Professional Entomology and the 44 Noisy Years since *Silent Spring*

Part 1

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When Rachel Carson's seminal work, *Silent Spring,* appeared in September 1962, it "delivered a galvanic jolt to public consciousness" (Wilson 2002). Portions of the book had been serialized three months earlier in the *New Yorker* magazine, as had Carson's two previous *New York Times* best-sellers, *The Sea Around Us* (Carson 1951) and *The Edge of the Sea* (Carson 1955). But *Silent Spring* roused a sense of urgency and alarm among its readership; it is credited with initiating the modern environmental movement (Graham 1970, Ehrlich 1978, Perkins 1982, Lear 1997) and promoting the establishment of what would eventually become the U.S. Environmental Protection Agency (EPA) (Lewis 1985, Casida and Quistad 1998, Wilson 2002). Wilson (2002) further asserts that the impact of *Silent Spring* helped set the stage for the passage in 1973 of the Endangered Species Act, which he considers the "most important piece of conservation legislation" in U.S. history.

Today, we may be hard pressed to find a knowledgeable entomologist or toxicologist who would argue for a return to the widespread application of broad-spectrum, persistent pesticides. Yet *Silent Spring* elicited an array of adverse responses, from defensive posturing and denouncement, to vituperative tracts against its author and intimidating threats against its publisher. Carson's detractors included not only the agricultural chemical and pesticide industries, but also the American Medical Association, the American Nutrition Foundation, the U.S. Department of Agriculture–Agricultural Research Service (USDA–ARS), and prominent economic entomologists. The hindsight of more than 40 years allows us to ask several questions: What accounted for these responses, particularly those of entomologists? What criticisms were leveled against the book and its author, and were they valid? Why is *Silent Spring* now widely regarded as one of the most significant books of the 20th century? And, in view of the revolutionary changes in the science of entomology as a result of the increased application of molecular biology (including the development of genetically modified crops), what can we learn from this 44-year history to avoid a new era of polarization (Miller 2004)?

To answer these questions, we must consider issues and perceptions surrounding pesticides and their use, before and immediately following the publication of *Silent Spring*. Although much has been written about this landmark book, no comprehensive analysis has been published that examines the gamut of entomologists' perceptions of insecticides from the 1940s through the 1960s; the quality and scope of Carson's source material for *Silent Spring*; the criticisms that Carson leveled against entomologists and their responses, compared with those from other scientific communities and interest groups; and the quantifiable changes in the entomological literature in the four decades since the book's publication.

In Part 1, we provide a historical context for *Silent Spring*, including pivotal events and perspectives from the DDT era, Carson's credentials, and an analysis of her book. In Part 2, we examine the gamut of responses that *Silent Spring* provoked, including the official response of the Entomologi-

cal Society of America (ESA). We also summarize publication data from the *Journal of Economic Entomology* in 1962, 1982, and 2002 and highlight the immediate and long-range impacts of Carson's book on society.

SILENT SPRING IN CONTEXT

DDT: From War to Peace

In the years during and immediately following World War I, louse-borne typhus caused the death of 300,000 soldiers and 3 million people globally (Berenbaum 1995). When the United States entered World War II in 1941, prevention of typhus and malaria outbreaks became top military priorities (Cushing 1957). Pyrethrum, used to control lice and mosquitoes as well as agricultural pests, was in short supply because Japan was the major U.S. supplier (Perkins 1982); and DDT appeared to be a promising substitute when early tests showed it to be extremely effective against lice and larval *Anopheles*.

A pivotal event occurred in 1944, when DDT was credited with having stemmed a typhus epidemic that threatened Naples, although application of pyrethrum and other factors likely had a greater impact (Harrison 1978, Berenbaum 1995). Under the auspices of the World Health Organization (WHO), 52 nations undertook DDT programs to eradicate malaria, and spectacular successes followed. In only three years, malaria cases on the Italian mainland plummeted from about 375,000 in 1946 to a few thousand per year (Casida and Quistad 1998), and malarial deaths were reduced to zero (Harrison 1978). In Sri Lanka, malaria cases decreased from 3 million in 1946 to 29 in 1964 (Harrison 1978). By 1966, malaria had been eradicated from endemic regions whose populations totaled more than 600 million people, and the probability of contracting the disease was greatly reduced for an additional 334 million people (Harrison 1978).

Understandably, DDT was hailed as a miracle pesticide. In his 1952 address as President of the American Association of Economic Entomologists (AAEE), E. F. Knipling (1953) estimated that DDT had saved approximately 5 million lives and prevented 100 million cases of arthropod-borne disease. The pesticide also boasted many favorable characteristics: it was very inexpensive, easily produced on a large-scale basis, effective for many months, amenable to aerial application, and did not have apparent harmful effects.

