephrine.

Fire Ants and Crop Agriculture: Losses and Benefits

In the early days, the fire ant was regarded largely as a rural, agricultural problem, causing damage to many crops and livestock. Much of the evidence was anecdotal or the product of surveys of farmers (Wilson and Eads, 1949). The EPA's notice of its decision to end mirex use (Johnson, 1976) cited various experts who testified that fire ant mounds can interfere with hay harvesting; that fire ants cause injury to farm animals, pastureland, livestock, soybeans, and other crops. None of these claims was based on careful estimates of the actual economic losses caused by fire ants. Although the mirex program was justified on the basis that *S. invicta* caused large economic losses, the program was implemented in the early 1960s without much evidence that the losses existed. The horse lagged behind the cart by over a decade—the first serious attempts to quantify losses did not appear until the mid 1970s (perhaps stimulated by the mirex cancellation hearings?), and interest in the subject fizzled by the mid-1980s, after the show was over. These studies have been summarized in three reviews (Ofiara, 1983; Lofgren, 1986a; Showler and Reagan, 1987), where the reader can also find a more exhaustive list of references. A number of papers reported direct damage to corn, citrus, okra, eggplant, cucumber, sunflower, longleaf-pine seedlings, and potatoes, but these came after the EPA's notice of decision and played no role in it. Even so, few were careful experimental studies, and few included serious estimates of economic losses, although several authors could not resist wild extrapolations.

At about the same time, reports of beneficial effects of fire ants were appearing, giving the debate a kind of good-ant, bad-ant aspect. Louisiana sugarcane was the first to weigh in. The benefits of a healthy fire-ant population had become apparent during the Second Fire Ant War, when sugar yields were lower in heptachlor-treated, fire ant–free fields. Experiments in the early 1970s showed that fire ants were by far the most important predator on sugarcane borer, reducing crop damage by this pest. In Florida sugarcane fields, cane borer is largely controlled by two species of insect parasitoids, and the impact of fire ants is less clear.

Other good-ant cases were soon added to the list as fire ants were discovered to prey on a number of agricultural pests, including velvetbean caterpillar, southern green stinkbug, tobacco-budworm eggs, pecan weevil, striped earwig, pine tip moth, soybean looper, and a number of others (listed in Sterling et al., 1979; Reagan, 1986). Some reported significant reductions of the pests; others simply reported the fact of predation. A more careful study of cotton in Texas showed that fire ants reduced the populations of boll weevil without reducing other beneficial insects. After fire ants advanced through areas of northeastern Louisiana, the lone star tick, a pest of cattle and wildlife, essentially disappeared. Ticks carry diseases such as tularemia, tick fever, Lyme disease, and Rocky Mountain spotted fever, so the fire ant invasion may even confer public-health benefits. In pastures, fire ants invade cowpies and reduce the populations of some of the pest insects that breed in them, including horn flies, stable flies, and face flies.

In the final analysis, is *S. invicta* friend or foe? No single answer is likely to be possible—it would depend on who, where, when, and what and would vary with the circumstances: geography, crop system, stage of crop development, farming practices, economic conditions, and other biotic factors. As in a ledger, one must add up all the credits and debits to obtain a meaningful balance, and this is undoubtedly a complex accounting problem. Losses in one area may be partly balanced by benefits in another area or at another time, and of course, not all effects of *S. invicta* can be assigned dollar values.

Economic Impacts

At the time of the EPA's cancellation hearings, no consensus about or even reasonable estimate of *S. invicta*'s economic impacts was available.

The situation has not improved much since then. Ofiara (1983) referred to the entire subject of fire ants in southeastern agriculture as "confusing and poorly documented," not allowing the assessment of the economic significance of the ant. The field was and still is plagued by low-quality, unreplicated, poorly designed studies and poorly chosen, small, or biased samples. Many are simply searches for evidence that fire ants are causing significant losses, rather than unbiased assessments of impacts, whereas others indulge in unjustified extrapolation across widely different geographic regions and agricultural situations. Little consideration is given to the many factors, in addition to fire ants, that affect yield and how these factors might interact with fire ants. Ofiara lamented, "limited, imperfect, biased data presently is [sic] all that is available." From such studies, no bottom line on the balance sheet can be computed or probably ever will be. The decisions of three scientific advisory committees that reviewed the subject during the 1960s and 1970s—that the ant was not economically significant in production of row crops—were therefore not surprising. A group of panels convened in 1982 came to similar conclusions and stated that the ant was primarily a nuisance and human health pest. This opinion was also voiced by the great majority of farmers in a Florida survey, which incidentally showed greater losses on mirex-treated farms than on untreated farms (Wilson, 1975).

Because direct estimation of economic impacts was so unsatisfactory, Semenov and his coworkers took an indirect approach, reasoning that, if the fire ant had a negative impact on crop production, production should have dropped after any given area was invaded (Semenov et al., 1997). Comparison of the productions of corn, cotton, sorghum, soybeans, and wheat before and after invasion by *S. invicta* (and adjustment for other variables that affect production) revealed a slight increase in cotton yield (+3%) and an equal decrease in soybean yield. Area harvested did not change significantly for any of the crops. Although this result suggests small effects of fire ants, it is still not an estimate of economic impacts. Crop yields and area might have been maintained at the cost of pesticide against fire ants, a cost that goes on the debit side of the ledger. Other costs might include changes in crop quality, equipment repair costs, and so on. No such data are available. Clearly, fire ants do not cause major losses in these crops, but whether they add to the cost of their production is still an open question. The ledger remains unbalanced.