At the close of the World War II in August 1945, DDT was released for civilian use, and from then until the 1960s, the United States witnessed widespread use of DDT and other organochlorine pesticides, particularly against insect pests of agriculture and forests. The surfeit of WWII airplanes made it possible to spray large geographic areas aerially, allowing the federal government to undertake mass eradication efforts. U.S. manufacturers produced 10 million pounds of DDT in 1944 (Perkins 1982), compared with about 160 million pounds at production peak in 1961, at which time DDT was registered for use in the United States on 334 agricultural crops (Metcalf 1973). An estimated 1.35 billion pounds were applied in the United States in its 30 years of usage (EPA 2005).

Entomologists Voice Environmental and Ecological Concerns

Entomologists, particularly insecticide application specialists, have been broadly portrayed as a zealous lot who championed the widespread use of DDT and other synthetic organic insecticides (Carson 1962, Ehrlich 1978, van den Bosch 1978). However, the published record reveals a more complex picture, as some leaders in the discipline urged caution and espoused approaches toward insect control in harmony with ecological and environmental principles.

Concerns about the potentially deleterious effects of DDT were voiced in the entomological literature well before *Silent Spring* sounded the alarm. In February 1945, the Special Committee on DDT of the AAEE reported that although DDT offered the promise to control numerous insects of medical and agricultural importance, certain caveats applied. Among those articulated were that DDT, as a pesticide of broad toxicity, would kill many beneficial insects and might create new problems; that not enough was known about its effects on plants, animals, and soils, and that research had shown its "definite toxicity to cold-blooded animal life including fish and frogs" (AAEE 1945).

In 1947, the *Journal of Economic Entomology* published a report by the AAEE Committee on the Relation of Entomology to Conservation. Carson herself could have written this remarkable document, given its complete alignment with the views advanced in *Silent Spring*. The report began by stating,

> All must admit that no insect can be controlled artificially without disturbing the environment, and we have no sympathy with the viewpoint that natural conditions are inviolate. (AAEE 1947, p. 149)

The report continued, presaging four main concerns underscored repeatedly in *Silent Spring*:

- Chemical control practices inevitably harm many other life forms.
- Large-scale pesticide applications, "especially the highly toxic new insecticides like DDT," approach "hazardous proportions."
- Widespread insecticide use against a forest pest leaves a scarcity of food for nestling birds, and if predators and parasitoids of the pest are also killed, pest populations can increase more rapidly, resulting in "an outbreak of even greater proportions."
- The repeated use of DDT in mosquito control could have "serious effects on life in the marshes and adjacent waters."

The committee commended cultural control efforts (sanitation salvage, silvicultural practices) to prevent outbreaks of forest pests and urged further

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investigations of DDT on other organisms so that

> this potent insecticide may be used with minimum risk, and so we shall not be tempted to use it in unwise ways. *Also your committee urges immediate experiments to test in the same manner the effects of various other synthetic organic chemicals that promise to become important insecticides, and we urge that they be used cautiously until their action on other forms of life and on the soil has been determined*. (AAEE 1947, p. 149)

The adverse effects of insecticides and other materials against natural enemies have been strikingly emphasized in recent years by the use of DDT and other new organic chemicals used in pest control. (DeBach, 1951)

The committee report ended with this admonition:

> ...it must be admitted that many entomologists are inclined to adopt a narrow and short time view of insecticidal control and do not give due consideration to the overall and long-time effects of insecticides. We call attention to the dangers of this restricted viewpoint, and urge expansion of ecological studies by the various federal, state and private agencies, in the interest of both insect control and conservation. (AAEE 1947, p. 150)

Similar concerns were aired in a 1950 symposium on the "Compatibility of Insecticide Programs with Biological Control," featured at the AAEE National Meeting. In his presentation, Paul DeBach estimated that almost 100% of the citrus acreage in California received one or more pest control applications per year. He added,

> The adverse effects of insecticides and other materials against natural enemies have been strikingly emphasized in recent years by the use of DDT and other new organic chemicals used in pest control. This is now such common knowledge that it would seem superfluous to discuss it in detail. (DeBach 1951, p. 446)

Citing the development of insecticide resistance in pest populations and the collateral reduction in populations of natural enemies, DeBach argued for a "complementary, mutually compatible program of chemical and biological control" (DeBach 1951, p. 446).