Other Impacts of Fire Ants

Many other sins have been attributed to fire ants, some of which are regularly trotted out to head the latest parade of horrors. These include killing farm animals, causing infections of milk-cow udders, increasing the cost of fence maintenance, chewing up the silicone seals in concrete highways, damaging airport landing lights, damaging insulated cables, and my personal favorite, eating the wax seal from under a toilet in a Florida state park, causing flooding and repairs. Occasional home and nursing-home invasions have been added to the list, and a report was even published of the invasion of three motorized vehicles, all belonging to USDA fire-ant researchers (revenge?) (Collins et al., 1993). In one, the ants made themselves comfortable in a camper. In another, they nested in the organic junk that accumulates at the top of the firewall under the hood, and in the third, they nested in the moist pollution-control canister and foraged on insects caught in the radiator. Are these ants smart, or what? Should we not feel admiration, even if only grudgingly?

One interesting association was not described until 1989 (and was therefore not a factor in the mirex hearings): fire ants are attracted to electric fields and therefore sometimes accumulate in outdoor electrical equipment, such as traffic-light relays and air conditioners, causing malfunctions, especially in Texas (MacKay, 1988; MacKay et al., 1990, 1992a, b; Vander Meer et al., 2002). Bill MacKay (with a coauthor appropriately named Sparks, among others) carried out experiments revealing that the relays were attractive only when powered, that both AC and DC fields were attractive, and that attraction increased with field voltage. Contact with the conducting surface was required. For this reason, ants seem to accumulate only in equipment with bare contacts, junctions, sockets, or plugs. The attraction is not the result of electromagnetic fields, ozone, or the type of insulation. The attraction is probably general to ants, but the reason for it is unknown, although the release of various exocrine secretions upon shock has been suggested.

The Cost-Benefit Ratio of the Mirex Program

As long as the mirex program's goal was eradication, the real effectiveness of mirex bait was an important issue. Because the USDA claimed almost 100% effectiveness of mirex, making eradication seem feasible, the EPA scrutinized these issues carefully. In reality, individual treatments often resulted in kill rates well short of 100%, for reasons that were not well understood. For example, on plots treated by air between 1969 and 1972, survival rates of 10 to 50% were fairly common. In the Tampa and Starkville eradication trials, control was adequate on only half the plots, allowing rapid repopulation by survivors. Even colonies treated with mirex emitted healthy, colony-founding sexuals for up to three months after treatment (Morrill and Bass, 1976).

Several reasons are possible for this lower-than-advertised effectiveness. First, uneven application was a persistent problem caused by poor equipment calibration, errors in flight-path alignment, and wind drift. Long strips were sometimes left with no bait at all, and colonies there survived. Second, colonies show idiosyncratic preferences for different food types (Glunn et al., 1981), and some may not have foraged on the oily baits. Third, well-fed colonies often do not take bait or do not distribute it as effectively within the colony. Fourth, rain or high temperatures may have reduced foraging or made the bait less lethal through weathering. Fifth, even under the best conditions, survival of small numbers of colonies was to be expected simply as a result of the statistics of toxicology. Sixth, occasional survival of mirex-poisoned colonies could not be ruled out because little was known about mirex's mode of toxicity or how it moved through the colony. USDA scientists assumed that workers shared the poisoned oil directly with the queen, but the little evidence that was available suggested that the queen was insulated from the direct effects of mirex because she was fed mostly on glandular secretions. In my laboratory, large colonies that I reduced to a queen and five workers survived and grew back into full colonies.

Of course, when the USDA changed the program's official goal from eradication to control, the question of effectiveness became less critical, but the EPA was also obliged to consider the cost-benefit ratio, and in this, the mirex program did not fare well. It had been deployed without even a clear identification of where the costs and benefits resided, other than "giving people relief from fire ants," especially where the state and local governmental agencies had requested federal cooperation. The program was, in effect, a huge federal give-away, pork barrel of the classic kind in which politicians gained favor with their largely rural power base by providing free federal services. In one of the few cases where a cost-benefit ratio was calculated, Wilson (1975) showed that, in a Florida panhandle county, the government was spending about five dollars for every dollar of benefit to the farmer. Florida's "farmer treatment program" required the farmer to pay only a fraction of the actual cost of applying mirex. Farmer participation in fire-ant control programs declined sharply when they were required to pay a large share of the cost.

Alternative Control Methods

EPA also considered the issue of alternate control methods. At the time of the mirex cancellation hearings, the only other pesticide registered for use against fire ants was chlordane. Most of the dozens of products available today had not yet been registered. Oddly, even the EPA notice of decision did not mention any nonpesticide alternatives. Not until the early 1970s did USDA scientists seek potential biological-control agents in South America, and 15 more years elapsed before serious development work on these agents began. The allure of pesticides faded slowly. This allure was not limited to fire ants, nor has it faded much in the intervening years. Pest control remains dominated by chemicals to this day, and millions of tons of pesticides are dispensed every year.