The 1950 AAEE symposium talk by G. C. Ullyett, of the Commonwealth Bureau of Biological Control in Ottawa, served as a harbinger of Carson's strident criticism of economic entomologists. Ullyett alleged that economic entomologists often ignore or lack knowledge of fundamental ecological principles and function less as biologists than as insecticide testers or salesmen (Ullyett 1951). He further asserted that without knowledge of the relationships between organisms and their environments, we "create chaos and additional problems" (Ullyett 1951, p. 459), and he urged that we acknowledge our place in nature and "abandon our attitude of human superiority" (Ullyett 1951, p. 459). Carson would echo these very sentiments in *Silent Spring*.

Speaking in the same AAEE symposium, J. T. Griffiths also voiced concerns that Carson would raise:

> During the past decade, there has been a tremendous increase in the use of chemicals for the control of insects and mites. Unfortunately, in many cases, the introduction of a new material has so upset the ecology of the insect fauna involved that the use of an additional pesticide has been necessitated. Perhaps the entomologist has too eagerly grasped the new tools produced by the agricultural chemist. (Griffiths 1951, p. 464)

Further Cautionary Entomological Literature

The *Journal of Economic Entomology* also published findings and official policy statements on pesticides issued by various federal agencies and affiliates. For instance, in April 1945, a joint policy statement by the U.S. Army and U.S. Public Health Service (USPHS) cautioned against large-scale use of DDT:

> Dramatic reports...and especially the spraying of DDT from aircraft have fired public imagination and fostered the hasty conclusion that DDT is a complete solution to all our insect-borne disease problems. However, it must be remembered that DDT distributed over the countryside not only wipes out malaria-carrying mosquitoes but also may kill other insects, many of which are beneficial. Much still must be learned about the effect of DDT on the balance of nature important to agriculture and wildlife.... (U.S. Army & USPHS, 1945, p. 284)

In 1946, the *Journal of Economic Entomology* summarized a symposium on the toxicity of DDT in agricultural usage. Convened under the auspices of the Biology Subcommittee of the U.S. National Research Council Insect Control Committee (NRCICC), the symposium included representatives of various state and federal agencies, including the USDA Bureau of Entomology and Plant Quarantine (BEPQ), and pharmacologists, medical researchers, and members of the insecticide industry. The committee concluded that the acute oral toxicity of DDT in lab animals was very low, but acknowledged that when ingested in large doses, the pesticide accumulated in fat reserves and chronic toxic effects (hyperexcitability, tremors, liver lesions) were observed. Furthermore, it noted that "our greatest lack of information appears to be in regard to the chronic toxicity of DDT which might result from dosages at residue levels," and experiments were called for to obtain such information (NRCICC 1946, p. 425).

George C. Decker, head of Economic Entomology, Illinois Natural History Survey and Illinois Agricultural Experiment Station, advanced this opinion in his address to the committee (Decker 1946). He argued that entomologists had had insufficient time to complete the necessary field tests that would enable them to make "exact recommendations or even specific suggestions" for DDT use. Yet while he acknowledged the potential human health hazard resulting from the accumulation of DDT in animal fat and milk, he urged that "this type of information should not be given wide publicity" to "avoid starting or fostering unwarranted fears" (Decker 1946, p. 561). Decker would soon become

convinced of the human safety of DDT, and even at this early date he expressed the view that

> one of the greatest hazards involved in the use of DDT is psychological in nature. As a result of the extensive unfavorable publicity given to DDT in the last year, many users are extremely apprehensive, and they frequently attribute a sore throat, headache, indigestion, lumbago, and imaginary ills to their contact with DDT. (Decker 1946, pp. 561–562)

Yet Decker recognized the ecological damage wrought by DDT and its contemporary insecticides. In a 1950 speech to the 29th Annual Conference of North Central States Entomologists, Decker stated, "many of the new insecticides can and often do upset the biological balance of an area and while promoting more effective control of one pest we produce an equally or even more destructive outbreak of some other lesser pest." (Dunlap 1981).

During the 1950s, Vernon M. Stern, Ray F. Smith, Robert van den Bosch, and Kenneth S. Hagen recognized the often deleterious effects of pesticides on the ecosystem, the population dynamics of natural enemies, and the pesticide resistance levels of pest populations. Their work culminated in a seminal paper entitled "The Integrated Control Concept" (Stern et al. 1959). With this paper, the authors (all of whom were employed by the University of California) laid the groundwork for integrated pest management (IPM) and established fundamental concepts such as economic injury level and economic threshold. They advocated classical biological control methods to augment natural enemies and urged adoption of selective insecticides.

Insect Pest Eradication Efforts

Despite concerns expressed about DDT, one of the early calls for insect pest eradication was issued by Clay Lyle in his 1947 AAEE presidential address, when he confidently announced, "We have the technical knowledge and equipment to eradicate the house fly, horn fly, cattle grubs, cattle lice, and several other insects" (Lyle 1947, p. 8). If Lyle was unrealistic in his appraisal, even he omitted pests of field, orchard, garden, and forest, stating, "our knowledge of insecticides effective against some of them is not yet sufficient to make certain that we would not greatly disturb the 'balance of nature' by large-scale field applications" (Lyle 1947, p. 8). He added that such applications might put insect pollinators at risk.

The published record demonstrates that entomologists articulated a number of caveats and concerns regarding broad-scale aerial pesticide applications. In 1958, ESA President R. L. Metcalf cautioned against blanket aerial spraying over densely populated areas (Russell 2001). Nevertheless, during the 1950s, the USDA mounted eradication campaigns against the gypsy moth, imported fire ant, and Japanese beetle. In addition, Dutch elm disease was spreading through residential areas of the eastern and midwestern United States, and the BEPQ recommended the use of DDT to kill bark beetles that act as vectors for the fungal disease.

Intending to eradicate the fire ant from the southern United States, the USDA sprayed heptachlor and dieldrin across a million acres in 1958, an effort that E. O. Wilson calls a "fiasco" and an "example of national impetuosity" (Wilson 2002, pp. 358, 359). In the fall of 1958, Wilson learned of Carson's intention to write about the effects of pest control and sent her critical source material on the fire ant, stating, "the subject is a vital one and needs to be aired by a writer of your gifts and prestige" (Lear 1997, p. 332). The following year, Carson, as a director of the Audubon Society, previewed the USDA–ARS promotional film "Fire Ant on Trial." Appalled that the film portrayed the broadcasting of persistent pesticides as harmless to wildlife and without hazard to human health, Carson related her concerns to Audubon Society President Irston Barnes. Barnes used Carson's report to protest the fire ant eradication campaign to USDA Secretary of Agriculture E. T. Benson (Lear 1992).

At the time of the fire ant eradication campaign, Carson was fully aware of the hazards that post-WWII pesticides posed to wildlife. She had completed a 16-year career with the U.S. federal government as an aquatic biologist, information specialist, and editor-in-chief for the U.S. Fish and Wildlife Service (USFWS). Her duties involved performing statistical analyses, comparing research findings from various sources, consulting with fisheries and wildlife biologists, and writing numerous reports and summaries (Lear 1992, 1997). As early as 1944, Carson had worked on a series of research reports on the effects of DDT by Elmer Higgins, her onetime supervisor at the U.S. Bureau of Fisheries, and Clarence Cottam, a highly regarded ornithologist who would become her supervisor as assistant director of USFWS (Lear 1997). These reports by Higgins and Cottam (cited in Lear 1997) indicated serious problems with DDT and fish and wildlife. Cottam openly criticized the eradication efforts and provided Carson with valuable data and information for her book well after he had left the federal government (Lear 1992).

Human Health Concerns Arose Early

Published reports and correspondence between BEPQ, USPHS, U.S. Food and Drug Administration (FDA), and representatives of the chemical industry indicate that concerns over the safety of DDT for humans, farm animals, and wildlife arose during WWII before its release for civilian use (Perkins 1982). Humans exposed to high levels of DDT recovered slowly from symptoms that included tremors, aching joints, and depression, and DDT had been shown to accumulate in body fat and breast milk (Dunlap 1981). Citing human health concerns, in 1946 the FDA set a zero tolerance level for DDT in milk and warned against its use in cattle feed and forage crops (Dunlap 1981).

In 1950, the FDA estimated that the American diet contained about 0.05 ppm DDT, based on analyses of human fat samples. USPHS toxicologist Wayland J. Hayes, Jr., testified before the Delaney

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Committee that this residual amount was attributable to accidental agricultural exposure rather than diet. However, a 1952 USPHS publication suggested otherwise: the level of DDT in the body fat of non-occupationally exposed people was comparable with that found in people living in Wenatchee, WA (a major producer of apples that had been treated with the pesticide) and Savannah, GA (a nonagricultural region). The average values for the three test groups ranged from 5.47 to 6.62 ppm DDT (Dunlap 1981).

A consensus about the toxicity of DDT could not be reached among members of the scientific community for two main reasons. First, the effect(s) of chronic exposure to DDT residues was essentially unknown. Although the compound was known to accumulate in fat tissue, this did not necessarily represent a cause for alarm. Second, the severity of losses associated with DDT was moot. How should one measure the benefits of killing harmful insects, particularly medically important ones, against the costs to nontarget organisms or the environment? Related to this was the fact that scientists whose research focused on wildlife, ecology, and classical biological control were much more likely than others to notice the deleterious effects of DDT use, even when applied at lower doses (e.g., 1 lb/acre) (Dunlap 1981, Perkins 1982).