Sundown for Mirex

In 1975, on the basis of information that came to light during the hearings, the EPA restricted aerial applications of mirex to one per year and placed other restrictions on its use. The USDA announced that, as of 30 June 1975, it would no longer fund the fire-ant program (states and private concerns were free to continue) and blamed it all on the EPA, beginning one of those petulant exchanges between government officials that occasionally make reading newspapers so rewarding (Anonymous, 1975a, b; Brody, 1975). Earl Butz, the Secretary of Agriculture, laid the blame for the fire ant program's failure squarely at the EPA's feet. The EPA's restrictions on the use of mirex had made the program "completely unworkable." Without fussy, wrong-headed interference from the EPA, the USDA could have eradicated the fire ant "with negligible effects on the environment." Instead, the department had now been "forced . . . to distribute persistent pesticides into the environment indefinitely." Butz ended with dire predictions of how the ant, loosed from its fetters, would now wreak havoc on a helpless South.

John Quarles, deputy administrator of the EPA, shot back that he was surprised that the USDA had suddenly chosen to eradicate rather than to control fire ants. He went on to point out that the USDA had abandoned the concept of eradication well before EPA had restricted the use of mirex. Twisting the knife, he also reminded the USDA that between 1962 and 1972, when use of mirex was unrestricted, the fire ant had been neither contained nor eradicated. The most memorable quote of the year came from E. O. Wilson, by then on the faculty of Harvard University. Taking note of the $148 million already spent on the fire-ant program, and its complete failure to halt the spread of the ant, Wilson pronounced the program "the Vietnam of entomology."

Butz's salvo was probably intended to shift the blame for the failed program away from the USDA at a time when the administration of President Gerald Ford was looking for ways to cut spending during a recession. It was certainly not the end of the Fire Ant Wars.

The mirex hearings were put on hold in March 1975, but negotiations between the EPA on one side and the USDA and Allied Chemical Corporation on the other dragged on. Restrictions on the use of mirex must have shrunk demand considerably. In 1976, Allied Chemical got tired of all the fuss, or perhaps simply saw the inevitable end of mirex, which was, after all, one of their minor products, and picked up their marbles and went home. Henceforth, they announced, they would no longer formulate mirex bait at the Aberdeen, Mississippi, plant. The state of Mississippi experienced severe withdrawal symptoms and bought the plant for $1.00. Using ingredients left behind by Allied Chemical, they continued formulating baits for sale to other states at $528 per metric ton (Crider, 1977). Negotiations continued but at this point between the state of Mississippi's Fire Ant Authority and the EPA, who finally settled out of court. On 29 December 1976, the EPA published its decision in the *Federal Register* (Johnson, 1976). Mirex was to be phased out over a period of 18 months, and the Mississippi authority agreed not to appeal this cancellation order. The hearings were to be suspended, and the EPA was to publish its reasons for cancellation. As a result of this agreement, no official finding was ever issued by Judge Harris, but of course the 13,000-page record of the hearings contains all the information advanced by both sides.

Meanwhile, back in Mississippi, the money from mirex sales financed research into alternate formulations of mirex. After running out of mirex, the plant shut down for five months but resumed operations after buying 11,340 kg of technical mirex from Hooker Chemical in New York. The Mississippi Commissioner of Agriculture, Jim Buck Ross, exulted, "We are back in business." He planned to make enough mirex bait to cover 7.3 million ha before the 31 December 1977 deadline prohibited aerial application.

The year 1978 was not a good one for the mirex interests. The National Cancer Institute concluded that kepone was also a carcinogen in laboratory rats and mice, and unfortunately, samples of mirex bait from the Mississippi production plant were found to contain up to 2.6 ppm of kepone, whose label had been cancelled in May. Could things get worse? You bet they could! The EPA found mirex in mothers' milk (that's *human* mothers!). Psychologically, that was hard to top. Finally, the out-of-court settlement between the EPA and the state of Mississippi took effect. As of 1 January 1978, mirex was no longer legal for aerial application, although mound and ground broadcast use was permitted through 30 June 1978. Thereafter, no uses whatsoever of mirex would be allowed. It had ended with a whimper. Adding injury to insult, the U.S. Office of Management and Budget reduced the annual appropriation for the fire ant program from $9 million to $900,000, saying it was "like pouring money down a rat hole." Congress appropriated about $1 million anyway for "methods development" and quarantine in fiscal year 1978 and $4.5 million for fire-ant control.

Ferriamicide: Mirex Tries to Rise from the Ashes

Meanwhile, chemists at the Mississippi State Chemical Laboratory were busy working behind the scenes to rescue their beloved mirex. The lesson they had learned in the previous decade was not that a hammer was the wrong tool but simply that it needed a bit of tweaking. If the persistence of mirex was the problem, why then they would make it less persistent! By adding ferrous chloride and an organic base to the mirex formulation, and reducing the amount of mirex, they claimed to have made mirex that was quickly degraded by exposure to sunlight (Alley, 1982). They called it ferriamicide; cynics immediately dubbed it "Son of Mirex," after the serial killer Son of Sam, who was very much in the news at the time. Mississippi hoped that ferriamicide would overcome the objections to mirex and soldiered on for six years, trying to make its pesticide business pay, but before long, it looked as though the dollar they had paid for the Allied Chemical plant had been a bad investment—damning facts popped up like mushrooms, and legal challenges multiplied. Table 5.1 chronicles the history of the ill-fated ferriamicide.

Table 5.1. ► History of ferriamicide, the "degradable form" of mirex.

Early 1977: Ferriamicide is announced. The manufacturer (the state of Mississippi) cl
the half-life of mirex to 0.15 year.

Late 1977: EPA grants an experimental use permit. Environmental groups claim that
political pressure.

31 December 1977: Aerial application of mirex becomes illegal; Mississippi applies f
exemption for aerial application of ferriamicide. The Environmental Defense Fund
because ferriamicide is based on mirex. EPA receives 12,000 letters and 15 calls fr
congressmen. The Federal Insecticide, Fungicide and Rodenticide Act is in revisio
committee includes several southern members.

March 1978: EPA grants 1-year "emergency" use permit for Mississippi, Alabama, a
restrictions apply: it can be packaged in one-pound bags only, homeowners must
have >50 fire ant colonies and must wear rubber gloves. Enforcement is infeasible
having the data to justify the permit.

Early 1979: Samples 54 days old contain up to 22 ppm kepone (a banned pesticide);
formulating bait contains 3 to 6 *percent* kepone. Kepone is shown to be a degrada
field. The Environmental Defense Fund legally challenges the permit.

February 1979: EPA "discovers" year-old Canadian studies (Smith, 1979) demonstrat
ferriamicide; ferriamicide breakdown products are more toxic than mirex. Environ
late discovery as more evidence that the EPA yielded to political pressure. The fin
EPA and Mississippi scientists (Alley, 1982).

September 1982: EPA grants a 1-year emergency exemption for Mississippi, Texas, a
Audubon Society, Environmental Defense Fund, Sierra Club, and National Wildlife
arguing that no emergency exists.

19 October 1982: District court issues a restraining order on sale of ferriamicide and
not following legal permitting procedures (Marshall, 1982). The court voices the o
distinction between the banned mirex and ferriamicide is without merit.

1983: EPA finds that 40% of the original mirex and 94% of the toxicant remains after
Ferriamicide is finished. Congressman George Brown of California accuses EPA of
pressure to "make a mockery of scientific principles and common sense" (an asto
from a politician!).

While the ferriamicide battle was going on, the pro-mirex faction made one more attempt to resurrect mirex. A congressman from Georgia attached an amendment to the Federal Insecticide, Fungicide and

Rodenticide Act that would lift the ban on aerial spraying of mirex for two years. Napoleon was to return from Elba. Several congressmen from non–fire ant states were most unkind during debate. The House resoundingly rejected the amendment by 224 to 167 in late November of 1979. Mirex had met its Waterloo.

The sun had set on mirex and was also setting on its kin. Did the failure of the mirex program discourage the USDA from large-scale chemical control projects? Do you need to ask? By 1982, USDA scientists had laboriously screened over 7500 chemicals as potential fire-ant poisons (Battenfield, 1982; Williams, 1983), but only one was effective enough to be a possible substitute for mirex. It was American Cyanamid's AC 217,300, trade-named Amdro. In 1979, the USDA tested an Amdro-based bait under an experimental-use permit. Like mirex, it was a slow-acting stomach poison consisting of 1% of the toxicant dissolved in soy oil and absorbed by puffed corn grits. The recommended dosage applied 10–15 g of the toxicant per hectare. It was considerably less effective than mirex bait, having average kill rates of 80 to 90%. On the other hand, it degraded rapidly in sunlight, left no toxic residues, was biodegradable by microorganisms, and was not biomagnified in the food chain. Once the USDA applied for a permanent registration, the EPA was under tremendous political pressure, including threats to its budget, to grant the registration, because mirex had been cancelled and ferriamicide was mortally wounded. Amdro was granted a conditional registration in August 1980, in record time. It could not be used on cropland, and could be aerially applied only on pastureland. Later entries in the fire ant–bait sweepstakes received no such rapid service, plodding through all the required steps over several years. Amdro was made available to the public at $125 for a twenty-five-pound bag. Questioned about the high price, an American Cyanamid spokesman remarked that, for the owner of a 0.41-ha lot, the bag was a 25-year supply (Bonner, 1980). Clearly, he did not expect Amdro to eliminate fire ants.

Scattered Guerilla Resistance

After Amdro, a crowd of chemical companies brought a long list of baits, fumigants, and mound drenches to market. The Fire Ant Wars may have been lost, but chemical manufacturers clearly perceived the retail market for weapons in the endless rearguard guerilla war that was to follow, and like arms dealers, they were ready to cash in on this lucrative business. Nowadays, walk into almost any garden-supply, hardware, building-supply, or nursery store in the Southeast, and you will face large displays of fire-ant poisons: stacks of orange bags, each with the image of a vicious-looking fire ant in full attack; pyramids of green shaker cans that dispense poison dust, promising to "kill the entire colony AND the queen"; and rows of red-and-white plastic bottles filled