Delaney and Miller Amendments

During 1950–1952, a Select Committee of the U.S. House of Representatives convened to investigate the safety of various food additives, cosmetic chemicals, and insecticides, with a view toward recommending legislation if necessary. A diverse array of witnesses testified before the committee, chaired by Representative James Delaney. This event, notable as the first public debate on DDT (Dunlap 1981), drew reactions from specialists that essentially divided them, formally and openly for the first time, into two camps: those who argued for the safety of DDT and opposed further regulations, and those who called for more scientific studies, particularly on the chronic toxicity of DDT. In the former group were officials from BEPQ (F. C. Bishopp, E. F. Knipling), economic entomologists (G. C. Decker), USPHS (W. Hayes), chemical and agricultural chemical industries, trade association officials, and representatives of farmers, manufacturers, and fruit growers. Those in the opposing group included FDA officials, scientists from universities and private research foundations, and officials from Beech-Nut, manufacturer of baby foods (Dunlap 1981, Perkins 1982).

In the midst of the Delaney Committee hearings, Knipling delivered his presidential address at the annual meeting of the AAEE, held jointly with the Entomological Society of America (AAEE and ESA would merge two weeks later) and members of the American Chemical Society. (Knipling spent his entire career with the USDA; in 1953, he became head of its ARS Entomological Research Division [ARS–ERD] [Perkins 1982].) Knipling restricted his remarks to medically important insects, his area of expertise. He acknowledged that DDT had "come under heavy fire," but argued that DDT, chlordane, and lindane enjoyed an extensive safety record and had saved millions of lives through disease prevention (Knipling 1953). He opined that alarmists were telling the public that insecticides represented a greater threat to human health than insects, and that the committee was being misinformed of pesticide hazards.

At the conclusion of the Delaney hearings, Representative A. L. Miller, a member of the committee, sponsored a bill based on the committee's recommendations. The Miller Amendment (to the Food, Drug, and Cosmetic Act of 1938), which passed in 1954, requires the manufacturer to provide evidence to the FDA that the expected residues of its pesticide comply with established legal doses and therefore are not hazardous to human health. The 1958 Delaney Amendment requires the FDA to set a zero tolerance level for any cancer-causing chemical.

Pesticide manufacturers vociferously opposed the Miller Amendment, arguing that it empowered the FDA to arbitrarily and perhaps indefinitely prevent agricultural chemicals from entering the marketplace (Dunlap 1981). And, although the Miller Amendment established pesticide tolerances for human safety, it did not address potential hazards to the environment or to wildlife.

Carson in Context: Three Events Heighten Public Concern

Historians contend that *Silent Spring* appeared at a time when the American public was poised to consider the hidden hazards of pesticides because of three events that received widespread news coverage. These events eroded public trust in the sagacity and safety of scientific advances and roused debate over the adequacy of federal regulations for pesticides (Potter 1964, Graham 1970, Dunlap 1981, Lear 1997).

The first event occurred in 1954, when radioactive fallout from a U.S. hydrogen-bomb test in the Bikini Atoll inadvertently rained on the seamen of a Japanese tuna boat, who suffered severe radiation poisoning and one fatality. Soon one boat in eight was hauling in radioactive fish, wreaking havoc on the Japanese fish industry, all of which was reported by the world press (Lutts 2000). The H-bomb test had released into the stratosphere strontium-90 (Sr-90; half-life 28 years), which accumulates in animal bones and mammalian milk. Public concern over environmental radiation intensified in 1961, when the "Baby Tooth Survey" revealed the presence of Sr-90 in babies' teeth (Reiss 1961, BML 2004). As the Cold War escalated and the threat from Cuba loomed[1], Americans built private bomb shelters and worried about fallout and nuclear war (Dunlap 1981, Lear 1997, Lutts 2000).

The second event, dubbed the "Great Cranberry Scare," erupted in November 1959, when the

[1] The Cuban missile crisis, which brought the world to the brink of nuclear war, occurred a month after the publication of *Silent Spring*.

U.S. Secretary of Health, Education and Welfare (USHEW) announced that the cranberry crops of 1957, 1958, and 1959 were contaminated with aminotriazole (Dunlap 1981, Lear 1997). The herbicide had been shown to cause thyroid cancer in rats, and the secretary recommended that cranberries and cranberry product sales cease until the FDA could complete its work in compliance with the Delaney Amendment. Grocery chains removed the products from their shelves (Fig. 1), and cranberry sales for the Thanksgiving holiday plummeted (Dunlap 1981, Lear 1997).