with toxic bait, ready to be offered as a final repast. Drenches, dusts, solutions, granular baits, aerosols, and fumigants all promise the satisfaction of a quick and complete kill. Death is promised as a result of stomach poisons, nerve poisons, suffocation, gassing, or drowning. Some products do not deliver death directly but instead interfere with larval development or egg laying by the queen so that the colony gradually dwindles away. The products have names like Affirm, Spectracide, Amdro, Logic, ProDrone, Exxant, Fire Ant Killer, and so on (Collins, 1992). Expect soon to see labels reading MegaDeath, Scorched Earth, Biocide, and the like. Every fall, as fire-ant colonies grow larger and more obvious, so do the displays. Sales are steady. It is big business—$50 million worth per year, $32 million of it spent by homeowners. The 1980s also saw a subtle change in attitudes, however, that was correlated with the suburbanization of the South and the movement of population to the Sunbelt. Killing fire ants was no longer carried out by large government programs serving mostly agricultural interests but became a pastime for individual, largely suburban southerners. In the scientific, extension, and regulatory communities, the wind had shifted too. Talk about eradication grew quieter and rarer, and words of accommodation more frequent. People were accepting that, as much as they hated it, *S. invicta* was here to stay, and they needed to learn to live with it.

Why Did the Wars Start at All?

Why did the Fire Ant Wars begin, and why did they rage for so long? They were a cultural phenomenon, but both sides needed to make the science work for them, because in these days you look like a fool if you support an issue that is clearly contradicted by science. The original choice of position, however, was based not on science but on the deeply held values and beliefs, often below the level of consciousness, that are rooted in history, family, culture, and *Weltanschauung* and that give emotional comfort. We can reduce the opponents in the fire ant wars to a simple cartoon. On the one hand are those people whose attitudes are fairly described by the metaphor in Genesis 1:26–28, in which God grants dominion over the earth to mankind and admonishes mankind to replenish it. At the other end of the spectrum are those who see that humans depend on healthy ecosystems and are part of them, both functionally and ethically.

The first point of view is broadly represented in our society, quite independently of religious beliefs, and divides the world into humans and directly useful animals and plants (us) and the rest (them). "The rest" is of little interest or value if a harmful action is "good for people." Here is a typical statement: "It is believed that the hazards evident from toxicological results [for ferriamicide] are mitigated by the low exposure expected *for humans*" (emphasis mine) (Alley, 1982). One USDA bulletin phrased it clearly: "Since before the dawn of civilization, insects . . . have wanted to occupy places chosen by man." Even the EPA's statement of decision on mirex (Johnson, 1976) devotes just nine lines of its nine small-type pages to "nontarget insects." Throughout the Fire Ant Wars, toxic baits were used without testing *even of their effects on other ants.* Spraying the entire Southeast was proposed in the absence of any knowledge of ecological side effects, and millions of hectares were poisoned with dieldrin and heptachlor.

Those at the other end of the spectrum have powerful allies in the ecological and evolutionary sciences, which provide their basic metaphor. If individuals of this persuasion read Genesis 1, they would take note that it is a message of both dominion and (in the word "replenish") stewardship.

Of course more mundane forces were at work, too. Many of the people involved in the development and marketing of mirex belonged to a generation that had recently won the most deadly war in history, largely through technology and a can-do attitude. Faith in technology was at an all-time high. Perhaps the "Us versus Them" thinking of the Cold War era spilled over into the entomological realm. After all, the official USDA common name was the *red* imported fire ant. Significantly, the war metaphor permeated the entire era of the Fire Ant Wars and must have conjured up powerful and motivating images in a generation that had experienced war. Words of war pepper news reports, the speeches of politicians, and the proclamations of USDA officials. The vocabulary included dangerous foreign invaders, beachheads, battles, attacks, advances, and retreats. There were body counts, eradications, new *Wunderwaffen*, and civilians to be rescued or caught in the cross fire. Even the equipment spoke of war—World War II bombers rescued from the scrap heap and modified to rain death on a different enemy.

But, of course, it was not a war. It was a massive effort to manipulate ecology and *much* more complicated than a war. To have any hope of succeeding, one needed a great deal of ecological knowledge, humility, and concern for nonhuman values. Victory required subtlety, sensitivity, and wisdom, not aggression and frontal attack. The generally entomophobic nature of the American public did not help bring the proper perspective to this undertaking, but ultimately, the entire fire-ant program and the public support it enjoyed were based on what one participant in a 1982 fire-ant symposium called "a pathology of the American perception of reality." The news media were responsible for much of the hysteria. Rather than inform, most news reports sensationalized, propagandized, incited, and misinformed, repeating the same litany of unsupported "factoids" over and over. Having no schooling in biology, reporters were sitting ducks for whatever wild stories came along. I spent many an interview with reporters trying to bring some balance, knowledge, and skepticism to their thinking. E. O. Wilson once quipped that I was "trying to get a fair deal for fire ants."

No doubt the balkanization of science also contributed. As a result of specialization, chemists can invent chemicals that not only are incredibly toxic to insects but have disastrous effects on ecosystems, and concern for ecosystems is not in the chemist's job description. For mirex, the lag between introduction and the recognition of undesirable side effects also played a role. It produced no pathetic windrows of dead animals as heptachlor had. Once the dangers of mirex became apparent, a great deal of denial, dismissal, and general resistance followed. Professional people tend to be defensive about their decisions. Some exhibited just plain cussedness, a kind of suicidal joy in sticking to contrary beliefs. How, otherwise, can we explain why a chemical-company executive ate a DDT-sprinkled bowl of breakfast cereal on television? Even some scientists carried this denial through the years, long after persistent pesticides had fallen out of favor. I often suspect that cultures change only as the old guard dies off.