The third event credited with enhancing public receptivity to *Silent Spring* occurred in July 1962, a month after the *New Yorker*'s initial serialization of Carson's book. Frances Kelsey, pharmacologist and FDA physician, was widely hailed by the print and television media as a heroine for having prevented the sale of thalidomide in the United States, despite pressure from its American manufacturer. The drug, which had been dispensed to pregnant women in 46 countries, caused phocomelia (severe deformation of limbs and organs) in 8,000 babies (Burkholz 1997).

RACHEL CARSON and *SILENT SPRING*

Carson's Credentials

As will be discussed, once *Silent Spring* had stirred public consternation and alarm, Carson was attacked on several fronts, including her scientific credentials. So that readers may assess Carson's qualifications, we highlight her formal education, professional experience, awards, and honors (see the sidebar "Milestones"). Clearly, Carson's ability for "taking dull scientific facts and translating them into poetical and lyric prose that enchanted the lay public" (Leonard 1964) was firmly established by 1962, but this approach did not meet with universal acclaim when she used it to write *Silent Spring*.

Silent Spring in Carson's Own Words

Silent Spring opens with a provocative "fable," which serves as a dramatic narrative foreshadowing, about familiar organisms and environments that are affected by pesticides and figure prominently in the book. Carson concludes the first chapter by asking, "What has already silenced the voices of spring in countless towns in America? This book is an attempt to explain."

Each chapter that follows is lyrically or emotionally titled (e.g., "Elixirs of Death," "Earth's Green Mantle," "Beyond the Dreams of the Borgias") and begins with a strong thesis. Carson explicitly states her case in Chapter 2.

> It is not my contention that chemical insecticides must never be used. I do contend that we have put poisonous and biologically potent chemicals indiscriminately into the hands of persons largely or wholly ignorant of their potentials for harm. We have subjected enormous numbers of people to contact with these poisons, without their consent and often without their knowledge. If the Bill of Rights contains no guarantee that a citizen shall be secure against lethal poisons distributed either by private individuals or by public officials, it is surely only because our forefathers… could conceive of no such problem. (Carson 1962, p. 12)

Fundamental concepts (e.g., resurgence and biomagnification) and the impact of humans on the planet, vis-à-vis radiation (Sr-90) and widespread pesticide use, are emphasized in Chapters 2 and 3. Her opinion of control entomologists is evident from her first reference to them:

> The crusade to create a chemically sterile, insect-free world seems to have engendered a fanatic zeal on the part of many specialists and most of the so-called control agencies…those engaged in spraying operations exercise a ruthless power. "The regulatory entomologists... function as prosecutor, judge and jury, tax assessor and collector and sheriff to enforce their own orders," said Connecticut entomologist Neely Turner." (Carson 1962, p. 12)

Fig. 1. During the "Great Cranberry Scare" of 1959, cans of cranberry sauce, tainted with aminotriazole, were removed from grocery store shelves on the eve of the Thanksgiving holiday season. (Photograph appeared in U.S. News & World Report, 23 November 1959; photo by Monkmeyer; permission to reprint, Corbis Images)

In Chapters 4 through 10, Carson traces a route of global pesticide contamination, beginning with surface and ground waters and moving to the soil, vegetation, wildlife of various habitats, rivers, and the atmosphere. Chapters 11 through 14 focus on pesticides in the home, yard, and garden. Carson speculates on the effects of chronic exposure to chlorinated hydrocarbons, explains synergism, and considers the possible effects of exposure to multiple pesticides. In Chapter 15, "Nature Fights Back," Carson discusses the impact of pesticides on natural enemies, pesticide resistance, the emergence of secondary pests, and the potential for biological control. In the next chapter, she examines resistance

Milestones

- 1929 B. A. degree in science, magna cum laude, Pennsylvania College for Women (Now Chatham College, Pittsburgh); awarded fellowship for summer study, Woods Hole Marine Biological Laboratory and a 1-year scholarship to Johns Hopkins University
- 1931 Instructor, University of Maryland; only female biology instructor in the dental school
- 1932 M. A. degree in zoology, Johns Hopkins University; thesis research on catfish embryology
- 1934 Resigns from Ph.D. candidacy, Johns Hopkins, to support family during Great Depression
- 1936 Scores first in civil service exam, begins 16-year career with U.S. Federal Government as Junior Aquatic Biologist, U.S. Bureau of Fisheries; one of only two professional women employed by the Bureau
- 1937–1949 Various nature-related articles published in *Atlantic Monthly*, *Yale Review, New Yorker*, *Collier's*, *Audubon Magazine*, *Field and Stream*
- 1941 *Under the Sea-Wind,* first book of Carson's trilogy on the sea, published
- 1944 Promotion to Aquatic Biologist, U.S. Fish and Wildlife Service (USFWS)
- 1946 Assistant-to-the-Chief, Office of Information, USFWS
- 1949 Editor-in-Chief, USFWS
- 1951 *The Sea Around Us*, second book in trilogy, published; wins National Book Award and John Burroughs Medal; eventually published in more than 25 languages
- 1952 Resigns from USFWS to pursue career as science and nature writer
- 1955 *Edge of the Sea*, final book in trilogy, published; cited by National Council of Women of the United States as outstanding book of the year; Carson wins Achievement Award of American Association of University Women
- 1960 Undergoes radical mastectomy
- 1962 *Silent Spring* published
- 1964 Carson dies of cancer and heart disease
- 1980 Presidential Medal of Freedom awarded posthumously