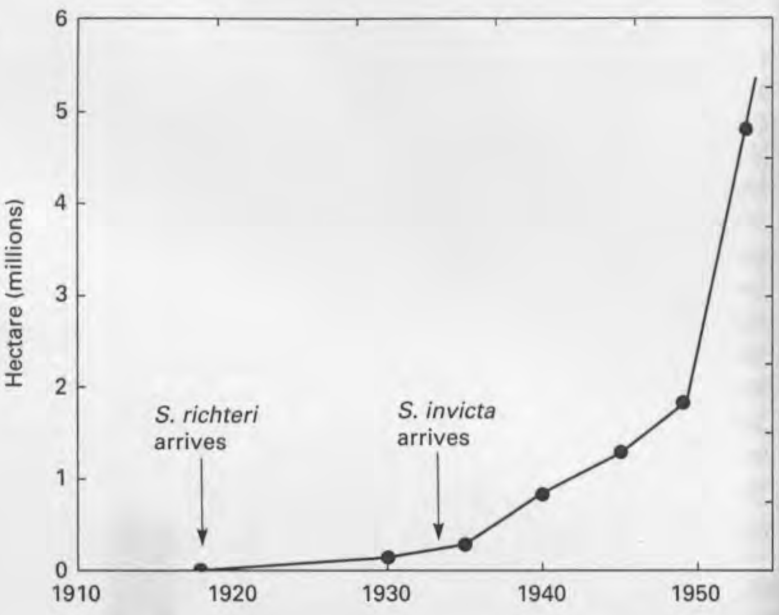
A large measure of the dubious "credit" must also go to agricultural commissioners in the still largely rural South, who were typically elected to office. To be elected and reelected, these commissioners had to deliver noticeable goods and services, including getting rid of fire ants. So much the better if the services came for free from our nation's capital. "Forget the ant," one official told a *Washington Post* reporter (14 February 1978). "The key is the money. It lets these guys launch fleets of spray planes and get up at the Fourth of July picnics and tell everyone that without us to get rid of those ants you would not be here." Decisions that should have involved a lot of science (though not just science) were made instead by politicians responding to the horror stories presented at agricultural commission meetings, state houses, or the halls of Congress.

Thus the drama unfolded, a complex brew of science, politics, journalistic hyperbole, public hysteria, and legal maneuvering. It roiled and boiled for more than two decades, and when it finally calmed to a simmer, the fire ant was the clear victor. The moral of this tale, if it has one, might be, "Know thine enemy."

Overview of Range Expansion from 1918 to 1995

Before 1958, estimation of the range of the fire ant was somewhat hit or miss. The best range estimates are probably those of Wilson (Wilson, 1951; Wilson and Brown, 1958) and Culpepper (1953). Plotting their data shows that *S. richteri* was expanding its range geometrically and that the pace of expansion increased after about 1940, when *S. invicta* took over. Between 1930 and 1949, the range increase was almost precisely geometric and best explained by constant radial growth outward from Mobile at a rate of 8–12 km per year (area = πr^2; doubling the radius of a circle increases its area fourfold). In 1953 the estimated range stood just short of 50,000 km^2 (Figure 5.5).

5.5. The range
ion of exotic *Solenopsis*
s in the USA before
lata from Wilson, 1951,
lson and Brown, 1958).



Once a quarantine was put on fire ant–infested counties in 1958, annual physical surveys were needed to determine which counties were within the range of *S. invicta* and which ones became newly occupied. Upon detection of fire ants, the county, or sometimes part of the county, was declared "infested" and placed under quarantine. Most range estimates since 1958 have used these data, although not always in the same way (George, 1958; Wilson and Brown, 1958; Adkins, 1970; Buren et al., 1974). Simply summing the total area of "infested counties or parts of counties" gives the year-by-year range of *S. invicta* in "infested acres." This measure is somewhat misleading because fire ants never occupy the total area of any county, being absent from areas of water and dense forest. The estimates are thus best considered simply to reflect the geographic range of the fire ant and to convey little or no information on the population densities within this range.

In 1996, Callcott and Collins cumulated all the data to estimate the ranges of fire ants from 1918 to 1995 (Callcott and Collins, 1996). They did not separate the two species in their analysis, but of course, after about 1940, most of the increase was of *S. invicta*. The progress of fire-ant range expansion (Figure 5.6) makes interesting viewing. The 5 million ha occupied by the ants in 1953 barely show up on the scale of the range of 112 million ha in 1995. As in the growth of a bacterial population, the period before about 1950 constitutes a lag phase, and the period after 1950 a rapid-growth phase. Twenty years (1955 to 1975) of rapid, approximately linear expansion of 3.4 million ha per year were followed by slower expansion between 1975 and 1995. By 1975, the colder climate to the north limited the ant's invasion, closing an entire frontier and slowing the expansion rate to about 1.5 million ha per year. Since about 1980 to 1985, nearly all of the range expansion has occurred along the western frontier, although a small expansion continued northward into the mild lowlands of Virginia, Maryland, and Delaware. The slowing of the westward expansion may be the result of aridity, but we cannot be sure. This question will resurface in the discussion of potential future range, below. In 1982, *S. invicta* was discovered in Puerto Rico (Buren, 1982). In 1986, it appeared in Mesa, Arizona, and was eradicated (Frank, 1988), but in 1988, it popped up again in Phoenix and reached St. Croix, U.S. Virgin Islands. By 2000 it had leapfrogged along the West Indies, taking the Turks and Caicos, Antigua, and Trinidad, just a stone's throw from South America's shores once again (Davis et al., 2001). As of 2005, it was invading El Paso, Texas (MacKay and Fagerlund, 1997), and had established populations in Oklahoma City, Oklahoma, and Lubbock, Texas. It has been discovered in Albuquerque, New Mexico. Although it appeared in Brownsville, Texas, in 1991, it honored the international border and had not crossed into Mexico 15 years later. In 1988, an infestation in a nursery in Santa Barbara, California, was eradicated, but 10 years later a large population was discovered in southern California, kicking off the Western Fire Ant War, which continued into the 21st century.

The status of the North American population in about 2005 is shown in Figure 5.7. In 2001, *S. invicta* was discovered in Brisbane, Australia, and Auckland, New Zealand. (Confusion surrounds *S. invicta*'s approved common name, the red imported fire ant, RIFA. Should it be

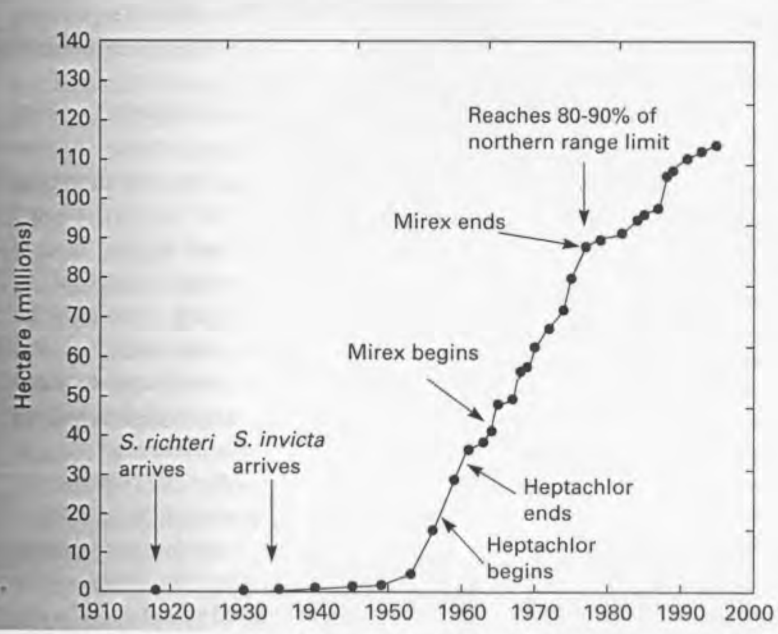
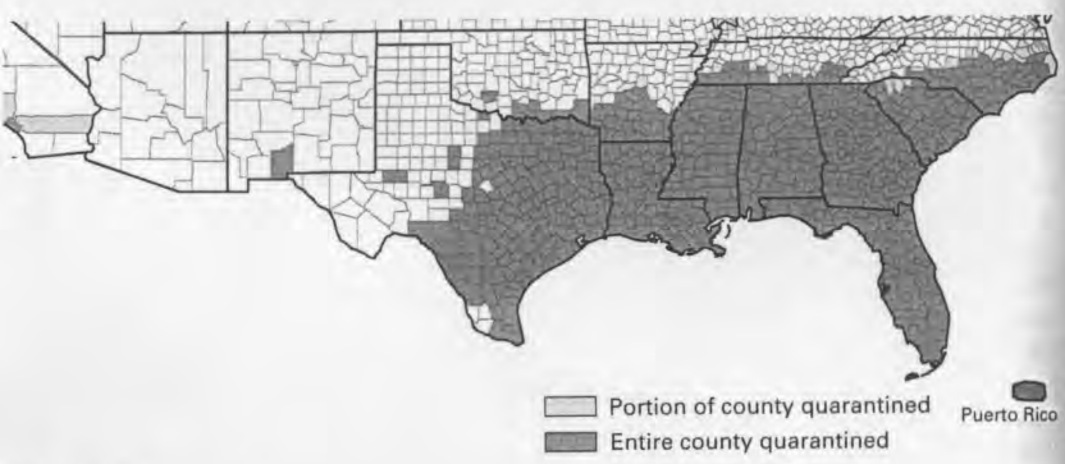


Figure
of exot
from 1!
indicat
of the
and mi
Adapte
Collins
1953 fr
Wilson



5.7. Range of *opsis invicta* in May 2000, on U.S. Department of ulture quarantine map of ies.

called the red *exported* fire ant, REFA, in South America? The arrival of *S. invicta* from the USA in Australia and New Zealand deepens the confusion. Should it now be called the red imported exported fire ant, RIEFA? Or the red imported² fire ant, RIIFA? But I digress . . .). In early 2005 *S. invicta* appeared on the shores of Taiwan, causing the Chinese to worry about a Taiwanese invasion of the mainland (the reverse of the usual relationship). Indeed, only months later, the ant was discovered in southern China. The source of all these migrants is almost certainly the huge North American population rather than the original South American homeland. As world commerce surges upward, *S. invicta* will find ever more chances to hitch rides to foreign places, repeatedly demonstrating its prowess as a traveler and invader. Thanks to humans, its heyday is far from over.