Rachel Carson at a microscope. (Courtesy Yale Collection of American Literature, Beinecke Rare Book and Manuscript Library).

Fellowships: Eugene F. Saxton Foundation, John Simon Guggenheim Foundation

Honors: Fellow of Royal Society of Literature, England, and Boston Science Museum; Election to American Academy of Arts and Letters; Distinguished Service Award, U.S. Department of Interior; Conservationist of Year Award, National Wildlife Federation; medals from National Audubon Society, American Geographical Society

Honorary Doctorates: Pennsylvania College for Women, Oberlin College, Drexel Institute for Technology, Smith College

*Information from Leonard 1964; Brooks 1972; Gartner 1983; Lear 1997, 1998, 2002.

in insect vectors of human diseases; she pointed out that although DDT killed typhus-transmitting body lice in Naples during WWII, by 1957, lice resistance to the pesticide had been widely reported.

With the closing chapter, entitled "The Other Road," Carson brings her case full circle. The title refers to the famous poem by Robert Frost, which Carson uses to argue that "the choice…is ours to make"—we can follow the road toward the dire fable that opens the book, or we can select the road to "new, imaginative, and creative approaches to the problem of sharing our earth with other creatures" (Carson 1962, pp. 295–296). As examples of the latter, she recounts successful and potential alternative approaches to pest control (e.g., classical biocontrol, screwworm sterilization, chemosterilants, chemical lures, and *Bacillus thuringiensis*). In this closing chapter, Carson speaks highly of many entomologists, including Edward Steinhaus ("an outstanding authority on insect pathology") and Edward Knipling, whom she regarded as a true visionary. Yet despite praise for specific entomologists, the closing paragraph of *Silent Spring* indisputably issues a damning and polarizing view of the field:

The concepts and practices of applied entomology for the most part date from the Stone Age of science. It is

our alarming misfortune that so primitive a science has armed itself with the modern and terrible weapons, and that in turning them against the insects it has also turned them against the earth. (Carson 1962, p. 297).

Silent Spring: Melding Science and Prose

Silent Spring was aimed primarily at the lay reader (Brooks 1972, Lear 1997), and its sales figures and numerous literary awards attest to Carson's exceptional skill as an author. Many analyses of the book have been written, and essentially all acknowledge (either with admiration or disdain) that Carson's writing style melded the realms of science and prose.

Gartner (2000) contends that *Silent Spring* was crafted as a pragmatic argument that used a "classical approach to rhetoric: to please *and* to teach," so as to mobilize readers into action. She likens Carson's approach to that of a lawyer, who builds a legal case by arguing from details, proofs, and the corroboration of expert witnesses. Several other rhetorical analyses of the book have been published (Waddell 2000).

A letter Carson wrote to her editor in early 1959 provides an illuminating view of her overall strategy and intent for *Silent Spring* (Brooks 1972). Carson stated that, while her exposition would be couched within an ecological framework, she would emphasize the threat to human health posed by the cumulative rather than acute effects of pesticides. She admitted that "no one now [could] honestly say what the effects of lifetime exposure in man" would be because of insufficient time, but recounted disturbing findings: DDT is present in all newborn children (breast-fed or not) and accumulates through development; young animals seem more susceptible to pesticides than adults; and insecticides appear to interfere with enzymatic processes basic to all living cells. She felt encouraged by research on alternatives to chemical pesticides and was most impressed with work by Edward Steinhaus, pioneer insect pathologist (with whom she corresponded). She also was pleased to learn that the new USDA–ARS Insect Physiology unit was exploring alternatives to chemical insecticides. Carson expounded on each of these points in *Silent Spring*.

Silent Spring: Source Material

As her research findings for *Silent Spring* mounted, Carson wrote her editor that her book would "achieve a synthesis of widely scattered facts, that have not heretofore been considered in relation to each other" (Brooks 1972, p.247). Graham (1970) affirmed this assessment, and Wilson wrote, "It was Rachel Carson's achievement to synthesize this knowledge [scattered through the technical literature] into a single image that everyone, scientists and the general public alike, could easily understand" (Wilson 2002, p. 357).