Comparing human efforts to eradicate the fire ant with the ant's range-growth curve is also instructive. Neither the Second Fire Ant War, the one based on heptachlor, nor the Third Fire Ant War, the mirex debacle, had a detectable effect on the rate at which the fire ant occupied new territory. Let us be fair, though. Heptachlor was applied to only about 10% of the then-current range before public outcry stopped the program. Without doubt, its use temporarily and locally decreased the abundance of the ant (as well as those of birds, fish, mammals, pets, and so on). Between 1964 and 1975, mirex was applied three times to about 20 million ha, close to half of the ant's total 1967 range. After 65 million kg of mirex bait was spread on these lands, at a cost estimated to be as high as $200 million, the program's effect on the fire ant's spread was undetectable (Figure 5.6) (Johnson, 1976). Even at the height of the program, the rate of spread did not even slow. Again, to be fair, the program surely reduced local fire ant densities temporarily. Also, because the range was calculated from the area of quarantined counties, it would show a decrease only if the quarantine were lifted from some areas. These data thus cannot really reflect any reduction in fire-ant population densities. Nevertheless, even with population reductions, even when the program had an explicit goal of eradication, the fire ant continued to spread as if it did not even notice the mirex program. Between the beginning and the end of the large-scale mirex program, the fire ant's range almost doubled, standing at about 90 million ha in 1975.

Here then is the final score. Between 1964 and 1975, 60 million ha (600,000 km^2, an area about six times the size of Alabama, somewhat more than half the range of the fire ant in the year 2000) were treated with mirex (Lofgren, 1986b). Airplanes flew over 15 million km, dropping over 86 million kg of mirex bait containing 320 metric tons of mirex. These numbers do not include mirex applied by state programs or by private individuals through purchase or give-away programs, all undoubtedly also large numbers.

Did Mirex Aid the Spread of Fire Ants?

The final irony of the Fire Ant Wars is that, in the long run, mirex and its predecessors and descendents probably had the opposite of the intended effect. Rather than eliminating *S. invicta*, it actually helped this invader gain a foothold in southeastern ecosystems faster and more firmly. A number of authors had taken note of the apparent increase in fire ant abundance after recolonization of mirex-treated areas. The first such reports went largely unheeded—Summerlin and his coworkers (Summerlin et al., 1977) used mirex to kill a diverse population of native ants and a few *S. invicta* in a Texas pasture. When ants recolonized the pasture, *S. invicta* had changed from a minor player to the dominant ant. Using its legendary colonizing abilities, *S. invicta* had simply beaten all the previous native ant inhabitants in reoccupying the formicine vacuum created by mirex. Unfortunately, the study lacked a control and was not replicated, as well as being on the spreading frontier of the fire ant population.

No matter. The question was specifically tested by Jerry Stimac, Lois Wood, and Bill Buren (Stimac and Alves, 1994), who treated some plots with mirex and some with Amdro and left some as untreated controls. Initially, all plots contained diverse populations of native ant species, including *S. geminata*, and *S. invicta* was only a minor presence. As expected, the ant population of the treated plots dropped sharply, but more importantly, when the plots were recolonized, all the treated plots were strongly dominated by *S. invicta*, which remained a minor component of a stable ant fauna in the control plots. Clearly, killing a diverse ant fauna with indiscriminate formicides created an empty habitat waiting for the fastest colonizer to take the lion's share, and that lion was *S. invicta*.

On the basis of this and other information, Bill Buren argued energetically in letters (pers. comm.) and print that large-scale pesticide programs were not defensible, because in the long run, they would produce higher populations of *S. invicta* through resurgence and the elimination of native ant competitors. He argued that repeated treatment with indiscriminate poisoned baits would create a situation in which *S. invicta* was the only ant present. It would be difficult for a community to recover from this situation, because inocula of native ants would be absent.

The widespread use of mirex over millions of hectares that were home to native ants, but few *S. invicta*, therefore probably sped the rate of invasion and increased the subsequent dominance by *S. invicta*. During the EPA hearings, a top USDA scientist testified that 29% of the 3.25 million ha treated in spring 1972 "contained almost no [fire] ants, and should not have been treated." Often, entire counties were treated in spite of inadequate pretreatment surveys establishing *S. invicta's* presence. Frequently, USDA workers were unable to find areas with enough fire ants in which to establish pretreatment plots so that they could later estimate the effect of the mirex treatment. At other times, areas known to harbor very few fire ants were treated in a kind of "holding action" to "prevent their spread." The unnecessary treatments probably killed many of the native ants and thereby left the areas more susceptible to invasion by fire ants.

Is this conclusion reasonable? I believe it is, because this situation is exactly parallel to that created in the studies by Stimac and Summerlin. This classic case of unintended consequences could have been anticipated with a little ecological research. The Florida official who described the purpose of his state's "farmer treatment program" as being "retarding, but by no means halting, the spread of this pest" certainly had no idea that his efforts were probably having the opposite effect. Perhaps in an era when pesticides were the answer to all insect problems, no one was very much concerned with taking a properly scientific approach.