Carson's appended list of sources amounted to 54 published pages comprising about 500 references (which excludes references cited more than once). Our analysis indicates that 80% of the total

Table 1. Summary of sources cited in *Silent Spring*.

Source Category	Total no.	% of total
Scientific Sources		
Journals/Review Articlex	212	51
Proc., Trans., Abstractx	34	8
Addresses, PhD Dissertations	11	3
Textbook	35	8
Magazines	13	3
WHO	4	1
USDA/CAN Dept Agriculture	36	9
USHEW, USPHS, USFDA	22	5
USFS, CAN Dept Forestry	3	1
USFWS/CAN Fisheries	10	2
U.S. Atomic Energy Commission	1	<1
State Publications	17	4
University Bulletins/Reports	9	2
Institute/Foundation Publications	9	2
Total	**416**	**80**
Audubon Societies		
U.S., Canadian National Audubon	11	52
U.S. State Audubon Societies	10	48
Total	**21**	**4**
Legal Testimonies		
U.S. Congress/House of Commons	16	62
Court Proceedings	10	38
Total	**26**	**5**
Letters to Carson	**39**	**8**
Other Sources		
Newspapers	6	40
Popular Magazines	3	20
Trade Magazines	3	20
Books	3	20
Total	**15**	**3**

Abbreviations: CAN, Canadian; Proc., Proceedings; Trans., Transactions; USFDA, U.S. Food and Drug Administration; USFS, U.S. Forest Service; USFWS, U.S. Fish and Wildlife Service; USHEW, U.S. Department of Health, Education, and Welfare; USPHS, U.S. Public Health Service; WHO, World Health Organization.

Notes on source categorization: scientific journal, is peer-reviewed, primary source (e.g., *J. Econ. Entomol.*); review article is peer-reviewed, scientific literature (e.g., *Annu. Rev. Entomol.*); scientific magazine is peer-reviewed, popular science literature; (e.g., *Scientific American*). Publications of Audubon Societies were placed in a separate category because of their stated mission in conservation.

Examples of other categories: state publications (*Clean Streams*, PA Dept. Health); university bulletins/reports (*University of Wisconsin Agricultural Experiment Station Annual Report*); institute/foundation publications (American Cancer Society); court proceedings (Brief, U.S. Court of Appeals); popular magazines (*Country Life*); trade magazines (*Pest Control Magazine*); books (*My Wilderness: The Pacific West*).

sources derive from the scientific literature; of these, 51% derive from scientific peer-reviewed journals or scientific review articles (Table 1). Of note, 14% of the 212 articles in the scientific journal/review category derive from the entomological literature: *Journal of Economic Entomology* (18 articles), *Bulletin of the Entomological Society of America* (7 articles), and the *Annual Review of Entomology* (5 articles). An additional 8% of sources derive from Carson's correspondence with experts (including entomologist Dale Newsom), and 5% from legal testimonies (Table 1; data summarized from Carson 1962, pp. 301–354).

Carson included the lengthy source list to indicate the thoroughness of her research and allow critical scrutiny of it (Lear 1997). To Carson's dismay, one particularly captious critic, William J. Darby, chair of the Department of Biochemistry and director of the Division of Nutrition at Vanderbilt University, could find no merit in the book and said of the source list:

> Its [apparent] bulk will appeal to those readers who are as uncritical as the author, or to those who find the flavor of her product to their taste. These consumers will include the organic gardeners, the antifluoride leaguers, the worshipers of "natural foods," those who cling to the philosophy of a vital principle, and pseudo-scientists and fadists. (Darby 1962).

Another damning review was that of Fredrick J. Stare, Department of Nutrition, Harvard University, who asserted that the scientific evidence she presented was fraught with "omission and commission" and that her research had been "limited to selective reading" (Stare 1963).

In our second paper (Part 2; *American Entomologist*, Spring 2007), we review the responses that *Silent Spring* elicited from the scientific, medical, chemical, and federal government communities, as well as the popular press. We pay particular attention to the immediate response of the ESA and consider the political, legislative and entomological impacts of the book.

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"What is it?" answer.

"What is it?" answer. This is a phengodid larva, glowing as it crawls among the leaf litter. It was submitted by Nancy C. Hinkle, Department of Entomology, University of Georgia, Athens, GA 30602-2603.

If you have a color photograph of an insect, insect part, or entomological apparatus that you would like to submit for the "What is it?" feature, please e-mail a 300 dpi TIFF and a description of the image to the editor at cdarwin@aol.com.

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